**Irrigation Water Policies: Micro and Macro Considerations**
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# Downstream Of Irrigation Water Pricing – The Infrastructure Design And Operational Management Considerations

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## ABSTRACT

This paper focuses on surface irrigation systems in Asia. Water pricing is typically the most debated issue of the present region-wide efforts to reform the water sector and the irrigation sub-sector through participatory irrigation management or irrigation management transfer.

The paper argues that it is important to analyze and understand the actual water management of the irrigation systems and correctly assess their performance and the level of service they provide to farmers. Design and operational issues contribute significantly to the high level of chaos and anarchy that characterizes the irrigation systems in the region. To a large extent, actual water management is very different from the stated water management as reflected in agencies' mandates, institutional setups and stated, intended or official system management and operation policies. Irrigation distribution rules seen to have failed to address the actual service requirement of the farmers, which they try to achieve though subverting existing rules or complementing surface water supply with conjunctive use or any other available means. A common issue is the diversification of rice-based systems in systems developed for paddy mono-culture.

A condition for a water pricing system to work would be that stated operation policies and distribution rules become the same as actual operation and distribution, and that these are consistent with farmers' requirements. IMT/PIM in theory would provide the opportunity to achieve this but a review of past and present IMT/PIM programmes in the region suggests that these usually fall short in a crucial area: the decision-making process leading to the decision on system operation strategies and service and performance objectives.

The establishment of water pricing systems may not lead to substantial water savings in irrigated systems. However, the introduction of water pricing would be welcome if it forced a negotiation between ISPs and individual users or WUAs of service levels to be provided and at what cost. The establishment of service agreements is a promising avenue. Monitoring and evaluation of system performance and achievement of service standards would require the development of water measurement systems consistent with service standards and the basis for the calculation of water tariffs. This will typically require a departure from mere rehabilitation and existing design standards and operating rules, serious attention to all details of system hardware and software, and more than cosmetic rehabilitation or installation or re-painting of water gauges.

Further work is needed on interactions between design standards, operation strategies, service level and water pricing.

## INTRODUCTION

Present developments in the irrigation sector in Asia are dominated to a large extent by Participatory Irrigation Management (PIM) and 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 resources 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.

Viewed in this context as an economic instrument to improve water allocation and foster an efficient use of the resource, providing incentives to water conservation and transfer water from low-value to high-value use and, within irrigated agriculture, from low-value to high-value crops, water pricing is a pivotal feature of these reforms, at the cross-roads of internal considerations of efficiency, fiscal or financial sustainability of the irrigation systems and external considerations. Water pricing may reflect the financial or supply cost of providing irrigation water, covering system management, operation and maintenance, investment cost, interest and depreciation on borrowed capital to obtain full supply cost through a water tariff. The government, water resources or river basin management authority may charge users a water fee for the use of country or basin resources to cover the cost of monitoring, river basin planning, development and management, assessment of water quality and quantity, etc. In a service perspective, the water fee would reflect the cost of bulk water supply service provision while the water tariff would reflect the cost of water delivery service provision.

For the economists, the economic or opportunity cost of water reflects its highest achievable value and in theory would be achieved through competitive market pricing. Economists thus call for the establishment of water markets or tradable water rights for optimal water allocation. The productivity of water varies much across sectors and the opportunity cost of water is often much higher than the supply cost. The philosopher’s stone where economists and technicians can meet is volumetric water delivery and pricing. However, for water to be used by farmers as an input subject to micro-economic calculus, volumetric delivery and pricing would not be sufficient: farmers would also need to have a degree of control on the exact timing and quantity of water they receive.

Integrating the environmental cost with these two costs would represent full cost pricing. There again various schemes for valuation of the resource are proposed, such as contingent pricing. For some, the main issue is the valuation of the eco-systems that compete with irrigation for the resource and of the services that they provide and pricing schemes advocated compete with or complement opportunity costs. For others, the main issue is the valuation of the environmental services provided by populations in the watersheds upstream of the users, these services justifying a financial or economic compensation that should be integrated in the water fee. A symmetrical debate concerns the valuation of the positive or negative externalities provided by irrigation systems.

