HOW DESIGN, MANAGEMENT AND POLICY AFFECT THE PERFORMANCE OF IRRIGATION PROJECTS

EMERGING MODERNIZATION PROCEDURES AND DESIGN STANDARDS

Hervé Plusquellec

FAO 2002
Bangkok, Thailand

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AN ADVOCACY DOCUMENT FOR ALL STAKEHOLDERS:
IRRIGATION AGENCIES, FINANCING INSTITUTIONS,
USER ASSOCIATIONS, PLANNERS, DESIGNERS
AND RESEARCH INSTITUTIONS

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations

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PREFACE

Irrigation is in a quiet crisis. Despite undeniable past successes in contributing to food production, irrigation expansion has dramatically lost momentum since the 1980s due to a considerable slowdown in new investment, losses of irrigated areas due to water logging, salinization, aquifer over-drafting and urban encroachment in some countries. However, irrigated agriculture still remains essential for future food security. The reduction of investments in the irrigation sector is not consistent with the identified needs for future food security, as indicated by numerous model studies on projections of food demand and supply. The increasing disinterest of donor agencies and governments in irrigated agriculture may have dramatic consequences in the coming years if the situation is not reversed soon.

One of the factors that have contributed to this disinterest is the relatively poor performance of large-scale canal irrigation projects. These systems are the most difficult to manage and have yielded the lowest returns compared to their expected potential. The paper emphasizes that performance of irrigation projects is determined by a combination of physical, institutional and policy factors. It focuses however on the importance of design and technology that is often denied or not recognized by decision-makers and others involved in the development of large-scale irrigation.

This document is rather an advocacy, not a design manual, for irrigation projects. However, it presents some important suggestions for the revision of the planning process of irrigation projects and of operational procedures which have an impact on the selection and design of water control structures. The paper touches the issue of projects with conjunctive use of canal and groundwater; but does not address the design issues of projects making use of groundwater only. The technical discussion on the design is limited to the structures found in irrigation projects, which determine water operation and distribution. It therefore excludes drops, escapes and communication structures.

This publication is divided into three main parts. The first part reviews the various causes of performance of irrigation and drainage projects below their expected potential as suggested by many irrigation analysts over the last four decades. This part concludes that the gap between potential and actual outcome is strongly related to over-optimistic assumptions on hydraulic performance at planning stage and in a number of cases to faulty and unrealistic designs. High overall efficiency can only been reached in well-operated irrigation systems, which require well-designed and constructed systems.

The second part describes the conventional design concepts and operational procedures of irrigation projects used in the countries with large irrigated areas. It then discusses the operational problems of the design standards used in some countries or resulting from inadequate transfer of technology.

The third part reviews various factors that should be considered in the selection of an overall irrigation and water control strategy. The final chapter proposes a process whereby agencies responsible for irrigation would review existing design procedures and standards in view of existing and future requirements in terms of service and performance. Agencies would have to assess the needs for change and the development of new design standards and procedures. The chapter concludes with a strategy for the revision and dissemination of revised guidelines.

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This publication, its analyses and considerations, are global in scope, although naturally Asian irrigation, its history and characteristics as well as transfers of technology to and within the region are extensively covered. We believe that the publication and its recommendations are particularly relevant to Asia. For this reason, the FAO Regional Office for Asia and the Pacific has undertaken to commission and publish this work.

Present developments in the irrigation sector in Asia are dominated to a large extent by Participatory Irrigation Management (PIM) and more recently Irrigation Management Transfer (IMT) reforms, which often have the stated objectives of providing sustainable and adequate financing for operation and maintenance of irrigation and drainage services and of facilitating investment in the required rehabilitation or upgrading of irrigation systems. Overall reform of water resource management often encompasses these reforms; it typically includes demand management to encourage efficient water allocation and imposes new externalities on irrigation systems in terms of environmental, economic and financial performance. Water pricing is often a pivotal feature of these reforms, at the intersection of internal considerations of efficiency, fiscal or financial sustainability of the irrigation systems and external water allocation and environmental considerations.

Lending for irrigation has progressively changed over time from project-specific investments to sector loans or projects that are national or regional in scope and support the objectives of reform, participation and capacity building. These projects often combine low cost rehabilitation projects and management reforms with attention to improved O&M and user participation. In Asia, where the older public schemes have reached the age of 30-40 years in most countries, the issue of rehabilitation is becoming increasingly important. The content and orientation of rehabilitation in a context of PIM/IMT will therefore be critical.

The limited success of the previous wave of PIM reforms in Asia has led some analysts to the conclusion that these reforms had been incomplete and that it was necessary to deepen the institutional reforms to ensure that they were successful. It has also led to an interest in importing to Asia reform models from other regions, particularly Latin America, which are estimated to be more successful.

While the merit of these recommendations is not denied, there is a risk that seeking remedies only in the institutional sphere to the problems faced by past institutional reforms will lead to a continuation of the lack of attention to design and operation problems that plague many large-scale irrigation systems in the region. This failure to address a significant cause of the low performance of the systems has certainly contributed to frustrating the expectations raised by sectoral reforms. The particular features of the irrigation systems in the region are such that the introduction of new concepts of service and accountability actually represents a greater challenge than in other regions.

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The level of chaos (difference between stated policies and actual policies) and of anarchy (subversion of policies) in the formal irrigation systems of the region, which comprise the great majority of irrigated areas with the exception of certain countries (Afghanistan, Nepal, Lao PDR), is often rather high. While lack of discipline and institutional issues contribute greatly to this situation, many of the problems can be traced to: problems in initial design; export of design concepts outside of their area of validity; difficulty in controlling and operating the systems; layouts with confused hierarchies; serious flaws in operation strategies; inconsistencies between operating rules at various levels and between operating rules and farmers' requirements; changes in farmers' requirements not reflected by changes in system policies; poor quality of the water delivery service to farms; and lack of flexibility at all levels.

As a result, the actual water management of the systems is usually quite different from the stated or intended water management. It seems that, generally, establishing any type of improved management system will require substantial efforts to restore water control but also probably improve water measurement throughout the irrigation systems. One can also reasonably assert that a condition for a management system to work would be that stated operation policies and distribution rules become the same as or close to actual operation and distribution, and that these be consistent with farmers' requirements. IMT should provide the opportunity to achieve this. A review of past and present IMT or PIM programmes in the region suggests however that they usually fall short in two crucial areas: the decision-making process leading to the decision on system operation strategies and service and performance objectives, and a proper attention to design and other technical issues.

In theory, rehabilitation provides an opportunity to take into account the management patterns of operators and irrigators. In practice, however, rehabilitation simply re-establishes the physical configuration of the original system. Low cost rehabilitation of irrigation infrastructure, in some cases an investment to catch up on years of differed maintenance, cannot correct deficiencies of the original design. The issue is whether basic flaws or constraints can be addressed with a light rehabilitation programme and whether not doing so hampers IMT/PIM or jeopardizes the success of reform in terms of sustainability of institutions and financial sustainability.

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The notions of water delivery service and of generalized service-orientation of institutions in the irrigation sector, whether river basin agencies, reformed irrigation agencies, irrigation service providers or water users' associations, have become central in new concepts and definitions of PIM and IMT. Literature on the evaluation of the impact of ongoing participatory irrigation management and irrigation management transfer programmes in terms of water service delivery, agricultural productivity and agricultural performance indicates however that, particularly in Asia, improved service is a problem area.

The general impression is that after turnover, services have substantially improved in regard to timeliness, reliability and equity. Increases in irrigated area and crop intensity are mentioned in many instances. Flexibility is not explicitly investigated but some results in terms of timeliness and adequacy are registered. Improvements in water use efficiency are more uncertain and their impact are typically not noticeable in terms of agricultural performance, change in irrigated area, crop patterns, cropping intensity or yields; PIM has neither improved nor interfered with agricultural productivity.

The future of farming is however seen to depend on crop diversification and a more commercial orientation. Diversification makes irrigation management more complex. The necessity of reengineering irrigation, i.e. of taking a fresh look at key processes and how they can best be carried out, and of considering both hardware and software elements is emphasized as irrigation becomes more commercial, but this is in apparent sharp contrast with actual design processes and their outcomes.

In Asia, the most common tool for planning rehabilitation or improvement works is the walk-through. PRA mapping and transects of land tenure, farming systems and ecosystems are also common. A diagnosis of operational procedures is usually not performed, physical works are rarely related to service or performance goals and expectations are low. The focus on upgrading is generally on reliability and equity, which are admittedly frequently the first issues to be addressed, but there is generally no vision of future requirements or discussion of flexibility.

PIM has generally led to modest efforts by farmers to improve management efficiency and responsiveness. Significant expenditures loom in the future unless the observed under-investment in operation and maintenance is halted. New programmes therefore emphasize gradual ongoing infrastructure improvements, with the objective to improve performance and ensure financial viability and physical sustainability of irrigation.

In summary, recent efforts in the region to improve the performance of irrigation systems have been dominated to a large extent by social and institutional aspects but results have been somewhat disappointing.

Other regions have often adopted a radically different approach. In contrast with this model, IMT in other regions has often taken a very different shape, with a deliberate effort to change the control logic of the systems from the top down and the transfer of large units of the systems to large water users' associations. To a large extent, engineering and institutional innovations have been introduced in an integrated and mutually reinforcing manner.

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Interactions between institutional, managerial and physical structures are increasingly debated. The prevailing view in recent years that, in irrigation management, there are no technical problems, only institutional and financial problems, is being challenged.

There is an emerging understanding that physical and institutional reforms of the irrigation sector should be combined, and that irrigation management transfer is not about transferring operation functions only but also governance to the irrigation users and a combination of the two at different levels. Rehabilitation is not enough in many cases and, whether institutions determine the technology or vice-versa, it is now acknowledged that technical aspects deserve more attention. For some, in order to improve irrigation performance, one must focus on management processes, irrespective of the institutional setup. Others, including this paper, argue that many problems are due to faulty design and operational procedures, which must be corrected. Physical features are also seen to possibly limit the scope of water sector reform and irrigation management transfer through lack of control and reliability to guarantee water allocations, poor performance or interfaces between levels that do not allow service agreements, volumetric charges or other water pricing systems to be established.

The recent debates at the International E-mail Conference on Irrigation Management Transfer organized by FAO and the International Network on Participatory Irrigation Management (July-October 2001) are an illustration of this new understanding. In their concluding statement, the conference organizers stated that *"IMT does indeed create an important opportunity to adopt needed technical, managerial and financial modernization. Modernization – which is custom-designed to fit local needs and circumstances – must be an essential part of IMT programmes in many places if irrigation systems and irrigated agriculture are to be sustainable. Even though* *many modernization activities may happen after formal transfer, this should NOT be seen as an indication that somehow modernization is less important or is not an essential part of IMT."*

It is estimated that the existing infrastructure may have an impact on the range of institutional options for reform: topics for research on IMT identified at the conference included the relation between infrastructure and institutional options, water scheduling and IMT and volumetric water delivery. It was also noted that "*increasingly, the emphasis in the 'design' of irrigation organizations is turning towards the introduction, primarily through contracts, of professional management expertise in combination with new forms of accountability and transparency towards users, and, perhaps, more flexibility in delivery*".

The performance or condition of many systems is a serious constraint to the desirability of transfer for users or sustainability if the level of agricultural performance cannot generate sufficient revenues for the users to pay their expected contributions to operation and maintenance of the schemes. The sustainability of the new water users' associations also depends on their capacity to provide an adequate water delivery service, control and allocate water, and provide an improved service to enable gains in agricultural productivity. This is essential for the farmers to pay for the water and for the associations to be financially viable.

Water rights and the necessity to satisfy different water uses with the same primary infrastructure will also become a major issue, together with obligations related to disposal and quality of effluents and other environmental requirements. Future requirements of water resource management, water scarcity, environment and agriculture will call for radical changes in management and technology as well as in the quality of water delivery service required by the users.

Rehabilitation, understood as reconstructing infrastructure as it was originally, is thus often not a desirable option. Improvements in infrastructure must be geared towards progressively and constantly adapting the systems to changes in demand. However, IMT programmes, in practice, are still often just a part of major rehabilitation projects and a focus on maintenance issues has probably led to neglecting issues related to the operation of irrigation systems. Participation of users in decisions about system operations and water scheduling should therefore be one of the main features of IMT. But this participation will be very limited in scope if there is only partial transfer or if IMT does not transfer governance over the entire system, as a single unit of management.

The objective of technology design should be to provide infrastructure that enables provision of an agreed level of service. This includes enabling implementation of particular distribution schedules as required by users for their agricultural operations. This general service orientation called for in the sector will often require a departure from established standard design procedures, a major retraining effort for engineers and managers as well as the provision of water users' associations with competent advisory and consulting services.

Some of the issues that need to be addressed in the sphere of design and planning of irrigation systems are: can one design systems taking into account human and institutional aspects and what would the repercussion be on the type of technology? How does one produce simple, transparent design and operational procedures? Does the knowledge exist on how to design and implement service-oriented water control and management? What are the tools and processes for decision-making in the level of service, in operational rules, in planning and design of rehabilitation works and how are the users involved? How is the decision on service related to financial decisions – service fees or farmers' contributions to operation, maintenance or physical works? How is it related to plans to upgrade management capacity?

Farmers' service requirements are often met from other sources than the intended delivery of the main surface systems. Farmers have responded to economic changes, poor or inadequate service or insufficient flows for intensive irrigation and tried to achieve flexibility, reliability and volumes required for the adoption of modern cultivation practices or for freedom in cropping strategies through illegal water trading, tampering with control structures, tapping additional resources, pumping from canals, drains, borrow pits etc. The explosion of groundwater irrigation is largely a response by farmers to the lack of flexibility and the unreliability of the canal systems. Managers also try to rectify management capacity and design shortcomings through recycling and conjunctive use.

This is inevitable. Farmers subvert water distribution rules which define patterns that do not match their feasible and desired goals. Making water delivery match goals is important. Responding to change requires adapting water distribution rules. Adoption of new on-farm technology requires improved operation of the main and conveyance systems. Inconsistent rules will also lead to inefficient and inequitable water distribution. The users, on the other hand, must accept the limitations on use imposed by water availability and the features of the system.

These considerations call for a greater attention to an analysis of operational rules at all levels in the system and particularly to their articulation at the interface between the future irrigation service providers and water users' associations, to the necessity of improving operations in the upper levels if the water users' associations are to be in a position to develop applicable rules and procedures, and to the necessity of incorporating at all levels the farmers' production objectives.