Thus, water pricing crystallizes and polarizes the expectations and concerns of the various stakeholders and constituencies and typically becomes the most debated and controversial aspect of the reforms but also unfortunately the most confusing. The confusion is exacerbated on the one hand by the complexity of the hydrological cycle in terms of land-water and upstream-downstream linkages, irregularity and seasonality at different time scales, water quality, water re-cycling and re-use, groundwater recharge and conjunctive use etc. and by the misconceptions or misunderstandings related to these phenomena and notions of water use efficiency or productivity, compounded generally by a dearth of meaningful data and, on the other hand, by the fact that water is but one of the inputs necessary for agricultural production, other inputs, resources and their uses being subject to all sorts of distortions themselves, and that irrigation policies including their water pricing aspects may finally be dictated by considerations that are totally external to water resources management or agriculture, such as national strategic security, internal politics or geopolitics.

In practice, water pricing as implemented in Asia has mostly taken the form of water tariffs to recover at least system operation and maintenance costs from users, although not always in their totality. Water fees are applied in some countries such as in China, with water fees for both surface water diversion and groundwater extraction, or in Vietnam, where some Irrigation Management Companies may buy bulk water supply from an upstream Irrigation Management Company. But in general, river basin organizations are still in their infancy in the region and water fees are the exception rather than the norm.

This paper positions itself downstream of the discussion on water pricing principles. It is important to understand the actual characteristics and water management in the systems that are the object of reform. The paper therefore looks at the actual irrigation systems in Asia as they are actually managed and what water delivery service they actually provide to farmers, how their design and operation influence their performance, and what has been the impact on service and performance of the previous participatory irrigation management or irrigation management transfer policies, of which water pricing is or has been a component.

There is indeed some concern that PIM/IMT reforms, having as their main thrust the restructuring of sector institutions, may have concerned themselves with reforming the stated management and operation of irrigation systems as it is described in reports and embodied in existing agencies and institutions. Financial flows related to collection of water tariffs or fees are typically structured along the lines of stated management and operation of the surface canal systems, which are usually replicated in multi-layered water user institutions. The actual management and operation of irrigation systems and actual circulation of water within the systems may be quite different: it may involve conjunctive use, re-circulation of drainage water and other "losses", etc. These aspects of system management, which are very important for the quality of service to farmers and overall system performance including in terms of project water use efficiency and productivity, do not usually appear in official documents and previous or reformed institutional setups.

There is a growing awareness that irrigation system infrastructure and its design and operation may be an important factor that should deserve more scrutiny. The recent FAO-INPIM international email conference on irrigation management transfer (2001) has identified as topics for further research the interaction between infrastructure and institutions and the links between infrastructure and water pricing systems including volumetric water delivery and pricing. This paper does not aim at providing definitive elements of response. Rather, the paper aims at strengthening the case for such research to be carried out and, more generally, for reforms including water pricing schemes to be designed based on a careful analysis of actual water management processes.

## 1. SOME DEFINITIONS

Irrigation management transfer (IMT) can be defined as the turning over of authority and responsibility to manage irrigation systems from government agencies to water user associations (Vermillion, 2000). This involves the authority to define what the irrigation services will be and the authority to arrange for the provision of those services. After IMT, the water users, typically organized into a water users association (WUA) decide what services should be provided, what their objectives and target should be, what service performance standards are acceptable. Arranging for the provision of those services includes choosing service providers and collecting whatever resources are required to implement the desired services.

Modernization of an irrigation system could be 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 (Bhuyan, 1996), or as a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes with the objective to improve resource utilization (labor, water, economics, environmental) and water delivery service to farms (FAO, 1997). The process involves institutional, organizational and technological changes. It 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 although improvements in canal operation will generally be a critical first step in the process. Modernization thus defined assumes that IMT has taken place and that farmers are in a position to decide on the level of service they want and are willing to pay for. The term "modernization" refers not only to the rehabilitation, upgrading or transformation of physical infrastructure in irrigation systems but also to transformation in how irrigation systems are operated and managed.

IMT programs commonly include efforts to rehabilitate, upgrade or modify irrigation infrastructure. They also often include efforts to introduce new management systems or procedures such as service agreements, management audits, asset management and information systems. 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 (Facon, 2001).

There is a general acceptance of the principle that water institutions should be consistent with hydraulic management units, either at the basin, system levels or within the systems, and in practice the configuration of the irrigation systems has had a great influence on the design on PIM/IMT programs. Other important linkages are related to the setting of objectives for the irrigation systems. Relevant to IMT would be among others the determination of cropping patterns by a previously top-down institution and of the service to be delivered to users and on the other hand the necessity to manage water supply and drainage effluents in a river basin/integrated water resources management perspective rather than for the single purpose of irrigating crops.

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 has become central in new concepts and definitions of PIM and IMT. Literature on the evaluation of impacts of on-going participatory irrigation management and irrigation management transfer programmes in terms of water service delivery, agricultural productivity and agricultural performance indicates that improved service is a problem area (Facon, 2000). The sustainability of the water users associations (WUAs) is however now seen to depend on their capacity to provide an adequate water delivery service and control and to allocate water and to provide an improved service to enable gains in agricultural productivity (Svendsen, 1997). This is essential for the capacity of farmers to pay water and for the water users associations to be financially viable. It is thus recommended that strategies of gradual improvement of irrigation systems be adopted to support the transfer of water management responsibilities and associated rights (Vermillion et al., 2000).

The concept of irrigation service was introduced in the 1980s together with methods to evaluate service quality (Burt et al. 1996). Service is not an abstract or generic notion: it can be qualified precisely in terms of equity, reliability and flexibility as well as adequacy. The degree of flexibility in frequency, rate, duration is what distinguishes and characterizes classes of service quality from rotation to on-demand. The decision on the flexibility at all levels and ultimately at the farm is thus the most important decision as regards service. Flexibility is most closely related to improvements in agricultural performance, crop diversification, etc. The service definition will also specify the responsibilities of all parties (farmers, WUAs, operators of the tertiary canal, operators of the secondary canals, operators of the main canals, and project authorities) in operating and maintaining all elements of the system. A main canal provides water, with a certain level of service, to secondary canals. Each upstream layer in a hydraulic distribution system provides service to the layer immediately downstream of it. The actual levels of service at each layer must be examined to understand the constraints behind the level of service that is provided to the field.

## 2. PIM/IMT, MODERNIZATION AND INTEGRATED WATER RESOURCES MANAGEMENT: THE NEED FOR A LONG-TERM VISION

Participatory irrigation management lies squarely within an integrated water resources management perspective and the policy and institutional changes that this new perspective demands. The growing understanding of the centrality of water rights and water allocation issues reinforces this integration. Clearer water rights and farmer participation in basin management to facilitate more equitable and efficient processes to improve water use efficiency and reallocate water among users become important. The question of the restructuring and reorientation of irrigation agencies to take on responsibilities in implementing water resources management strengthen these linkages (Vermillion, 2000).

IWRM is a continuing process that needs to be integrated into economic development processes. In this context, it is necessary to have a long-term vision of IWRM and of the transformations that will be required in each sector. For this purpose, the validity of strategic planning approaches to identify actions that need to be taken by each actor in each sector by redefining missions, goals, objectives, strategies and priority plans for immediate action has been tested by FAO and ESCAP in four countries: Malaysia, Philippines, Thailand and Vietnam in 2000 (LeHuu Ti and Facon, T., 2001). At the occasion of national round tables, these countries have reconfirmed their national water visions, defined sectoral visions and developed priority action plans. Significantly, irrigation management transfer and participatory irrigation management as well as water pricing were high on the agenda in each country. In the irrigation sector, Vietnam and the Philippines found that mere rehabilitation of irrigation infrastructure would not be sufficient to achieve the vision and pilot introduction of modern water control and management concepts was identified among the main priorities. Modernization of irrigation systems is already an integral part of Malaysia's water resources management strategies and is one of the measures being studied at present in Thailand. In practice, an IWRM perspective, even in the long term, required changes now.

Historically, modifications to irrigation projects have not given thorough consideration to environmental consequences. But scarce water and concern for environmental impacts increase the need for improved on-farm irrigation management. The critical importance of maintaining minimum flow rates and water qualities in natural drains and rivers is increasingly being understood. The quantities and timing of river diversions, and qualities and quantities of irrigation return flows, have a tremendous impact on the environment. Low irrigation efficiencies have been documented in various projects, and improved irrigation efficiencies are often listed as a major source of "new" water. However, it is now evident that return flows from an "inefficient" project are often the supply for downstream projects, in the form of surface flows or groundwater recharge (Seckler, 1996). Therefore, typical project irrigation efficiencies in the 20-30% range by themselves give no indication of the amount of potential water savings within a hydrological basin unless that project is at the tail end of the basin. Conservation within one project may deprive a downstream project of part of its accustomed water supply. Most "new" water for existing basins and projects will only appear if there is improved irrigation water manageability by farmers. In Malaysia, Japan, Korea, modernization strategies already incorporate environmental objectives for rivers. Increasingly the issues will have to be explicitly dealt with by irrigation systems and farmers in the region.