The question whether the technical/hydraulic dimension of irrigation can be brought under the control of agents focused on non-technical user-derived objectives is central as this would characterize a service-oriented management. The case for reassessing the design standards, configuration and operational procedures at the moment of transfer as a result of a review or resetting of both internal objectives in terms of service with the water users and external objectives with water resource institutions therefore seems to be compelling.

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Design processes have been a problem in the past. This paper shows that administrative and behavioural reasons such as lack of experience, accountability and feedback from operation of designers and lack of accountability of operators and managers to the users are partly to blame. IMT can correct the root cause of institutional, administrative and behavioural problems but institutional measures cannot correct existing infrastructure.

Modernization of an irrigation system is defined as the act of upgrading or improving the system capacity to enable it to respond appropriately to the water service demands of the current times, keeping in perspective future needs, or as a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes with the objective to improve resource utilization (labour, water, economics, environment) and water delivery service to farms. This involves institutional, organizational and technological changes and implies changes at all operational levels of irrigation schemes from water supply and conveyance to the farm level. The objective is to improve irrigation services to farmers and improvement in canal operation will generally be a critical first step in the process. In the context of IMT, modernization is related to the process of transformation from supply-driven to service-oriented water delivery and to changes in governance of the systems for goal setting, which includes the decision on the service.

Modern design processes select the configuration and physical components in light of a well-defined, realistic operational plan based on the service concept and use of advanced hydraulic engineering, agronomy and social concepts to arrive at the most simple and workable solution. The most important issue is the system ability to achieve a specific level of operational performance at all levels within the system. A proper operational plan is the instrument that combines the various perspectives and reconciles expectations between users, project manager, field operators and the country policy objectives.

The second step is the decisions about water delivery, i.e. the flexibility (frequency, rate and duration) at all levels. Flexibility distinguishes and characterizes classes of service quality from rotation to on-demand and is most closely related to improvements in agricultural performance, crop diversification etc. Service agreements together with strategic management are increasingly adopted to encapsulate the iterative decision process on level of service and associated financial decisions, accountability, monitoring and evaluation as well as plans to upgrade management and infrastructure.

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This publication is intended to be of interest to all stakeholders of the irrigation sector: irrigation agencies, financing institutions, water users' associations, planners, designers, training and research institutions. It is hoped that it will stimulate and bring a useful contribution to the debate on irrigation sector reform and modernization and to the success of efforts to improve the performance of irrigation and to provide a better service to the farmers, by increasing the awareness of the critical importance of proper modernization procedures and design criteria.

Bangkok, August 2002

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PART I: AN HISTORICAL PERSPECTIVE

I. THE CAUSES OF THE POOR PERFORMANCE OF IRRIGATION PROJECTS: AN UNFINISHED DEBATE

> *"Irrigation systems in many parts of the world are known to be performing well below their potential."* (ICID past president)

Most analytical reports on the irrigation and drainage sector start with a laudatory statement on the contribution of irrigation and drainage to world food security during the last three decades and an observation on the declining growth of irrigated lands worldwide.[1] These are followed by a discussion on the projected contribution of irrigation to meeting the food and fibre needs of the world population by 2025. Next is the observation that the overall performance of irrigation and drainage investments has too often fallen short of the expectations of planners, governments and financing institutions alike (FAO). The consensus between irrigation analysts ends at this point. Most recent reports differ on the causes of the poor performance of irrigation projects. The focus may reflect the main interest or, in some cases, the bias or ideology of the individual author or of the agency. This report moves straightforward to an

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[1] Worldwide 267 million hectares were irrigated in 1997, or about 18 percent of cultivated lands. In the 1970s, the area of irrigated land expanded faster than 2 percent per year. This rate slowed down to about 1.8 percent in the 1980s and has now fallen to about 1.4 percent per year. FAO estimates that the rate of expansion will continue to drop to less than 1 percent in the next decade. There are, however, large regional variations in the rates of expansion of irrigated lands. Out of the worldwide increase of 18 million ha during the five-year period 1990-95, about 13.5 million (75 percent) were in Asia. Irrigated areas in India alone increased by 8 million ha during that period, at a rate of 3.5 percent per year. China showed an increase of 1.8 million ha during the same period. A large part of the increase in Asian countries during the last decade is due to the explosive use of groundwater. An unsolved question is whether some areas served by the existing surface irrigation systems have been counted twice.

historical review of the causes of the poor performance of the irrigation systems that have been identified in many reports since the great expansion of irrigation in developing countries in the 1960s and 1970s.

This report first presents the reasons of the poor performance that are rooted in the perceived weaknesses of design and management concepts of irrigation projects. It then presents the administrative and behavioural reasons through a review of the critics made by some analysts against other groups, such as design engineers and financial institutions.

Perceived deficiencies in technical design and management

A forty-year-old report of the former Office National des Irrigations in Morocco noted that the question of how to make the most rational use of large investments in the construction of dams and large irrigation projects was a matter of great concern worldwide: "*It became evident during the 1950s that even with the installation of an expensive irrigation infrastructure, water use was below the expected level. This is attributed to the need for a programme of land consolidation in conjunction with the irrigation investment.*" At that time, irrigation infrastructure built by the governments consisted only of primary and secondary canals, with a few farm outlets. Farmers were then expected to bring water to their own plots by building tertiary canals and ditches. This type of investment without on-farm development was the model for irrigation development in a number of countries in the 1960s. While this model promoted the rapid growth of irrigation, it was obviously inadequate in the countries with smallholders, who could not organize themselves for the financing and implementation of on-farm works and adopt modern irrigation water delivery. Farmers were obliged to continue with century-old methods of cultivation and irrigation fostering mediocre crop yields. This cause of poor performance was partly corrected by the systematic construction of the tertiary system by the irrigation agencies with, in some cases, the financial or labour participation of the farmers. This practice is now well accepted by national governments and donor agencies. A few countries, such as

Morocco and Thailand, decided in the 1960s and 1970s to proceed with a consolidation programme of the irrigable lands before undertaking the construction of the tertiary system and on-farm works. Some form of land consolidation is essential for optimal use of water in projects where excessive land fragmentation prevails.

Extension of the construction of the irrigation systems down to the tertiary systems was not enough, however, to push the performance of irrigation systems to their expected level. Since the most apparent problems of water management are wastage of water below the farm outlets, the common response in the 1970s was to promote on-farm development, including introduction of modern water application methods and precise land levelling. Another response at that time was to promote the creation of water user groups at the level of tertiary canals. External assistance supported these approaches in countries such as Pakistan, Egypt and the Philippines. This response addressed only part of the problem, since no efforts were made to improve management at the higher level. A third technical response to the disappointing performance of schemes consisted in refining measuring techniques. Since it was widely accepted that water measurement is essential to effective water management, many donor-supported projects finance the installation of measuring devices at each branching point of irrigation systems. However, water measurement in irrigation systems should be adapted to the actual field conditions to be effective. The conditions in irrigation systems are very different from flow measurements in hydrology and hydraulics research. Repetitive use of conventional measuring devices requires training and dedication of operators and does not prevent malfunctioning of control structures. These and other developments in the technical hardware contributed little, however, to solving the problems encountered in irrigation schemes. In the 1970s certain leading professionals started to pay attention to what they described as the software of irrigation systems.

Conventional engineering solutions failed to solve the problem of irrigation performance and this progressively led to a new way of thinking in the 1980s which is still strongly entrenched among the irrigation community. Widespread wisdom has it that the poor performance of irrigation systems is due predominantly to management. A keynote speaker at an ICID congress in 1992 said: *"There is now a wide recognition that deficiencies in management and related institutional problems, rather than the technology of irrigation, were the chief constraints of poor performance of irrigation systems."* [2] This statement was cited and hardened by the author of an article on the problems of irrigation in developing countries, which observed: "*In the developing countries, the heads of the agencies concerned are usually engineers, but they often lack the knowledge of critically important non-technical factors such as the social structure of the farmers to be benefited, economic constraints at local and national levels, and environmental issues"* (Kirpich). A discussant of that article went even further by stating that the technical solutions to the irrigation and drainage projects were trivial when compared to political, institutional and cultural problems. He therefore recommended that degrees for professional engineering include courses in anthropology, business development and economics. The support given to the creation of the International Irrigation Management Institute in 1984 was based on the emerging consensus among irrigation professionals that most solutions were to be found in the field of management. The focus of IIMI has continuously been on management, and irrigation technology received a very low level of attention since the elevation of IIMI activities to those of IWMI.

Admittedly, there are important management-related and institutional deficiencies in irrigation, such as conflicts between farmers and irrigation agencies, poor cost recovery of investments and recurrent costs, lack of coordination between agriculture and irrigation agencies, and lack of farmer participation in design and management. However, the advocates of the key role of management in irrigation

[2] C. Burt (1999) strongly disagrees with this statement and comments that "such statements are common in part because traditional civil engineers have botched so many irrigation project designs and modernization efforts. The result is now worldwide programmes which are promoting the development of water user associations that ignore the relationship between technical and institutional worlds".

performance have yet to fully explore the technical deficiencies in the design of irrigation projects. These technical deficiencies will be discussed in Part II of this document.

Administrative and behavioural reasons

Once the technical solutions to the poor performance of irrigation projects were apparently exhausted, some analysts started looking at the professional competence and capability of other experts to achieve high irrigation performance. Engineers were the first obvious target of these critics. However, irrigation agencies and donor organizations were also strongly criticized.

Criticism of engineers

Box 1: Not by engineers alone

For all its impressive engineering, modern water development has adhered to a fairly simple formula: estimate the demand for water and then built new supply projects to meet it. It is an approach that ignores concern about human equity, the health of ecosystems, other species and the welfare of future generations. In a world of resource abundance, it may have served humanity adequately. In the new world of scarcity, it is fuelling conflict and degradation. Policymakers have vastly underestimated the influence of water scarcity on economics progress, food security, and regional peace and stability. Many have yet to realize that water problems can no longer be fixed by engineers alone. (Postel)

Social scientists have generally been in the frontline of criticism against engineers. Diemer (1996) states that irrigation engineers know little about the actual principles of water distribution in schemes in developing countries. They often assume that, in their schemes, which are mostly gravity-irrigated, there is no better way of distributing water than according to the rules they had in mind when they designed and built the irrigation systems. The design procedure focuses on crop and construction issues with the aim of reducing expenditure on construction, management and maintenance. The engineers usually base their design solely on physical data. The only social components likely to be considered are demographic information (such as labour force and land tenure) and the potential economic and financial yield of the scheme and plots. Empirical data on the diversity in dynamics of farms, group of irrigators, organizational patterns and local political structures are rarely available.

The revised FAO guidelines on the preparation of irrigation projects support these views: *"Building ownership and commitment through participation has often been difficult to achieve in the past. The conventional sequence of identification/preparation carried out against tight deadlines by external planning teams has seldom allowed time for genuine participation either by government staff or farmers. On implementation, government engineers, for their part, have usually seen irrigation only from an engineering rather than a farming or social perspective. They have been reluctant to adopt participatory approaches with farmers, mainly because of a misplaced belief that farmers are unable to understand or make any contribution to technical matters, or because of concern that participation might delay implementation or result in design changes that compromise the quality of the final product."*

According to Diemer, the institutional contexts of scheme development and scheme management do not encourage irrigation engineers to acquire or disseminate knowledge on actual distribution practices either. Foreign engineers are usually contracted by donor agencies to produce designs for new schemes or to supervise construction. They are rarely involved in the management of their schemes and so cannot incorporate feedback on the distribution practices into their design methods and their assumptions about management. This lack of feedback has led to many schemes deteriorating quickly and needing rehabilitation after only a few years. In theory, such rehabilitation provides an opportunity to take into account the management patterns of operators and irrigators. In practice, rehabilitation simply re-establishes the physical configuration of the original system.

Engineers contracted to produce a feasibility report will hesitate to describe a proposal as unfeasible because they risk losing their contracts, either for the design and implementation of the proposal or for the assessment of new proposals. Helweg goes as far as accusing the consulting firms from developed countries of wasting millions of dollars because they lack cultural literacy.

The professional context explains why design irrigation engineers know little about actual distribution processes. It is sufficient and even more beneficial to them to accept current assumptions about the cultivator and his crops, to see farmers as a group and to accept the need for central management of the schemes, because these assumptions fit the goals of the donor agency and the recipient government. The designers' interest lies in maintaining the status quo.

Engineers from government agencies have also been the targets of the critics: because the funding of most irrigation agencies is dependent on budget allocations and not on their performance in water delivery, most national engineers have little incentives to wrangle with farmers, colleagues and politicians to improve water delivery. Operation usually deviates from the assumptions in design. Political patronage and corruption are endemic in many schemes because they form part of the national political landscape. Maintaining the status quo is also the interest of national engineers. (Diemer)

Criticism of financial institutions

For a deeper understanding of technical assistance in irrigation one needs to look beyond the engineers to the donor agencies that manage the public development funds and to the national departments of planning, agriculture or water that set objectives for agricultural development. Together, these institutions define the terms of reference that the irrigation engineers are contracted to implement. Almost invariably, these bureaucracies are the initiators of the large schemes. After conclusive feasibility studies, calculations of the possible internal rates of return of various design options, and negotiations on funding, the donor agency allocates the millions of dollars requested.

Some critics suggest that financial institutions should review their lending policies and priorities: *"Most of the financial institutions tend to give priority to hardware development – probably because software development is more difficult to plan and implement. They argue that software development is essential and should receive higher priority."* This view is supported by the statement, similar to the one from ICID quoted earlier, that most irrigation projects fail to realize their targets not because of engineering shortcomings but rather due to the local organization's shortcomings (Anukul-armphai)[3].

Nijman has studied the links between donor agencies, national governments and irrigation agencies and their connections with their environments, with the aim of identifying the causes of the annual loss of million of dollars in the irrigation sector. Several points stand out:

i) The first is that development banks and other donor agencies have so much public capital at their disposal that is earmarked for investment in developing countries that their officers have difficulty finding sufficient outlets and are under constant pressure to maximize loans and grants. This pressure often adversely affects the quality of the investment decisions. Real-life feasibility and functionality of the investments, as opposed to the feasibility and functionality assumed in the design reports, are not assessed. Performance of the agency and of similar schemes is ignored.

ii) Investment appraisal techniques such as the economic rate of return, cost-benefit analysis and related sensitivity analysis did not

[3] This view, expressed by a high-level expert well known in Southeast Asia, have been diametrically opposed by Professor V. Anbumozhi from the Institute of Environmental Studies, University of Tokyo, in his intervention during the PIM Electronic Conference: *"In the rehabilitation/modernization programmes, it is very common to find that major emphasis has been placed on water users. The importance of engineering aspects is overlooked or minimized. There are several reasons for that, one of which is the donor-driven approach, in which software components are emphasized and hardware components are underestimated."*

render any of the cases (studied by Nijman) unfeasible, as these studies were done after the political decision had been taken to construct a scheme at a certain site. The studies were used to justify the subsidies for irrigation, not to improve economic decision-making.

iii) The fact that development banks are under pressure to transfer public funds to developing countries, plus the fact that much irrigation investment is politically motivated, have instilled an attitude of rent-seeking in the national irrigation agencies. (Diemer)

The performance of international research and donor organizations is criticized in even stronger terms: *"A number of international organizations sponsored regional task forces and technical assistance committees...They, however, did not even try to address long-term social and planning issues, which could have provided comprehensive solutions to some of the* [water management] *problems. On balance, none of the international organizations made a decisive impact on water management in the water-short areas of the world"* (Tibor). This rather pessimistic statement lacks fairness, as it does not recognize the contribution of these organizations to the promotion of user participation in irrigation management and of the service concept in the definition of modernization since the mid 1990s.

The slow recognition of design as a main reason of the poor performance of irrigation systems

Few writers have challenged the widespread view that managerial and institutional deficiencies, not the technology of irrigation, are the main causes of poor performance of irrigation projects. However, a few authors have consistently alerted the irrigation community to the importance of technology in the performance of irrigation projects:

i) The question of whether irrigation performance can be improved solely through improved management or whether physical facilities need to be upgraded as well was raised in a World Bank technical paper fifteen years ago (Plusquellec 1985). That paper was cautious enough to state that the different approaches to design of irrigation projects have different managerial and financial requirements and should not be used indiscriminately. It examined the design and management of water distribution at farm level and the relation of the main system to the tertiary system. Finally it concluded that management alone may not substantially improve irrigation performance, unless combined with physical improvements, some at a modest cost.

ii) An audio-visual training programme on how to improve the operation of canal irrigation systems was produced by the external training department of the World Bank in 1988. It stated that the planning, design and construction process must produce a system and conditions capable of accommodating effective management practices. Although significant results were achieved through improved system management in several pilot projects in the 1980s, the programme concluded that changes in physical infrastructure were often needed to push the performance of these systems to a higher level.

iii) Examples of unrealistic designs and operational procedures were discussed in detail in a World Bank technical paper (Plusquellec et al. 1994). Many designs are difficult to manage under real field conditions. Many failures and problems are caused by a design approach that pays insufficient attention to operational aspects.

iv) The ICID publication on automation of canal irrigation systems states that *"one of the main factors contributing to poor performance is lack of effective water control"* (Goussard). Without further elaboration on that issue, that publication moves to the discussion of the problems of canal operation and presents a state-of-the-art review of the concepts and technologies applicable to automatic operation of canal irrigation systems above farm level.

The author of an IWMI publication on the dilemmas of irrigation systems design (Horst 1998) raises rather unusual and provocative questions: *"Is management really the crux of irrigation problems? ... Do we need to apply cosmetic surgery by only trying to improve the* *management environment without considering the technology? Is it not time to examine the root of the problem: the design of irrigation systems?"*

Horst recognizes the link between design and management by raising the question of whether it would be possible to design irrigation systems taking into account human and institutional aspects and, if so, what the repercussion on the type of technology would be. He raises some valid questions about complicated technologies and operational procedures, and advocates the simplification of design and operation. He further states that the underlying reasons for writing his book were the combination of denial of the importance of technology vis-à-vis management, increasing indifference to system design and lack of transparency of technology and operational procedures.

Despite the evidence of the negative effect of inappropriate design technology on irrigation performance, it is still puzzling that not much attention has been given to that aspect by policymakers and donors, and even by research institutions. The International Programme for Technological Research on Irrigation and Drainage was created at the initiative of the International Commission on Irrigation and Drainage to specifically address the technical aspects of irrigation research and development. Modernization was one of the themes identified as a major gap in irrigation research in developing countries. However, that theme did not really attract the interest of donors. That the international research institutes involved in irrigation research do not attach more importance to the issue of technology and design of irrigation projects is a matter of concern. The 1998 SWIM paper prepared jointly by IWMI and IRRI staff discusses five main strategies or options for increasing the effective use of irrigation water in rice irrigation systems. That otherwise excellent paper is weak in discussing the rehabilitation and modernization of irrigation projects. It refers to an evaluation of paddy irrigation systems in Asia (Rice) by the Operations Evaluation Department (OED) of the World Bank and cites its questionable conclusion that poor operation and management have a negligible impact on irrigated crop production. It fails, however, to report the main conclusion of the OED study, which was that faulty designs were the main causes of performance far below expected targets.

It is also a matter of concern that, until recently, the importance of appropriate and necessary technology was largely left out of the discussion in the intensive campaign for the transfer of irrigation management to user associations under the World Bank initiative called the International Network for Participatory Irrigation Management.

The dawn of a new approach to irrigation design and management

The historical background discussed above is rather pessimistic, and may leave not much hope that a new approach to irrigation management is going to be adopted worldwide soon. However, the efforts deployed during the last few years by highly motivated individuals from international organizations are encouraging:

i) In the 1990s, the Information Techniques for Irrigation Systems (ITIS) of IIMI together with FAO and national research institutions organized a number of international meetings in Sri Lanka, Pakistan, Malaysia, Morocco and India to exchange experiences on the application of information techniques in irrigation systems and on practical improvements for manual operation.

ii) The FAO Office for Asia and the Pacific organized an expert consultation on "Modernization of irrigation systems – past experiences and future options" in 1996 with the aims to examine the various aspects of modernization and to provide a framework for assessing the need and possibility for adopting the measures required for modernization. This consultation led to the adoption of a multi-disciplinary definition of modernization. There was also a consensus on a number of conclusions including: a) the lack of an appropriate knowledge base to provide adequate forecast of the impact of specific modernization steps; b) the need for essential institutional and policy changes, such as accountability of providers of water services, enabling legislation and enforcement capability; c) the need to expand training from policymakers to farmers; and d) the development of upgraded design and procedure manuals.

iii) In 1994, the World Bank published a technical paper entitled “Modern water control in irrigation: concepts, issues and applications” to stimulate debate among professionals and to increase awareness of the potential of modern technologies for water control and sustainable agriculture. The authors argued that modern design was a thought process which started with the definition of a proper operational plan based on the concept of service.

iv) In response to the need to document the impact of modernization on the performance of irrigation projects, in 1996 the World Bank financed a comparative study of 16 projects. A new method of rapid assessment based on a well-structured questionnaire was developed and used for that study, which evaluates both the input/output external indicators and internal indicators that reflect the mechanisms of operation and management. That study was seminal for the series of training courses on irrigation modernization currently carried out by FAO in Asian countries (Thailand, Iran, Viet Nam).

The above studies and international events remain the initiatives of a few individual experts or staff members (which may last only as long as the staff members remain in place) rather than the result of a policy shared at the highest decision level of their organizations. The need to improve the performance of irrigation projects through a re-visioning of management and design is not given a high priority on the agendas of international forums on water and supporting organizations, such as the World Water Council and the Global Water Partnership. The low profile of irrigation in the debates of the World Water Forum in The Hague in March 2000 contrasting with the fierce debates about water supply and privatization is disturbing. The background paper “A vision of water for food and rural development” presented at the Hague water forum is a comprehensive document dealing with the food demand and the growth in water supply for irrigation and rural development over the next 25 years. The proposed comprehensive strategy to realize the vision includes actions for the development of institutions and human resources and for private-sector development, investment in infrastructure and investment policies. However, the paper is very brief on the deficiencies of existing systems and it fails to present the magnitude of the investments required for rehabilitating and improving the existing irrigation infrastructure. The paper rightly states that the technology to supply crops with an optimal amount of water is already available in drip and sprinkler systems but concedes that there is little chance that all the gravity areas will be converted to more efficient pressure techniques.[4] The proposed strategy to realize the vision of water for food suggests direct investments to increase water productivity in a number of areas, including the modernization of irrigation and drainage systems, particularly in water-scarce areas, and the dry-season irrigation schemes in Southeast Asia. This seems to ignore the deficient performance of irrigation projects in the humid tropics during the wet season. Overall, the recommendations of the specialized FAO agency at the Water and Sustainable Development International conference in Paris in March 1998 have not been well echoed in the Hague forum, a highly visible international event.

Unfortunately, few large-scale irrigation systems provide on-demand irrigation service to farmers, which is a precondition for efficient water use. There is an urgent need to modernize and upgrade the water control system in most large irrigation schemes by introducing modern management principles, such as volumetric water charges, in order to facilitate crop diversification. Application of new technology generally requires a conducive environment, including knowledge, finance and markets, and needs to be inserted in adequate policies that lift the constraints of agriculture (H. Wolter).

It is encouraging that the topic of modernization was given full recognition at the electronic conference organized by INPIM and

[4] The “Vision” paper suggests that making available at low cost and workable in the gravity systems the networks of sensors, processors and controllers connected to computers controlling water flows and nutrient supplies in drip and sprinkler systems responding to real time crop requirements can considerably increase water productivity.

FAO in September 2001[5]. Recognizing the role of the users in the modernization process and the importance of modernization for the sustainability of water user associations is a major step forward.

Considerable efforts have been made by lending agencies to revise their strategy for the water sector and to encourage governments to reform legislation and the role of agencies. These efforts at the global water level are now followed by work to define a new irrigation strategy and to identify the actions needed to implement it. The India Irrigation Sector Review in 1998 is a major initiative of the World Bank in that direction. In a preface to this review, the Indian ministry of Water Resources emphasizes that what is needed is a total revolution in irrigated agriculture, with more focus on the improvement of the performance of existing facilities and provision of a client-focused irrigation service. It supports the recommendations of:

- launching planned programmes, linked with irrigation management transfer to water user associations and participation in decisions and investment costs by these associations, to rehabilitate and then progressively modernize the irrigation systems and
- forming water user associations at the minor and distribution levels and federating them to provide advice on water management at higher hydraulic levels.

These recommendations encompass the most important elements of the new strategy, which will be developed in this paper: the need to shift toward a service-oriented mode of operation and to involve the users in the modernization of the irrigation systems.

II. PERFORMANCE OF IRRIGATION SYSTEMS

Most research studies on performance of irrigation have aimed to monitor the performance over time, for example to determine the impact of a management change, or to analyse the performance of

[5] Documents and proceedings can be consulted at the following URL: http://www.FAO.org/ag/agl/aglw/waterinstitutions/toconf.stm

comparable projects. These evaluations mostly focus on an analysis of inputs and outputs of irrigation projects (water, land, labour, value of production, cost of operation and maintenance). These indicators are often referred to as external indicators. These indicators in general do not provide significant information when comparing projects. Obviously projects producing fruit and vegetables have a better productivity than single-crop rice projects. In this chapter, we refer to the performance of irrigation projects compared to the values expected at appraisal or feasibility stage. In Chapter 13, we will define and discuss the use of internal indicators as a tool for the diagnosis of irrigation projects.

The World Bank, as other donor agencies, evaluates the performance of all its operations at the end of the implementation phase, shortly after final disbursements. These evaluations undertaken by its independent Operations Evaluation Department compare outcome then with expectations at appraisal.

Out of the 430 irrigation projects that have been approved by the World Bank since 1950, 313 have been the subject of a post-evaluation. About two thirds of the evaluated projects have had a satisfactory outcome, which is better than the average for all Bank-supported agricultural projects, but slightly worse than the figure for all Bank projects. However, since the late 1980s, the Bank projects are rated for not only their outcome but also their sustainability and institutional development. About 35 percent of the irrigation projects were rated sustainable and about 35 percent would have a satisfactory institutional development impact. These results cast serious doubt about the long-term performance of irrigation projects.

Completion of a project is an opportune time to assess the extent to which operations achieve their stated objectives and to draw valuable lessons for the future. However, conclusions about the technical and economic efficiency of irrigation projects are still speculative at the time when the Bank makes its final disbursements. Impact evaluations are done for a small proportion of operations at full development about five years after completion to determine project impact and sustainability. Impact evaluations are particularly appropriate for irrigation projects whose benefits are long to mature. In 1987, an assessment study of the performance of large-scale gravity irrigation projects was carried out in six countries in different climatic and social environments. An important lesson of that study was the need for more realistic assumptions in the adoption of design standards, especially irrigation efficiency, which in turn affect the cropping intensity, the overall productivity of the project and its economic viability. The main cause for the lower-than-expected performance in economic terms was related to the frequent overoptimistic assumptions regarding efficiency, and the often overlooked impact of poor physical performance in terms of water distribution and concurrent poor construction standards on agricultural productivity (Plusquellec 1990).

The findings of the above study were confirmed by a formal review of 21 evaluations of irrigation projects carried out up to 1990. The review showed that the performance of irrigation projects in economic terms had been less than satisfactory at full development than at either appraisal or completion of their investment phase. For the 21 projects the average outcomes were 17.7 percent at appraisal, 14.8 percent at project completion and only 9.3 percent at impact evaluation. However, their social impact had been substantial and their contribution to food security and poverty alleviation was not in doubt.

Overall efficiency values used for Bank-supported projects in India during the peak lending period 1975-95 were systematically above 50 percent. Most of these projects were rated unsatisfactory at completion when OED started to attach more importance to the links between physical and economic performance of irrigation projects.

Another OED study carried out in 1997 examined the impact of investments in six gravity irrigation schemes in Southeast Asia (Rice). The estimates of economic rates of return not only fell short of appraisal projections by substantial margins, but were all below 8 percent. In one case, the economic rate of return was even negative because the project could not supply half of its design command area. The study stated that the dominant paradigm for government-operated gravity-fed irrigation schemes in the humid tropics was to ascribe the low economic return of irrigation projects to poor operation and maintenance and inadequate farmer organizations. Findings from this 1997 review contradicted this model. The reasons identified for the performance gaps were falling paddy prices, over-optimism about the crop area to be served and projects design faults, including the choice of unsuitable technology.

Box 2: The results of a performance assessment study in six countries

The study covered six countries, three in arid and semi-arid zones, Mexico, Morocco and Sudan, and three in tropical zones, Colombia, the Philippines and Thailand. (The Bank did not finance the projects in Colombia and Sudan.)

Water use efficiencies: Overall project efficiency was re-estimated at or below 40 percent in all cases, with the exception of the Gezira project in Sudan and the gravity and sprinkler projects in Morocco. These values are between 50 and 85 percent of appraisal estimates. For example, the overall efficiency used during the appraisal of the Lampao project in Thailand was 58 percent for paddy (and 51 percent for other crops) and is now estimated at 28 percent. The high operational performance of the Gezira project in Sudan is due to the specific nature of the soils and the innovative design of the minor night-storage canals. The relatively high performance of the project in Morocco is due to the sophisticated water control. (None of these projects had facilities for significant reuse of drained or groundwater.)

Cropping intensity: In all the projects, with one exception in Mexico, the actual cropping intensity was lower than expected at appraisal. Actual cropping intensity was substantially lower at impact evaluation than was estimated at project completion for full development.

Economic rates of return: The economic rates of return were recalculated at impact evaluation for eight projects. The rates were about the same at appraisal for the two sprinkler projects in Morocco, but less than the overoptimistic projections re-estimated at completion. The lower viability of the other projects was adversely affected by lower cropping intensities than expected at completion, lower production and lower prices.

Contrary to well-entrenched ideas, actual low-price commodities were not the key factor driving the economic rates of return to low levels. For one of the projects, substituting the inflated rice prices at appraisal for the actual prices at completion lifted the re-estimated rate of return by only one point. Another fact which depressed the economic rate of return of these projects was that diversification out of paddy failed to occur at any scheme. Even if the 1980 projections of the price of rice had been realized, a combination of lower-than-expected production and lack of diversification would nevertheless have undermined the economic viability of the investments. That study, which was the more perspicacious of the OED studies on irrigation, was completed when lending for the irrigation sector fell to its lowest historical level. Its findings are still overlooked in the policy discussions on the water and irrigation sectors.

III. A REVIEW OF THE ROLE OF INTERNATIONAL ORGANIZATIONS

The objective of this chapter is to discuss the validity of the criticisms of the international organizations in their support of irrigation development. This chapter reviews the policies and procedures of lending agencies that may affect the performance of irrigation projects. Since the FAO Cooperative Programme (FAO/CP) assists the governments in the preparation of most agricultural projects financed by the World Bank, the Asian Development Bank and other donor agencies, the FAO/CP guidelines are also examined.

1. The World Bank

The lack of an irrigation policy paper: The World Bank has not issued any paper on irrigation policy during its thirty years of lending for that sector, although irrigation has accounted for about 10 percent of its total lending.[6] [7]

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[6] Lending for irrigation by the World Bank became significant in the 1960s and rose dramatically to over 250 projects in the 1970s and 1980s. Average annual lending more than trebled in the 1970-80s compared to the 1960s. Since then lending for irrigation has fallen considerably. During the five-year period FY1995-99, the World Bank had only 39 projects for irrigation

During the period of expansion of irrigation, between 1970 and the early 1980s, the Central Department of the World Bank stressed mostly the importance of drainage and greater cost recovery. Cost recovery was particularly salient for the Bank. Policy discussions on cost recovery dominated the debate on irrigation during that period. In 1993, the World Bank published a policy paper on water resources management. The issue of irrigation water pricing generated considerable debate during the review process of the paper. The paper advocates a comprehensive approach to water resources, decentralization, stakeholder participation and environmental protection. However, a water policy paper is not a substitute for an irrigation paper, which should provide sector-specific guidance on diagnosing and improving the performance of irrigation projects. The only reference to modern irrigation systems in the water policy paper is made for the objective of pursuing pricing policies that encourage conservation and efficient use of water.

As advocated in this paper, there is a strong need to move from a broad water strategy to the specifics of an irrigation strategy and to adopt a long-term perspective for the improvement and sustainability of irrigated agriculture. Some countries such as India and Brazil, which have developed an irrigation policy with the collaboration of the World Bank, are showing the lead in the right direction.

Pressure to lend: The donor agencies are frequently criticized for their pressure to lend. That issue is frequently addressed within these organizations and strongly rejected by their high-level management.

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with an annual average lending reaching US$750 million because of a few large-size operations in China, India and Mexico. Lending in the last three years has fallen to about US$300 million.

[7] The 1993 OED review explained *"this deficiency by the resistance from Operations Department which saw an irrigation policy paper as an attempt by economists (from the Central Projects Department) to interfere with the freedom of engineers to do their jobs"*. The reviewers pointed out that irrigation is the most variegated and site-specific sub-sector of agriculture. Therefore they argued there are, by nature, few generalizations that apply to irrigation as a whole. Irrigation requires maximum ingenuity to solve the specific problems of specific sites (OED).

However, any task manager and member of a preparation or appraisal mission is aware of the consequences of a negative evaluation. The efforts of all the members of the mission naturally concur to make the project attractive.

The Bank evaluates the viability of its supported projects in terms of technical, economic, financial and environmental viability. The key parameter of these evaluations has consistently been the estimation of the project economic rate of return, which should exceed the opportunity cost. As mentioned in Chapter 2, a PhD thesis found that the investment appraisal techniques did not render any of the case studied unfeasible, as the studies were done after the political decision had been taken to construct a scheme at a certain site. This strong criticism deserves some comments. On the one hand, the projects examined by the Bank and not submitted to its board for approval, whatever the reasons, are not entered in Bank statistics. It is therefore impossible to determine the proportion of projects that have been rejected because they were not justified economically. On the other hand, senior Bank staff and consulting firms are familiar with the sensitivity of rate of return calculation. They have gained the “expertise” needed for exceeding the rate-of-return threshold value by “manipulating” the key estimated parameters which are used for its calculation, within reasonable limits. This has always been well known but very few designers or Bank staff members have ever pleaded guilty until recently[8]. The Thai government rejected the Irrigation XIII project after its appraisal by the Bank because of overproduction of rice and sharply declining world prices in the early 1980s. If approved, this marginally justified project would have been rated unsatisfactory at completion. Most of the projects that are dropped during preparation are discarded because of political or other government considerations.

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[8] The South Asia area manager of a consulting firm wrote: *“It is a scourge of irrigation projects in Asia that the original cost-benefit estimates are seldom honest, water never reaches much of the area notified to be irrigated, crop productivity increase is less than expected, and environmental and social damage is far more than expected.”*

Use of overoptimistic assumptions during design and appraisal: The use of overoptimistic assumptions during project design and evaluation was noted in Chapter 1. This point has been well emphasized in some country irrigation studies. For example, the India irrigation sector review in 1998 stated that there was a tendency to overstate water availability through the analysis procedures used because of social pressures to maximize area coverage and because irrigation efficiency was systematically overestimated. The same India review stated that dependability of water was based on averages rather than on statistical analysis of demand, which would better show the peak demand in dry years, a point which will be examined further in this paper.

2. The Asian Development Bank

In 1998, the Asian Development Bank (ADB) published a working paper "The Bank Policy on Water" after intensive consultation with other policy stakeholders, including member countries, the private sector, NGOs and other external support agencies.[9] These consultations result in the formulation of principles of effective water policy, which includes the delegation of water services to autonomous and accountable public, private or cooperative agencies providing measured water services to their customers for an appropriate fee. The ADB paper identifies the main challenges to meet these objectives as: i) how to increase investments in new water delivery systems that will effectively meet customer demand; ii) how to upgrade and manage existing systems to reduce demand and run more efficiently; and iii) how to reduce water pollution through recycling. The consultations pointed out the need for higher efficiency in irrigation requiring policies and legal provisions on water rights. The paper states that successful modernization of

[9] Almost 20 percent of past ADB lending has been invested in water-related projects, of which about half for irrigation. The water-sector share of ADB lending has, however, declined substantially over the past 15 years – from more than 30 percent of total lending in the early 1980s to an average of 15 percent in the 1990s. The volume of lending for the water sector has even declined in real terms.

irrigation systems will generally require viable cycles of investment, operation and management by autonomous and accountable service agencies, with user participation. Explicitly, the ADB water policy recognizes:

- the need to shift toward a service-oriented mode of operation of irrigation systems;
- the importance of modernization of irrigation systems for the successful implementation of the global water policy; and
- the importance to involve the users in the modernization process.

3. The FAO Cooperative Programme guidelinesIdentification and preparation of irrigation projects (1984)

Like other financing institutions, the World Bank requires that feasibility studies for conventional specific projects be completed before appraisal. National or international consulting firms commonly assist borrowers in the preparation of projects. Although this phase in the planning process is in principle the responsibility of the borrower, the FAO Cooperative Programme was created in 1967 to provide assistance to borrowers where national capacity was inadequate. In 1984, this FAO division prepared a paper on the "Identification and preparation of irrigation projects" to provide guidance to its staff and that of consulting firms.

The document provided general guidance on the different activities for the comparison of various options, such as: review of available database; assessment of topography, soils and land capability; estimates of irrigation water requirements; assessment of available water resources; and preliminary cost-benefit analysis

The document also provided guidance for the preparation of the engineering studies necessary for the planning of the preferred option before the appraisal of the project. The objective was to provide the necessary technical information to produce preliminary designs upon which estimates of quantities and cost estimates, and ultimately the economic analysis, could be based.

Remarkably, the document did not provide any specific guidance on the technical aspects of project preparation, with the exception of the estimates of irrigation water requirements for the proposed cropping patterns. The document suggested specifically to use an 80-percent probability of excess effective rainfall in the determination of project water requirements and to convert from net to gross water requirements on the basis of empirical local data for efficiency of the types of irrigation systems under consideration or from the FAO Irrigation and Drainage Paper No 24. The last revision (1992) of the FAO document on "Crop water requirements" provides values of conveyance, field canal distribution (Ed) and field application (Ea) efficiencies based on a 1974 survey of ICID and U.S. sources with the remark that these values are applicable to well-designed schemes in operation for some years.

The overall project efficiencies of projects with rotational supply and surface or sprinkler application methods, using ICID value ranges, do not exceed 38 percent for surface application methods and 43 percent for sprinkler. [10]

Table 1 Overall efficiency rates based on the ICID survey

Management and communication	Furrow irrigation Ea = 57	Basin and level border Ea = 58	Sprinkler Ea = 67	Rice Ea = 32
Adequate Ed = 65	37	38	43	21
Sufficient Ed = 55	31	32	37	18
Insufficient Ed = 40	23	23	27	13

[10] Using the values of field application efficiency from the U.S. Soil Conservation, the overall efficiency rates range from 39 to 52 percent for basin irrigation and adequate management, and from 30 to 38 percent for "sufficient" management and furrow irrigation. These overall efficiency rates are slightly above those obtained with the Ea ICID values. However, they are lower than the ones used in feasibility studies.

These overall efficiencies are of the same order as the values estimated at the impact evaluation of irrigation projects and confirm the over-optimism of the values adopted during the planning of irrigation projects. The FAO document, particularly its last revision, should have called the attention of the users of these guidelines to the importance of realistic estimates of the overall efficiency. As indicated in Chapter 1, the gap between appraisal estimates and actual efficiency rates can reach about 40 percent.

Why are planners and designers of irrigation projects from government agencies and financing institutions so optimistic about the hydraulic performance of irrigation projects during the planning process? A participant, from a consulting firm, to a World Bank irrigation seminar in the 1980s answered that question in blunt terms: “If we were realistic, all of us would be out of business.” Low efficiency reduces the irrigable areas and/or the cropping patterns and affects negatively the economic viability of the project. It is very intriguing that the over-optimism of consulting firms was neither raised as an issue during the preparation phase of irrigation projects with FAO/CP assistance or during the appraisal by the financing agencies. It is acknowledged here that water lost in a surface irrigation project can be re-used beneficially through recirculation or further downstream. This question of project versus basin efficiency is further discussed in Chapter 6.

The efficiencies assumed during the planning process could be obtained if a number of conditions were met. Designs have to be not only technically sound but also realistic when taking into consideration social and institutional aspects and practical considerations such as access-road conditions, night-shift work and motivation of low-pay staff members, which affect the efficiency of water delivery.

Updating of the 1984 FAO irrigation guidelines (1996)

The 1996 document entitled “Guidelines for planning irrigation and drainage investment projects” prepared by the FAO Investment Centre focuses on new types of thinking and approaches to the planning process of irrigation as crystallized in the 1993 World Bank policy paper “Water resources management” and in the findings of a 1992 Portfolio Management Task Force of the World Bank. That task force concluded that the main problems that constrain the performance of investment projects in various sectors are inadequate consideration of institutional constraints and poor planning of implementation, and a lack of commitment to the success of the projects by the government and users. The 1996 FAO guidelines assume that water policy reviews indicate that irrigation is a justifiable option within the context of the overall water resource strategy of a country. The guidelines therefore discuss issues specific to the implementation ability of the irrigation sector:

- the participation of all stakeholders in the planning and implementation process, to create a sense of ownership and of commitment to the project;
- the creation of water user associations and the transfer of operation and maintenance responsibility;
- the possible role of NGOs in participatory development; and
- the issue of fiscal sustainability, including contribution to capital costs.

The technical deficiencies of irrigation projects and the alternative options to improve design and operation were discussed in sundry workshops, conferences and seminars in the 1980s and 1990s. However, these aspects were deliberately not covered when updating the 1984 FAO paper, because they were available in a number of FAO, World Bank and other papers, conference proceedings and miscellaneous publications. Most of the purely technical content of the 1984 documents reflecting the conventional approach to project planning was repeated where appropriate.

The only additions to the 1984 version on aspects of water management and system operation were limited to short discussions of the planning process and choice of technology and to the questions to be addressed in a typical project document. The complete text of the FAO guidelines on water management aspects is reproduced in annex.[11]

The section on the choice of technology is a brief reference to a long and passionate debate within the World Bank on competing design visions which was oversimplified in the 1994 review of the Bank experience in irrigation by presenting a polarization of the bank engineers into two camps.

One subgroup sees the problem largely as one of the hydraulic instability of extensively gated, manually operated systems and sees the solution as being the modernization of these systems with automatic downstream control structures and feedback mechanisms to achieve hydraulic stability. The other subgroup of design engineers has accepted the reality of farmer damage in the wet season and gone to the cruder and more robust "structured design", giving up the possibility of just-on-time "on demand" delivery of water to crops in the hope of preserving the civil works.

The conclusion of the World Bank review was that there was inconclusive evidence to favour one camp or the other. The discussion on technology was closed by stating that it was beyond the review's scope to compare and assess the merits of the crop-based or water-based systems. The FAO document states that the discussion need not be continued since it is well covered elsewhere. Alluding to the issue does not provide much guidance to the users of the guidelines.

In summary, both the 1984 and 1996 FAO guidelines for preparation of irrigation projects as well as the World Bank instructions are still driven by the concern of banking institutions. The objective of the engineering studies is to obtain a cost estimate with plus or minus 15-percent accuracy. The changes in project design to improve

[11] The additions to the 1984 guidelines on water management and system operation are nothing but the comments made by the World Bank (the author of this paper) on a draft of the revised guidelines, with the expectations that these comments would be considerably developed by FAO.

implementation ability through the devolution of operation and maintenance responsibilities to the users was driven by the recognition that the challenges of operating and maintaining the irrigation infrastructure are often beyond the financial capacity of public-sector institutions.

Not much progress has been made in official thinking about the challenge of closing the gap between the expected and actual outcome of irrigation projects, about improving service to the users, increasing food production and preserving the environment within the constraints of decreasing water resource allocation for irrigation.

Lending for irrigation has progressively changed over time from project-specific investments to sector loans or national/regional projects supporting the objectives of participation and capacity building. These projects often are a mix of low-cost rehabilitation endeavours and management reforms with attention to improved operation and maintenance, and user participation. Low-cost rehabilitation of irrigation infrastructure, in some cases an investment to catch up with years of differed maintenance, cannot correct the deficiencies of the original design, if the causes of such deficiencies are not identified through an in-depth diagnosis of the current system.

IV. TECHNICAL VERSUS MANAGERIAL CHANGES

The idea that the performance of irrigation can be improved by managerial changes was and is still widely spread within the irrigation community. Indeed there are some examples of improved system performance achieved through operational changes supported by effective communication between the agency and the farmers. One of these is the Lower Talavera irrigation system in the Philippines. The research programme carried out by the Rice International Research Institute (IRRI) and the National Irrigation Agency (NIA) developed a rotational water supply schedule which produced dramatic results. Operation of the system was simply converted from continuous supply to a supply by turns between the upper and lower sections of the lateral canals. Water efficiency and productivity were enhanced because of reduced runoff from the head-end areas and increased yields of tail-end farms. This change in operation was indeed rather crude.

Much more complex was the change made in the Dantiwada project in Gujarat, India, where the operation of the main canal system was upgraded to near downstream control through frequent communications between gatekeepers of cross regulators[12]. It is important to emphasize that this change was achieved through intensive training of the field staff: this unique case might not pass the test of time because of the intensive management and dedication required.

Malano correctly argues that one level of service can be provided with several types of flow control and, conversely, one type of flow control can be used to provide different levels of service. For example, the same water-control technology is used in Mexico to provide water on prearranged demand and in Thailand and the Philippines on the basis of centralized scheduling. The provision of a higher level of service with a given type of flow control requires additional staffing with greater skills and proficiency for planning and executing the system operations. However, the number of staff members needed to operate a system under, say, manual upstream control can be substantially reduced if the same level of service is provided by an automatic system. In most modern irrigation projects in Morocco, where operating on arranged demand would be feasible, water distribution is decided by the irrigation agency, including flow rate, duration and frequency. A local attempt by an innovative water-master in the Doukkala project confirms, if need be, the feasibility of operating these systems on arranged demand.

[12] The 46km-long Dantiwada main canal is equipped with eight gated cross regulators. Gatekeepers are instructed to maintain constant water levels upstream of the cross regulators, the normal practice in upstream controlled systems. However, they also communicate with the staff of the upstream cross regulator to modify the incoming flow up to the diversion point, as in a downstream-controlled system.

The trade-off between flow control technology and management has implications on the operational efficiency of the system. It is easy to supply water on demand with a manually operated upstream-controlled system by continuously operating the system largely in excess of the actual demand. Such an operation results in significant wastage of water when demand is low, for instance at night. Thus, the Grand Valley water user association in Colorado provides water on demand with upstream control. The district operates the canals at high flow rate. However, there is a large percentage of spillback to the river. The Seyhan project in Turkey, with abundant water resources, is operated with minimum adjustments for limited demand at night. This mode of operation is known in Pakistan as operation by refusal.

There are unfortunately many unsuccessful examples of schemes throughout Asia where operational changes attempted with the support of research programmes have failed (for example, the introduction of a rigid water distribution pattern in the Nong Wai project in Thailand). The question is whether the practices introduced through pilot projects will continue once these projects end. The more equitable new water-saving distribution strategy is often discontinued because big landowners at the head of the systems exercise their political power to restore their privileges or because the farmers downstream are not consulted.

Focus on managerial changes was the basis of the Bank-supported National Water Management project in India in the mid 1980s. The most important element was the preparation of an operational plan. On the basis of water availability, system characteristics and agricultural options, the plan was expected to define how the system would be operated with respect to the timing and quantity of water deliveries. Only low-cost improvements to the infrastructure needed to support the improved operational plan were supported by the project. The results fell short of appraisal estimates. The completion report concluded that *"projects of this type which not only involve technical changes but also have significant social aspects require a high level of farmer participation in irrigation management to be successful"*. It also stated that introduction of such concepts will require in turn the use of more advanced technologies in irrigation management, which are currently available in India and abroad.

In the same way, examples abound where technological changes alone have not yielded the expected benefits because of a lack of training capabilities during design, construction and operation of the scheme. One such example is the Sidorejo project in Indonesia (Box 3), which was implemented without the full commitment of the irrigation agency.

Box 3: The Sidorejo irrigation project in Indonesia

In the mid 1980s, the Indonesia irrigation agency (DGWRD) selected the Sidorejo irrigation project, a subsystem of the Kedung-Ombo multipurpose project, to test modern canal control techniques and determine whether they were applicable to other irrigation systems in Indonesia. The 13km-long main canal was designed for downstream control and the secondary canals for upstream control, with the use of automatic float-operated gates for the entire system. The concept was similar to the one used in some projects in North Africa. However, it differed in the control structures for the distribution system, by using small-size float-operated gates, which could be easily tampered with, instead of the more robust static structures such as the diagonal or long-crested weirs used in North Africa.

This modern pilot project has not been successful for a number of reasons. The quality of construction was poor. Several sections of the lined main canals failed, so that the main canal could not be operated under downstream control. Installation of hydro-mechanical equipment was faulty. Precise vertical settings were needed. The agency was not really aware of the need for high standards of construction for modern-design systems. Local operation and maintenance personnel were not trained for the operation of a system unknown in Indonesia and they went on using national standards.

Sustainable improved performance in irrigation is obtained when combining physical, managerial and institutional changes. The case of the State of Victoria in Australia where the reform process combined all these changes is described in Box 4.

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Box 4. The technical and political reform process in the State of Victoria, Australia

Irrigation enterprises with low profitability, aging infrastructure, large public debt, and environmental degradation through salinity and water-logging were the situation in the State of Victoria, Australia, in the 1980s. Operation of the complex irrigation channel systems was inflexible and highly reactive. Operation of the irrigation systems was driven from the head works down. Renewing infrastructure provided the opportunity to redesign the system to create much more effective water-delivery systems. The first step taken was to fundamentally change the approach to managing the irrigation systems with the objectives of reducing the costs of delivering services and of building a base with new technology to allow more sophisticated water services and tariff arrangements. Instead of replacing the infrastructure as it existed, careful analysis of the system revealed opportunities to create better, more effective irrigation systems. The roster system requiring the irrigators to take water on a fixed schedule was converted into a water-on-order system allowing the farmers to better meet the needs of their crops, make more efficient use of water and reduce pumping costs. A telemetry system combined with SCADA provided real operations of flows and water levels.

The new system was a significant step in the development of irrigation in Victoria. It allowed leasing of water rights, diversion licenses, and sale entitlements between farmers with certain conditions. The shortfall of revenues was considerably reduced. (Langford)

The Office du Niger in Mali, which was often referred to as an example of a fiscally burdened organization, is now a success story for Africa and other regions (Box 5). In both cases, the restructuring of the agencies was combined with a modernization plan of the scheme to improve the flexibility and reliability of water delivery

There is a need to revise the strategy for irrigated agriculture and to address the poor management practices of the large canal irrigation systems through a rethinking of irrigation policy, formulation and technical design of projects, as illustrated by the two successful examples.

Box 5: Restructuring of the Office du Niger, Mali, West Africa

The Office du Niger in Mali was known for many years as an example of an irrigation system with a heavy financial burden. It is now seen as a success story. The Office du Niger was created in the early 1930s to reduce the dependence of France on cotton imported from the British colonies. The project was managed by a parastatal organization, following the model of the Gezira project in Sudan. The 25 000 resettled farmers were seen as agricultural workers. In the 1950s cultivation of cotton was abandoned because of rapid development of water-logging conditions, a major contrast with the heavy soils of the Gezira project, which are highly suitable for cotton cultivation. The restructuring of the Office du Niger focused on both institutional and technical aspects. The paddy processing and commercialization functions of the Office du Niger were progressively privatized. The activities of the Office are now concentrated around its essential functions of water services, planning and maintenance.

The physical upgrading consists in modern water control of the main conveyance and distribution network and precise levelling of paddy lands. The improved water delivery and land levelling make the adoption of transplanting and high–yield varieties possible, with an increase of paddy yields of 1.5 to 6 tons per hectare.

The technical and institutional restructuring of the Office du Niger makes it possible for the agronomic and economic performances of the project to skyrocket, responding to the need for financial balance and to market opportunities in a context of liberalization and privatization. (Couture)

V. TECHNOLOGY VERSUS INSTITUTIONAL REFORMS: USER PARTICIPATION

From social to business associations

By the mid 1970s some irrigation researchers from non-governmental organizations, such as the Ford Foundation, and others argued that sustainable irrigation systems required the active participation of the users. By the 1980s several countries started to implement irrigation management transfer programmes whereby irrigators were encouraged to participate in operation and maintenance. Some of these programmes consisted in the creation of pilot user associations spread over a number of irrigation schemes to test the feasibility of involving the farmers in operation and maintenance activities (Maharashtra State in India). Other programmes consisted in a large-scale transfer of the lower level, such as in Pakistan, the Philippines or Indonesia. In Pakistan, over 17 000 associations have been created at the watercourse level, but very few are still active after completion of the lining programme[13]. In 1987, the Indonesian government decided that all irrigation systems of less than 500 hectares would be transferred to water user associations by the year 2003, with priority given to the systems of less than 150 hectares. The objective of these countrywide programmes was to involve the farmers directly in maintenance activities of the lower level of the irrigation systems, and in some cases to assist the government agencies in collecting irrigation service fees. Management transfer involved only a partial devolution of responsibilities. The government retained some control over operation and maintenance plans and continued to contribute to the financing of operation and maintenance activities. The number of farmers and the areas covered by each association (from 200 to 500 hectares) were usually small.

The approach to irrigation management transfer took a different orientation in the late 1980s with the implementation of the transfer programme in Mexico. In the first phase, the user associations in that country took over the financial and managerial responsibilities for operating the systems below the main canals. In the second phase of the process, still ongoing, the responsibilities of operation and maintenance of the main systems have been handed over to limited-responsibility societies. The average size of the 406 associations created in Mexico by the end of 1999 was about 7 000 hectares, with some reaching 30 000 hectares. The same approach was later successfully adopted in Turkey, where the irrigation agency transferred the management of about 1.6 million hectares[14]. This leap

[13] A new programme involving reforms of provincial irrigation departments, creation of area water boards at command level and farmers' organizations at distributary or minor canal level is now under implementation in Pakistan with the joint support of the World Bank and the Asian Development Bank.
[14] About 1.1 million hectares was transferred during a three-year accelerated programme between 1994 and 1996. The average size of the 222

in scale and rate of transfer has stimulated some other countries to shift to accelerated programmes, for example the State of Andhra Pradesh in India, which created over 10 000 associations in July-August 1997.

A key difference exists between the approach adopted in the 1970s-1980s, mostly in Asian countries, and the one developed in Mexico and Turkey. In these two countries, the programmes aimed to involve farmers in representative governance and not to maximize direct user farmer participation in operation and maintenance. The associations created in these two countries have similar designs, responsibilities and functions to those of the existing associations in the United States, Spain and some Latin America countries such as Chile, Peru and Colombia. The Asian and Mexican models are sometimes referred to as "social" and "business" associations respectively (Facon). The creation of social water user associations has tended to follow a gradual approach experimenting with pilot associations.

The business-prone associations are responsible for water distribution, fee collection, maintenance, conflict resolution, and representation of farmers with discussions with public agencies. To fulfil these functions, these associations are legal entities that can enter into contracts. They have the power to enforce rules and regulations. The farmers are not directly involved in the management of their systems. These associations hire professional staff for the actual management. The members of these associations through their elected boards define the rules and regulations to be followed by the hired employees.

The social associations are seldom self-sustaining. The concept of business-type associations is rejected by the irrigation bureaucratic establishment or not applicable because of the perceived incapacity of farmers to manage large systems. A multi-tiered organization is now emerging as a possible solution for the management of large-scale irrigation schemes with a large number of small farmers. This

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associations, created as of the end of December 1997, was 5 300 hectares, but some were exceeding 20 000 hectares.

model consisting in multi-level organizations is consistent with the definition of modern irrigation. A modern irrigation system consists of several subsystems or levels with clearly defined interfaces where water is controlled and measured. The strict application of that model with a formal independent organization at each level could result in an excessive number of layers of management and formal farmer organizations. For example, the proposed organizational structure of the Mahakali project in Western Nepal would include a central coordinating committee at the project level, eight coordinating committees at area level, forty user associations at the block level, 1405 tertiary committees and nearly 10 000 water user groups at the outlet level. It would be not only time consuming but even counterproductive to organize so many associations and groups at each level.

In practice, some levels of management can be combined within one organization, while maintaining the modern concept of service from the higher to the lower level. In addition, the responsibilities transferred to each user organization could be either governance or management functions, or a combination of the two. For example, the higher-level user organizations could be involved in major decision processes, such as rules and regulations, the annual maintenance work programme, revision of the water charge structure, the annual budget and the timing of the irrigation season, the day-to-day management of the main system being the responsibility of an irrigation agency or company. Operation and maintenance of the two middle levels of a system could be transferred to water user organizations. This model can be applied in a pragmatic way depending on the size of the scheme and configuration of the irrigation system, the capability of the farmers and the willingness of the irrigation agencies to accept fundamental changes in their roles.

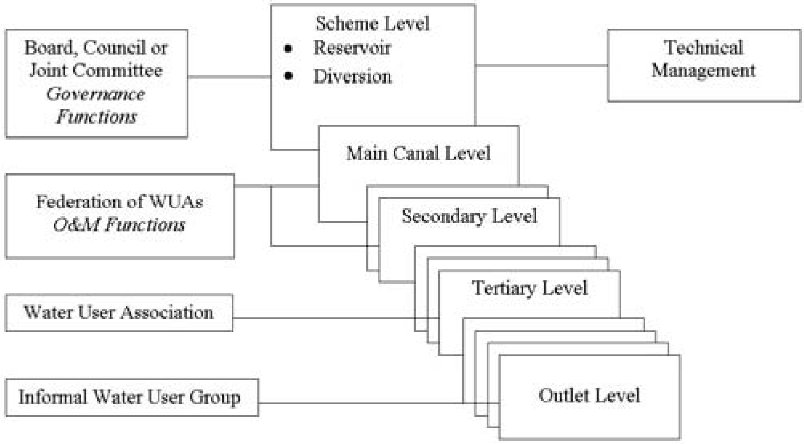

Figure 1 A multi-tiered user organization/agency of a surface irrigation scheme

Note: Each user organization may have either governance and management functions or both

Impact of irrigation management transfer over performance of irrigation projects

A number of specialists thought that taking irrigation and drainage system management out of the direct governmental sphere would inevitably lead to improvements in the sustainability of irrigation and drainage systems and in agricultural production. The philosophy was that users were more likely to operate systems effectively and according to their requirements and also pay for the operation if they were also the owners. The dominant perception was that public irrigation management organizations lacked the incentives and responsiveness to enhance performance whereas water users had a direct interest in cost efficiency, profitability and proper physical condition of the irrigation facilities.

However, despite the widespread adoption of management transfer programmes, there is still little information about their impact on the agricultural performance of irrigation systems. A review of PIM impact studies in 1997 noted that the impact is typically not noticeable in terms of agricultural performance. In Sri Lanka there has been no detectable change in irrigated area, crop patterns, cropping intensity or yields. PIM has neither improved nor interfered with agricultural productivity (Vermillion).

Another review of experiences in irrigation management transfer in selected countries in Asia revealed that the main impact has been a gradual decline in government financing of the operation and maintenance of irrigation systems, whereas water user groups are making a modest contribution towards maintenance. The analysis also shows that there has been a modest improvement in the irrigation service following transfer. The review concludes: *"the evidence of the impact of IMT on systems' operations is not conclusive but seems to suggest that it has not resulted in a deterioration of systems' operations nor in a decline in agricultural performance"* (Samad).

The general impression of an international workshop in Cali, Colombia, in 1996 organized to examine the impact of irrigation management transfer (IMT) in selected countries was that after turnover, services were substantially improved in terms of timeliness, reliability and equity in four countries (Mexico, Turkey, Colombia and Taiwan). By contrast, the social water user associations that were developed for the purpose of providing cheap labour for maintenance and collecting water fees were consistently found weak or paper associations. The business-type water user associations that hired staff to distribute water and ran the distribution system similar to a business operation were often very strong.

Two papers on Mexico irrigation presented at the ICID Congress in Granada, Spain, in 1997 illustrate the inconclusive evidence of the impact of irrigation management transfer on the performance of irrigation projects. Johnson noted that the water user associations have proven capable of managing irrigation systems and in the process have reduced annual government subsidies for irrigation water by more than US$200 million. Maintenance activities by the user associations have stopped the deterioration of the infrastructure.

However, Johnson concluded on a pessimistic projection by stating that *"In Mexico with relatively good irrigation under the irrigation agency, it is unlikely that IMT alone would result in dramatic increases in production"*. A second paper presented by specialists from the Mexican irrigation agency noted that the agricultural productivity of 38 irrigation districts transferred in 1994 had dramatically increased. The average crop yield increased by 39 percent from 7.9 to 11 ton/ha and the water productivity by 62 percent from 750 to 1220 kg/1000 m^3 between 1989 and 1996. Wheat yield increased by 41 percent after the transfer. This paper, however, noted that this increase was the result of the transfer programme and two complementary programmes: a rehabilitation, modernization and on-farm improvement programme coupled with the modernization and improved techniques of on-farm irrigation.

Some projects claim a substantial increase in cropping intensity and crop yields, but these projects were performing at a very low level before the transfer. The transfer of management to user associations may have contributed to reducing the chaos in water distribution and the level of inequity between head- and tail-enders. The impact is less evident in projects that were previously managed by irrigation agencies according to well-established rules. These agencies have transferred their practices to the associations. For example, the user associations have adopted the mode of water delivery on pre-arranged demand used in most Latin American countries after transfer. Some improvement in the service provided, such as reducing the time lag between demand and actual delivery could be made through technological changes such as an improved communications system, computers and operational procedures.

In conclusion of this chapter on user participation, this paper argues that:

- Simply rearranging the "deck chairs" is not likely to achieve significant improvements in irrigated agricultural productivity and will not meet the broader objectives of integrated water resource management (Malano);

- Small and social associations or water groups responsible for operation and maintenance at the tertiary level have little potential for improvement;
- Most institutional improvements cannot be fully implemented without the right physical environment;
- Physical and institutional improvements in irrigation are not isolated actions but are self-supportive;
- Any strategy for improving performance of the irrigation sector should consider the relationship between the design of user associations and their functions and the strategy for a higher level of service.

The rapid devolution of management to business-minded associations adopted by some countries is likely to be a better strategy than the formation of social associations. However, it requires a high level of commitment by the political authorities and the government agencies and by the farmers, a massive mobilization effort by the government to convince the farmers to take over and to organize the associations and a massive training programme in a number of water management, accounting and operational issues. This does not imply that formation of small groups of users is a bad strategy. These small groups are needed to organize water distribution at the lowest level in irrigated areas where small farms dominate. However, if these water groups are nested in a multi-tiered organization up to the main system or project level, they can participate in important decisions on activities affecting their lives. This is the basis of the emerging new concept where new concepts of user participation and modernization of the systems are converging.

VI. IMPROVED IRRIGATION IN THE CONTEXT OF WATER RESOURCE MANAGEMENT

In recent years there has been a growing interest, particularly among IWMI researchers, in improving the understanding of the concepts of efficiency, water loss and agricultural water use. Although only a part of the water diverted to an irrigation system is effectively used by the crops, typically less than 50 percent, the remaining water either drains to the river system or seeps into the ground. In both cases it can be used downstream for another purpose or pumped for irrigation, very much increasing the overall efficiency at the project and at the basin levels. Drainage water that flows back into a stream or to subsurface areas is not lost or wasted in physical terms. The distinction between field efficiency, project efficiency and river basin efficiency is very important. Improving irrigation efficiency to increase cropping intensity or expand irrigable land might deprive another irrigation system or another use downstream, such as navigation, water supply or environmental flows to control marine intrusion in deltaic areas. These issues have led to an ongoing discussion on whether efficiency improvements can produce any water that can be reallocated to other users. For example, some California planners dismiss the potential for water use efficiency improvements in that state because, they argue, such improvements will not produce much “real” water.

This discussion should however not be an excuse for not improving irrigation systems.

The main cause of water-logging and salinization, requiring expensive drainage works, is excessive irrigation. Improving water application can substantially reduce the hazard of salinization as well as the cost of drainage. Increasing irrigation efficiency can have a significant effect in reducing the load of salts that must be removed from the soil annually (Hillel). Drainage water gets polluted by removing salts from the soil, as well as by fertilizers and pesticides.

Inefficiency at irrigation-project level increases pumping costs in projects that depend on lift from a river, such as many projects in Romania pumping from the Danube River or the very large Kashi project in Uzbekistan.

Inefficiency makes uneconomic a number of investments in irrigation because it reduces the areas that can be irrigated and the expected benefits. Inefficiency also depresses crop yields, particularly in the tail end of irrigation projects, because of changes in irrigation scheduling such as increased intervals of irrigation, to compensate for the rapid depletion of water resources.

Inefficiency increases non-beneficial losses by increasing evaporation and transpiration from soil and free water surfaces. This is the case, for example, in the Tarim basin in China where inefficient irrigation has caused large waterlogged and saline areas surrounding the lower areas of surface irrigation projects. It has been claimed that the overall efficiency of the Nile system in Egypt may be as high as 90 percent, counting part of the water flows released to the sea as requirements for environmental purposes. However, it is not known how much water is lost through unproductive evaporation from fallow and wet lands throughout the valley and the delta.

Efficiency improvements also produce other benefits, including improvements in human health, more reliable in-stream flows, ecosystem and habitat restoration, reductions in the cost of treating drinking water, less environmental contamination by agricultural chemicals, and reductions in the economic cost of multiple unnecessary withdrawals of water (Gleick).

It would be a mistake to leave the impression that improving the efficiency of irrigation systems is not an issue because the lost water can be re-circulated or used further downstream. It would also be incorrect to suggest that the highest efficiency should be obtained in all circumstances, especially where there is a high potential for groundwater reuse.

PART II: CHANGING APPROACHES TO THE DESIGN OF IRRIGATION PROJECTS

The time for grand vision and flowery rhetoric has passed. The challenges ahead require sharper focus, real commitment, and concrete action.

VII. IRRIGATION DESIGN CONCEPTS IN SELECTED COUNTRIES

This chapter presents the salient features of the design, management and performance of irrigation systems in key countries. Obviously it is not an exhaustive presentation. The objective is to highlight the large differences regarding designs and management of systems caused by the climatic differences and the economic, political and social relations in the different countries. The second part of the chapter discusses the problems with the transfer of technology from one region to another one with different social environment.

A. Traditional irrigation systems

Traditional irrigation is rooted far back in history. Although traditional irrigation schemes now represent a small percentage of the 265 million hectares under irrigation worldwide, they still play an important role in most developing countries such as Nepal, Indonesia, Morocco, Peru or the Philippines. Century-old schemes in Spain have been the models for the development of irrigation in the New World and have attracted the attention of engineers from colonial powers in the 19th century at the onset of irrigation development in the Indus basin and elsewhere. Traditional schemes are relatively small in scale, from a few tens to a few hundreds of hectares. However, some traditional schemes reach a few thousand hectares, such as the Maujis Chautra project (10 000 ha) in Nepal and the Khanabad project covering more than 30 000 ha in Afghanistan. These schemes have been built and maintained by local communities with little or no government support. Local customs regarding water allocation and distribution in these systems have evolved over time and are well adapted to local and ecological conditions. Although the term "local customs" may be interpreted as the opposite of scientific, the rules of water distribution can in fact be very sophisticated. Their complexity increases with the degree of water scarcity. By contrast, the infrastructure for water allocation is rather simple and all the users can understand their operation. The most frequently found water control structure in traditional irrigation is the flow divider to allocate water proportionally to fixed water allocation ratios related either to water rights or to the irrigated areas. The most famous traditional irrigation scheme is the 16 000 ha Valencia project in Spain, known for its oldest water tribunal. Complex operational procedures of this project prescribe different rules for three levels of water availability.

The cohesion and social bounds among members of local communities are the main reasons for the success and sustainability of traditional schemes which have been under existence for hundred of years. These social bounds do not usually exist in rural areas where settlers of various ethnic groups move shortly after the development of irrigation systems. Extending the finding of social research studies on traditional irrigation systems to the large-scale systems built in the last decades should be done with great caution. Self-enforcement of the rules is much weaker in these projects. For example, stealing water from the distribution canals in the Indus basin is common practice since water is perceived by the farmers as belonging to the government. By contrast, rules are strictly enforced once the water is diverted to the lower level managed by the users.

B. Country experience

1. INDIA

The large irrigation systems built in northern India in the 1800s were designed for drought protection to avoid famine. The objective was to distribute irrigation water to the maximum number of farmers. The design capacity of canals was as low as 0.25 litre/second/hectare or three times less than the irrigation requirements of intensive irrigation.

Agro-climatic and socioeconomic conditions in India vary widely depending on geographic location, and irrigation systems have evolved reflecting this diversity.

There are several models of distribution of water below field outlets in surface irrigation systems: i) the *warabundi* system of Northwest India (Punjab, Haryana, Rajasthan and Uttar Pradesh), ii) the *shejpali* and block systems (Maharashtra and Gujarat) and iii) the localized system used in the southern states.

Under the *warabundi* system the available water is allocated to all farmers within a block, irrespective of their crops and location of their holdings, under a rigid weekly scheduling. The share of water is proportional to the holding area in the outlet command and allocated in terms of time interval as a fraction of the total hours of the week. Advocates of *warabundi* claim that this system is highly equitable. This would be right if the seepage losses in the field channels of the block were negligible. Seepage losses of unlined channels may represent 40 percent of the diverted flows.

Under the *shejpali* system, the government enters into some sort of agreement with the farmers for supplying water to them. The farmers file applications and the government issues permits for the supply of water and the two constitute the agreement. The water is distributed according to a predetermined date in each rotation. A preliminary programme is drawn every year depending on the availability of water. Farmers submit applications for supply of water indicating the crops they wish to grow and the areas under them. Water is then apportioned on the basis of the crops and the overall demand. A schedule fixing the turns of supplying farmers in the sanctioned areas is prepared for each rotation. The irrigation interval depends on the rate of water consumption by the crops. The schedule is notified in advance and every farmer of the command area has prior information about his turn of supply. The system is called "rigid *shejpali*" if the duration of supplying water in the various fields along with the date is also recorded on the permits issued to the farmers for sanctioned areas. Application of the *shejpali* system is based on a high intensity of adjustable gates and their frequent resetting. The objective of matching supply with demand is rarely met because of the difficulty of operating manually adjustable gates.

Under the *block* system, a long-term arrangement for supply of water is done particularly for perennial crops, but irrigation from season to season proceeds through *shejpali*. The blocks are sanctioned for six to twelve years. (Mandavia)

The advantages and disadvantages of the different designs used in India have been the subject of several research studies, which led to intense debate. There is, however, wide recognition that, overall, the performance of surface irrigation in India needs considerable improvement. Bhavanishankar states: *"The reliability and predictability of water supplies is not assured in most of the schemes. Conflicts are common in most of the systems, leading to vandalism and disruption of the physical facilities and degradation of the system. The present method of delivering the water as per the demand of the powerful group among the farmers is often arbitrary and wasteful with considerable inequity in distribution."*

The unreliability and/or rigidity of water distribution from the surface irrigation systems in India as well as the under-sizing of the canals to deliver water for intensive irrigation have contributed to the uncontrolled development of groundwater during the last decades.

2. PAKISTAN

Of the 16.2 million hectares irrigated in Pakistan in the early 1990s, about 93 percent are under the command of the Indus River Irrigation System. This system, the largest in the world, encompasses three storage reservoirs, 19 barrages or head works, 12 link canals, 43 command areas and 107 000 watercourses, each one serving an area of about 250 to 700 acres. Water to the watercourse is diverted from the distributary and minor canals through ungated structures known as *mogha*. The design is similar to the one used in northwest

India. With the exception of the link and main canals, the system was designed to operate at or near full supply. The *mogha* is designed to allow for a constant discharge. Within the watercourse command, farmers receive water proportionally to their landholding. The entire discharge to the watercourse is given to one farmer for a specified period on a seven-day rotation.

The canal system was designed as a run-of-the-river project to maximize the cropped area, with minimum water consumption, and simple operation and administration. Canals were intended to provide equitable distribution, with no interference by the canal establishment[15].

Extensive performance studies by IWMI and others have demonstrated that water distribution, contrary to the stated objectives, is not equitable. The greatest inequity is between watercourses. Some head *mogha* draw two or three times their allocated shares while tail *mogha* may only receive half or less. The main causes of inequity are the opposition of the farmers to the abolition of the privileged water allocations granted during the colonial period, the tampering of the *mogha* structures and installation of illegal outlets, as well as changes in water profile due to siltation[16] and lack of maintenance. The overall efficiency of canal

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[15] Field reality differs considerably from this idealistic equity objective. Abundant literature has documented the policy of the colonial state which tended to allocate privileged and customary rights to local elites as "compensation" for governing their local communities in line with the interests of the colonial state or other services rendered. After Independence, the strict application of an equitable and proportional water allocation was strongly opposed by both the civil authorities and the farmers when the irrigation departments tried to formalize an equitable policy. For example, water allowances at the distributary canal head of the Lower Chenab Command range from .19 to .32 l/s/ha with an average of .24 l/s/ha. Water allowances at the outlets within the same command range from .13 to .84 l/s/ha.

[16] As a result of lack of maintenance (weed and silt cleaning), the higher water levels in the upper reaches of the systems cause higher than foreseen

systems serving individual command areas is below 40 percent. Losses contribute to groundwater recharge.

Groundwater use has been a main factor in the intensification of irrigated agriculture in Pakistan during the last two decades. Groundwater not only supplies additional water but provides the flexibility to match water supplies with the crop demands. The originally expected cropping intensity has increased on average from 120 to over 160 percent in some areas of Punjab. The overexploitation of groundwater is discussed in Chapter 9.

Irrigation systems were initially developed without provision for drainage. Irrigation without drainage in an environment like the Indus basin inevitably leads to the rising of water tables and salinity. About 30 percent of the Indus command area is currently waterlogged and about 14 percent severely or moderately salt-affected. (World Bank 1994)

The basic design concept in northwest India and in the Indus basin was to provide equitable distribution of water with minimum interference and low-cost operation by limited staff and means of communication. Distributary and minor canals were operated in on/off rotation from continuously running main systems. Ungated outlets discharge water from these canals into the watercourses from where farmers get their water shares under the *warabundi* system. This system was expected to be effective and equitable but it was not related to crop water requirements. It is up to the farmers to arrange their cropping pattern and watering to suit the delivery of water at a fixed flow and predetermined time. For the reasons given above, there is great inequity in actual withdrawals between head and tail watercourses.

Groundwater development has obviously contributed to the reliability and flexibility of water allocation in the Indus basin. A valid question is whether the development of groundwater has

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discharges through the outlets in these reaches, resulting in less water being available downstream.

improved the equity of distribution. Few research studies have been made on the performance of conjunctive use of water in the Indus basin. It is assumed that the equity between the mid and upper sections of command areas has improved. However inequity may have increased for the lower sections because of the poor quality of groundwater and the lower density of wells.

Box 6: "By refusal" water control strategy application in Pakistan

The Lower Swat Canal in the North West Frontier Province of Pakistan was "modernized" in the 1980s to meet future crop and salt leaching requirements. The modernization objectives consisted in the rising of the water delivery capacity from .36 to .78 l/s/ha (and up to 1.34 l/s/ha to provide operational flexibility) and the provision of facilities to gradually transform the operation into a "modern" demand-based irrigation scheduling. The canals are run at full supply, except in February when river discharge is low, and in December, when there is hardly any need for water. The majority of the watercourses can now get nearly three times as much water as was used before "modernization". The pre-project situation of a water-scarce system has been converted into a near ideal agricultural system in which a farmer can grow anything he wants and water has become abundant to the extent that night irrigation can be abandoned for months every year. Since the drainage water effluent returns to the Kabul River and ultimately is available for use in the Indus system in Punjab and Sindh provinces, the irrigation department considers this is as no problem at all. (Communication of van Hanselma)

The same strategy is now adopted for the Chasma Right Bank Canal (CRBC), construction of which started in the late 1970s and is not yet completed. The CRBC design reflects much of the old design tradition in terms of control structures. In 1989, IWMI was contracted to help define a flexible management approach for irrigation operations responding to crop requirements (the so-called crop-based irrigation operation). Despite intensive research on simulation of the hydraulic conditions of the main canal, the study failed to define and implement any practical operational procedures, given the difficulty and frequency of gate settings. The actual operation and water delivery reflects the practices found in the Lower Swat Canal system. Farmers manage their irrigation on personal agreements. They frequently refuse water by partially or fully closing their outlets. The "refused" water drains to the Indus River flowing at a short distance from the main canal.

Use of untreated wastewater is a usual practice around most cities in Pakistan – and many other countries. Wastewater is valued by the farmers not only because of its nutrient content, but also for its reliability of supply, which makes cultivation of vegetables, the most common crop in Punjab, possible.

Adoption of modern design approaches was attempted in the North-West Frontier Province, Pakistan, which benefits from relatively abundant water resources. The higher capacity of the canals, without enough consideration of variable flow conditions and risk of siltation, has resulted in the adoption of a control "by refusal". This ad-hoc strategy consists in operating the main and secondary canals at or near full supply and letting the farmers and operators release the excess water directly from the canals to the drainage systems.

3. EGYPT: the Nile Valley system

Irrigation was practised throughout the Nile Valley from the earliest times. Until the mid 19th century, this was realized by natural inundation from flood waters. The system has been converted from flood to perennial irrigation following the construction of the Aswan dam and delta barrages. Of the 3.3 million hectares irrigated in Egypt, nearly 95 percent are supplied from the Nile irrigation system. Barrages on the Nile divert water to the main canals. Main canals supply branch and sub-branch canals, which provide water to private farm watercourses, called *meskas*. Flows released in the main canals are based on crop water requirements and expected distribution and farm losses. The branch canals are operated on rotation based on the requirements of the dominant crop. During a typical 12-day rotation, branch canals receive water during 4 days and are off during 8 days. A unique feature of the Nile system is that most branch canals and *meskas* are below ground level. Farmers used to lift water from the *meskas* through animal-driven pumps. Irrigation was mostly practised during daytime. The relatively low flow of individual pumps ensured a high level of equity of water allocation between head- and tail-enders and avoided over-watering of the cultivated lands, by contrast with gravity systems. The situation changed dramatically with rapid replacement of traditional pumps by individually owned diesel pumps or electric pumps since the 1970s, creating large inequities of water extraction along *meskas* and social inequities between tail- and head-enders. Tail farmers responded by looking for other sources of water, mainly by pumping from the drain system. The Nile system is similar in its architecture and operation by rotation to the Indus system. However it differs in four key aspects:

- the releases from the Nile to the canal system are based on irrigation requirements;
- the watercourses are below ground level, forcing the farmers to pump;
- the farmers are free to irrigate at any time when their branch canal is “on”; and
- the design capacity of the canals is about three times higher.

The Ministry of Irrigation is now implementing a modernization irrigation project to reduce the inequity and the re-use of poor-quality water in the Nile delta following the adoption of diesel pumps. The objective of the modernization is to create night storage in the secondary canals and to replace individual lift pumps by a common lift pump serving a raised *meska*. This plan is based on the adoption of a rotational distribution of water by the farmers organized for this purpose in water associations at the *meska*-pump level. This is a unique case of modernization in which farmers have to accept the conversion from a free-demand (when their canals are “on”) to a rotational system requiring coordination and discipline.

4. SUDAN: the Gezira project

The Gezira project lies between the Blue and White Nile rivers south of Khartoum. The Sennar diversion dam built in 1925 and the multipurpose Roseires dam completed in 1966 regulate the flow of the Blue Nile. The Gezira scheme was designed in the 1920s after prolonged experiments had been carried out at pilot scale. It was designed with the main objective of producing cotton, a single cash crop. Other crops are grown to provide food for the farmers and to help in the maintenance of soil fertility. Cotton, wheat, groundnut and sorghum are now cultivated in a four-crop rotation including fallow. The farmers do not own the land. The scheme is divided between 102 000 tenants with an average of about 8 hectares.

The irrigation system was laid out to suit the size of tenancy and crop rotation. The flat and featureless topography was favourable to the adoption of a regular gridiron layout. The basic unit is a group of four adjacent fields of 90 *feddans*. One crop is grown on each strip following the four-crop rotation system. Each block is divided into 18 tenant fields of 2.2 hectares each.

The irrigation system comprises twin main canals running from head works at the Sennar dam with a combined capacity of 354 m^3/s, a network of 2 300 kilometres of branch and main canals, and about 1 500 minor canals with a total length of over 8 000 kilometres. All canals are divided into reaches by cross regulators which are the control points for the off-taking canals.

The minor, branch and main canals are designed as regime conveyance channels. The minor canals are also designed for storing water flowing continuously from the main canals at night.

Operation of the scheme is centrally controlled: the management is divided between the Ministry of Irrigation (MOI), which is responsible for the irrigation network, and the Sudan Gezira Board (SGB), which is responsible for agricultural operation and for determining the irrigation water requirements. The water orders (or indents) are passed to the MOI engineers, summed out throughout the system up to the head works at the Sennar dam.

Water flows from the main to the minor canals are controlled by movable weirs, which provide accurate and easy water measurements, but have the serious disadvantage to be highly sensitive to upstream variations of water level.

The Gezira scheme is not a sophisticated one by present-day standards. It was designed before the development of modern technologies of canal water control. The design, however, took the best advantage of some favourable and unique features of Gezira: the flat topography and the adopted tenancy system, i.e. the absence of constraints imposed by small, fragmented, field plots found in many developing countries. The adoption of the night storage system resolved the issue of night irrigation found in many schemes. It provides a remarkable solution to the complex problem of adjusting water releases at the head works and at critical points of the system to the demand without excessive losses. A negative characteristic of the minor canals, which was probably overlooked, is their ability to trap the silt released into the system.

For about forty years, the Gezira scheme was operated satisfactorily on the basis of the original design and operational concept. The management of the Gezira scheme ran into problems in the early 1970s shortly after the scheme reached its present extension. The steady deterioration of trade in Sudan led to shortages of financial resources. Funds became insufficient to finance the high recurrent operation and maintenance costs and to replace machinery and equipment. For lack of financial resources, MOI was not able to cope with the removal of silt and clearance of weed. The situation was worsened by the breakdown of the telephone system, which was a vital tool for communication between SGB and MOI for the water indent process. All these factors resulted in inadequate use of the system. The degree of siltation in some minor canals is such that precious little water reaches the tail blocks and some areas are out of production. The tenants lost confidence in the untimely operation of the system and, to some extent, took over the management of the minor canals. The original night storage system gave way to continuous irrigation water delivery to the fields. By adopting unattended continuous irrigation, the tenants have reduced irrigation labour costs. They also appreciate the flexibility of the new de-facto on-demand system since they took control of the opening of the field outlets. The departure from the originally planned method of irrigation has given rise to a new management and water application. The intention of MOI is to re-establish the night storage system, which was based on a strict discipline of water scheduling. An informal management offset the decline in the performance of the official system. However, the unique design of the system played a major role in maintaining irrigation service in the 1980s and in the adoption of a new informal management system. The minor canals playing the role of terminal reservoirs are the key features of that transformation. It is now demonstrated that water delivery in the Gezira scheme can be based on either rigid or highly flexible scheduling, as long as the indenting ensures adequate refilling of the minor canals. In other words, the design was able to adjust to a major departure from the original management thanks to the flexibility in operation provided by the design of the minor canals. The main drawbacks of this unique feature are its silt-trapping efficiency and high health hazards during manual weed clearance.

The suggestion made by a foreign consultant to narrow the minor canals to reduce weed and silt clearance would not totally solve the problem of siltation and weed infestation, although it would eliminate the buffer storage in the minor canals, a critical feature of the design of the Gezira scheme. It would also considerably increase the complexity of operation.

5. CHINA

China has very detailed standards and regulations for the design of large water structures. Typical structures are found in most provinces. Irrigation projects belong to the category of manually operated gated systems. Some gates built in concrete in the 1960s are very difficult to handle. Many systems in China are operated during periods of about 20 days each totalling about 80-100 days per year, generally at or close to full supply. Water is released after a long consultation between the local authorities and farmer groups. The design is very basic but management relies on the active participation of users or local communities at all levels. This strongly advocated approach for improving irrigation performance has rarely succeeded in other countries.

A characteristic feature of the configuration of irrigation systems in mid and southern China is the number of large, medium and small reservoirs, which form an integral part of the systems. Large reservoirs created by the construction of large dams are connected to medium reservoirs and to hundreds of thousands of village reservoirs and ponds. For example, the Pi-Shi-hang Irrigation districts, which serve 680 000 hectares in Henan province, consist of a network of canals connected to five large reservoirs, 24 medium-sized reservoirs with a total active capacity of 420 million m^3, 113 small reservoirs with an active capacity of 205 million m^3 and 210 000 storage ponds. The reliability and flexibility of water delivery of these systems are very high.

China has developed a water-saving technique for irrigating paddy fields consisting in alternating wetting with shallow water and drying periods. This method is now applied on about 3.5 million hectares out of the 21.3 million hectares of irrigated paddy fields in China. It not only saves a considerable volume of water but also leads to higher yields of rice. Application of this method requires a high level of management at both on-farm and off-farm levels.

A singular feature of irrigation in China is found in its management as a result of a series of reforms that took place in the water management sector during the last decades. The authority for owning and managing irrigation projects is determined according to investment. Large irrigation districts are usually managed by organizations at various levels such as prefecture, county, township and village. In the 1980s, the government launched the production contract responsibility systems in the rural areas to support individual initiatives. The government also changed irrigation management from centralized control to contract management in order to facilitate decentralization. The contracting organization may be a company, a farmers' group, a joint household or an individual. The contractors have the right to operate and manage the irrigation facilities and should take full responsibility for profits and losses. As a result of the contract management, the management organization is optimized; especially, the workers' income is closely related to their performances of the contracted targets. China is now experimenting with several models of contract management, particularly in Shandong province. China is clearly a country where management improvement has been a substitute for a very basic water control infrastructure.

6. NORTH AFRICAN COUNTRIES

Development of modern irrigation in the three North African countries (Tunisia, Algeria and Morocco) started in the late 1930s, more than fifty years later than in South Asia and Egypt, accelerating only after World War II to reach peak development after Independence. This late development was possibly the reason for the fundamentally different approaches to the planning of irrigation projects in that region. According to verbal sources, the low level of education of the rural population stimulated the colonial government agencies to design irrigation projects which met the dual objective of being operated with minimum intervention of operators and simple operational procedures and being flexible enough to meet the irrigation requirements.

An intensive research programme with the support of the private industry led to the development of hydro-mechanical equipment to automatically control upstream or downstream water levels and water flows as well as fixed static structures such as flow limiters and long-crested weirs, known also as duckbill weirs. These weirs provide nearly stable water levels in canals. The concept of canals operated by downstream and upstream control and the combination of these techniques were refined over the years. The use of these innovative designs became standard practice for irrigation projects in these three countries and in most Mediterranean countries. It was later extended to other regions but generally on a project, case-by-case basis.

The canals are designed to be able to answer irrigation requirements during peak demand for the cropping pattern adopted at design stage. However, the specific design capacity is multiplied by a factor of up to 50 percent from the main system to the tertiary canals to provide some flexibility in order to accommodate variations in demand and deviations from the project cropping pattern. For example, the design capacities of the Doukkala project in Morocco increases from 0.65 l/s/ha for the main canal to 1 l/s/ha at the tertiary level.

Most of the main canals are concrete-lined and the secondary and tertiary canals consist of prefabricated *canaletti* (flumes) using the most advanced pre-stressing concrete techniques. The concrete lining of main canals is about 30 percent thicker than the lining of canals of similar sizes in other countries.

As a result of the high standards of design and construction, and the small variations in water levels, the life of the irrigation systems is remarkably better in these three North Africa countries than in some other regions. Some projects built in the 1950s are still under operation. The first rehabilitation projects in Morocco were related to undersized projects built before World War II, which became incompatible with the intensification of irrigated agriculture.

Another feature of irrigation in Morocco is the systematic consolidation of irrigable lands before the installation of the infrastructure. Before project, irrigable lands are highly fragmented and boundaries of individual plots are randomly organized. The model adopted by the Moroccan administration in the 1960s, after testing different models, is based on the same principle as the model used in Gezira in Sudan. The objective was to facilitate the adoption of modern irrigation scheduling and mechanized farming practices in a context of smallholdings. Geometric blocks of 30 hectares were divided into four to six crop strips of equal width and the farm holdings were arranged with boundaries parallel to the other direction. Permanent quaternary canals were associated with a farm road and farm ditch. The number of farm plots was reduced about five times in some projects.

To be successful this model requires the strict discipline of the farmers in respecting the government-imposed cropping patterns and joint organization of agricultural works within each crop strip. The farmers progressively deviated from the imposed cropping. However, the most serious deviation from the original plan was in on-farm water management. The quaternary canals owned collectively by the farmers of a block were not maintained, and land levelling badly degraded, eliminating the possibility to adopt furrow irrigation or border irrigation. The farmers came back to the century-old inefficient irrigation method of small basins.

Although there are some variations between regions, water distribution in Morocco is largely decided by the irrigation agencies (ORMVA). The basic principle of water distribution is that each farmer receives a predetermined volume of water per irrigation turn. ORMVA decide on the implementation of the irrigation turn, its duration, and the volumes per hectare for the various crops, depending on the availability of water in the storage reservoirs. Farmers can decide whether to take water during a turn or to reduce the duration. They sign a note of acceptance, which specifies the date, time, duration discharge and total volume delivered which will be used for assessing the water charges. Although the system has the capacity to be operated on prearranged demand and to provide the flexibility required to meet the farmers' needs, it is essentially a centralized system. This mode of operation was justified when rain-fed farmers were converted into irrigators a few decades ago. It does not respond to the needs of modern agriculture in Morocco.

Irrigation in the North African countries is not performing at the expected level, although the level of technology of the delivery system is of the highest standards. The main reason may be found in the poor on-farm use of water, which is related to the outdated delivery procedure and land consolidation model.

7. IRAN

Iran is an interesting example of a country without national design standards. Two basically different approaches to irrigation planning are found in that country. In the Khuzistan province in the south, old design standards of the Bureau of Reclamation have been used for the design of the Dez multipurpose project and adopted for all irrigation projects in that region. In the northern provinces, the most frequent design standards are those introduced for the design of the Isfahan and Guilan projects by a French consulting firm with long experience in North Africa. The two design standards used in the northern and southern parts of Iran belong to the category of fully gated systems. The design objective in both cases is to distribute water according to requests of individuals or group of farmers with flexible scheduling. However, they differ by the control function. All gates in the south are manually operated whereas the northern systems benefit from a high degree of hydraulic automation, which simplifies their operation. Box 7 provides a detailed discussion of the Guilan project, which is a unique success story of transfer of technology from an arid region to the paddy systems with humid climate along the Caspian Sea.

Box 7: The Guilan project

Most parts of Iran have an arid or semi-arid climate. However, Northern Iran between the Caspian Sea and the Elburz mountains is reminiscent of the mid-south region of China, with skilfully terraced paddy fields bestrewn with plastic-covered nurseries. As in China, the traditional irrigation systems comprise many small reservoirs. The 142 000-ha rice-predominant Guilan project was built in the 1960s. The irrigation infrastructure is typical of those found in North Africa with a network of concrete *canaletti* supplied by canals equipped with long-crested weirs, automatic hydraulically operated gates and modular distributors. This unusual combination of East Asia farming practices with Western technology is unexpected in the Middle East. The high level of performance of that project is little known among the irrigation community, possibly because of the lack of external financial assistance. A rapid assessment of the project in 1995 concluded that the project is performing as expected at design stage, after nearly 30 years of operation. The volume of water diverted for the irrigation of the command area compares well with the one calculated at the feasibility stage. The low level of vandalism and tampering with control structures is an indication of the high level of satisfaction of the farmers. Three factors can explain the harmony between actual and expected results: the calculations of the water requirements at farm level were supported by detailed tests to determine the evapotranspiration and, more important, the percolation losses; the water control system is user-friendly, reliable and does not require frequent adjustments of gate openings by operators; and the rainfall pattern during the growing season is relatively uniform, without high intensity precipitation and excessive drought spells.

The Guilan project contradicts the paradigm that a design consisting in reticulated fully gated canals is not suitable for irrigation projects in the humid tropics. It also contradicts the well-accepted paradigm that the irrigation technology of arid and semi-arid countries is not suitable for humid tropics.

8. MALAYSIA

Malaysia is another example of a country without national design standards. Foreign consultants have introduced three different design standards that reflect their own experience, as illustrated by the examples of the Muda, Kemubu and Kriang-Kerian schemes.

The Muda scheme: This 98 000-ha scheme, designed by a British firm, accounts for 40 percent of the national rice production and is critical to the rice policy of Malaysia. The main infrastructure is comprised of two storage reservoirs connected by a tunnel, a diversion dam further downstream, and two main canals. At the time of construction, a remote monitoring system was installed to provide the operating engineers with real time information on reservoirs and canal water levels and on rainfall in the catchment area between the storage and diversion dams to predict the unregulated flow. Cross regulators on the main canals are equipped with overshot motorized gates. Furthermore, pumping facilities and tidal gates were installed to recapture the drained water in the lower part of the scheme. The combination of these devices with remote monitoring has contributed to the efficient operation of the main system. Service to rice growers was irregular, however, because of the difficulty of managing the delivery system equipped with manual gates. To achieve the better control over volumes of water and timing required for new techniques of direct seeding, the farmers install their own pumps to lift water from public canals and drains.

The Kemubu scheme: This low-lift pumping scheme, designed by French consultants, adopted downstream control for the main canal and the pumping station and upstream control for the secondary system equipped with long-crested weirs and modular distributors.[17] As in the Muda scheme, the operational problem is the difficulty of controlling flows in the minor system and meeting the requirements of increasingly diversified cropping. Different control structures were later adopted for an extension of the scheme, consisting of adjustable flow-dividing structures.

The Kriang-Kerian scheme: That scheme was developed using the old standards of the Bureau of Reclamation, mainly the use of constant head orifice. These are discussed in the next section. This project is now under modernization through low-cost automation.

9. INDONESIA

Irrigation in Indonesia, particularly on Bali and Java islands, has been practised for the cultivation of rice since ancient times. The old and non-technical systems represent a large part of the six million hectares currently irrigated. Design of the systems built during the colonial period and soon after Independence was rustic. Individual control structures were improved over time, but not enough consideration was given to the functioning of the entire system.

- To improve measurement and control of flows diverted from one parent canal to the next-level canal, an adjustable weir gate, known as *Rominj* gate, was developed in the 1950s. This gate is a precise measuring device but has the disadvantage to be sensitive to the variations of water level in the parent canal, which are frequent in run-of-the-river projects.
- Indonesia design standards were improved in the 1980s by foreign consultants. One of the proposed innovations was to replace the flashboards of check structures by conventional sliding gates. The main reason for this change was that flashboards were risky and difficult to handle.

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[17] For a long time, the Kemubu scheme suffered from poor functioning of the pumping plant, for reasons not well identified, which affected the operation of the main canal under downstream control.

The result of these two independent local improvements is a combination of hydraulic structures, the worst solution for the operation of a canal system. The sensitivity and hydraulic stability of structures are discussed in several books and design manuals (Horst, Ankum).
The *Rominj* gate was again unsuccessfully introduced in the design of the Mae Khlong project in Thailand.

10. UNITED STATES OF AMERICA

Application of modern technologies in water projects in the United States attracted the attention of many foreign visitors, as is the case in other developed countries (drip irrigation and wastewater use in Israel, Canal de Provence in France). The most comprehensive application of automation through central supervisory control is found in the control system of the Central Arizona project, which delivers water to urban, agricultural and industrial water users in central and southern Arizona. This system includes a large number of in-line pumping plants. The first effort to develop devices for local automatic control of canal systems in the United States dates back to the mid 1950s and was faced with the problem of instability in case of large flow changes.

Less well known is that many of the canal irrigation systems in the United States are far from having been modernized. Almost all control on irrigation canals is upstream control. Some systems still operate on rigid rotation schedules. In California, it is unusual to operate on pure demand. Water delivery to users is usually arranged. The average advance time for request is 26 hours for the 60 irrigation districts surveyed by Burt. Almost none of these districts have downstream control. Farmers, however, enjoy flexibility in flow rates. The flexibility in delivery can be offered because of excellent communications, high mobility of staff, high density of turnouts and judicious use of proper equipment such as weirs, regulating reservoirs and recirculation of excess water through interceptors and numerous applications of remote monitoring through SCADA. There is almost always measurement of flow rates at all turnouts.

In the Grand Valley district in Colorado, water is delivered on demand with a crude upstream control and few regulators. The system is operated at high flows with a large proportion of flow back to the river.

Burt has identified some aspects of the social and legal environment in the United States that have a bearing on the success and failure of irrigation projects, such as:

- The projects benefit from water rights and have the ability to enforce water rights and rules;
- Projects have excellent legislation for the formation of water user associations. Most of these associations are operated as businesses with professional management staff responsible to the elected boards of directors;
- Most consultants in modernization are private local consultants who must live with the results of their work; news on bad projects travel fast;
- Good living conditions (health, education) in rural areas; and
- There is excellent infrastructure for spare parts and new equipment.

This environment is not found in many developing countries, where modernization of irrigation projects is therefore more difficult to undertake and sustain.

C. USE OF OLD U.S. BUREAU OF RECLAMATION STANDARDS IN DEVELOPING COUNTRIES

Design standards for the projects supported by the Bureau of Reclamation in the Western States are the most detailed standards that can be found worldwide. They have been widely disseminated through technical assistance and consulting firms to a number of developing countries. In some of these countries, such as Thailand, the Philippines, Mexico and Turkey, U.S. Bureau standards have become de facto national standards for a few decades. In countries without national standards, they were used for specific projects, such as the Kriang project in Malaysia or the San Lorenzo project in Peru.

The basic design consists of a reticulated network of canals equipped with manually operated structures. Cross regulators are equipped with one or more radial or flat gates which are hand-operated or motorized. In some cases, a small lateral weir section is provided for emergency purposes, not for normal operation. Typical off-takes are equipped with constant-head orifice gates designed to measure and control flows. That infrastructure is in theory compatible with different methods of water distribution: prearranged, rotational or centralized.

A large number of these projects have a low hydraulic, agronomic and economic performance, as demonstrated by a number of recent studies (FAO). The U.S. Bureau standards were acceptable for the specific conditions of some Western States: short rainy season, relatively large farms, good road network and communications, and highly dedicated and trained operating staff. Good quality of construction was also a condition of success. All these conditions were generally not present in the countries which adopted these standards. An exception is the arid north-western region of Mexico (states of Sonora and Sinaloa). As in the U.S. irrigation districts, water is distributed in Mexico on a prearranged basis whereas centralized distribution is the rule in East Asian countries.

Projects supported by other federal or state agencies in the United States are not necessarily applying the Bureau standards. A number of irrigation systems and large conveyance systems in the United States have been upgraded either at design stage or later through rehabilitation and improvement programmes. Automated data collection and control has become an integral part of most large water delivery systems and is becoming more prevalent on smaller projects as well. From its beginning with simple gate controllers, canal automation has evolved to include large supervisory control systems that oversee entire projects. The California Aqueduct and the Central Arizona project are operated under a central remote system. The Salt River project, which was under remote monitoring, has been

Technical and managerial deficiencies in irrigation projects

Photo 1 Dominican Republic: A tampered gated check structure

Viet Nam. Dau Tieng Project

Photo 2 Canals designed for operation at full supply cannot deliver water to the lower level because of a lack of check structures