## 3. IRRIGATION SYSTEMS IN ASIA

The actual irrigation systems[1]

The concepts of protective irrigation used for the development of irrigation by colonial powers in South Asia were adapted to the conditions and to the objectives of irrigation in the past. Irrigation was extensive and the water resources were not regulated by large storage reservoirs. The present operation of these systems covering large areas of India and of the Indus basin in Pakistan, embodied in the warabandi, still conforms today to initial principles. Continuous unregulated flows throughout the system are apportioned to areas and the quaternaries are fed by a rigid rotation. Farmers receive water according to a rigid schedule and they have no control over frequency, duration or rate. In practice, some informal water trading occurs within the quaternaries. The only way, which is being tested in some pilot projects, for quaternaries to have some control over their water supply is by refusing to receive scheduled water. The introduction of the warabandi systems to countries with high rainfall such as Thailand has been largely a failure.

The design standards adopted in many developed and developing countries after the mid 1900s to deliver water according to crop demand were conceptually more advanced. However most of them fail to meet that objective because of the deficiencies of the water control technology and complexity of the operational procedures. Managing an irrigation system equipped with manually operated gates at each branching point is a very complex task. In many cases, the systems were designed following the USBR design manuals to be operated at full capacity without consideration for operation at less than full supply. The use of technology with continually adjustable structures, which has been the norm during the three decades of intensive development of irrigation in developing countries from 1960 to 1990, has badly affected the performance of irrigated agriculture in many countries. Even the most qualified and motivated managers and operators would not be able to manage these systems to the highest standards. They simply cannot work.

[1] Most of the material in this section originates from a FAO publication under preparation: Design, Policy, Management and Performance of Irrigation projects: Emerging New Modernization Procedures And Design Standards and was anticipated in the Thematic note on Irrigation Rehabilitation and Modernization, FAO-INPIM email conference on IMT, 2001

Some see the problem largely as one of the hydraulic instability of extensively gated, manually operated systems and see the solution as being the modernization of these systems with automatic downstream control structures and feedback mechanisms to achieve hydraulic stability. Other design engineers have accepted the reality of farmer damage and gone to the cruder, 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. In this design, downstream of the off-takes of the sub-secondary canals, the system is un-gated. Tertiary canals are supplied through concrete flow dividers and the watercourses through adjustable proportional modules, as used in northern India. This simplifies operations compared with a fully gated system at the expense of flexibility in meeting the variations in demand due to factors such as local variations in rainfall and excessively long staggering of rice cultivation. Typically, in such systems, towards the end of the growing season, some farmers still request irrigation water while others are ready to harvest. The lack of a drainage system and of operational flexibility in the structured design imposes severe operational constraints, which affect productivity. The duty limitations of the main systems designed with low flow rates make them still very dependent on monsoon rainfall.

Very few countries have adopted the full spectrum of modern irrigation concepts and standards. In a few cases, the design makes use of the most advanced technologies for water control but the water distribution strategy lacks the flexibility required for service oriented delivery. In other cases, the technology is inadequate to satisfy the stated objective of modern irrigation. More frequently, neither the technology nor the strategy meet the definition of service orientation, including the projects with faulty designs, and operational procedures designed for the convenience of the operators, not of the users.

**Experience on service-oriented design in Nepal**

A service-oriented design process has involved the users within the WUAs of the Khageri (3,900 ha) and Panchakany (600 ha) systems in the definition of the operational game plan of their irrigation schemes. At this occasion, the farmers rejected the proportional flow dividers proposed by the Department of Irrigation in favor of adjustable gated structures. These structures allow them to rotate and concentrate flows in the tertiary canals in the dry season so that they can practice furrow irrigation for dry season crops such as maize. This consideration derived from the farmers' agricultural objectives was the main decision related to the design of the rehabilitation works on the systems. Detailed design and field layout were the final steps. Water users introduced concepts of re-circulation and their specifications for operation made perfect sense to overcome initial design limitations (low and insufficient flows) and improve service to the field. On-farm improvement is facilitated by improvement in main canal operation. This has been a significant departure from standard designs, which could be accommodated in the budget ceilings set by Department of Irrigation fro rehabilitation works. The view that farmers prefer proportional distribution was contradicted: they understood that equity can be achieved through improved water control and alternative operational strategies.

The preference for proportional flow division is due partly to the fact that in many traditional systems water rights are in theory related to irrigated areas. In practice there is a high degree of flexibility in these systems when water supply is satisfactory. It is also due to the view that proportional flow division is transparent and has low management requirements. In most recent projects, such as in the Philippines, the decision on proportional flow division has been made and farmers are only consulted on final details of canal layout. However, the difficulties generated by this distribution strategy for diversification of crops and how farmers subvert proportional flow division by blocking flows and storing water in the canals to release it at higher flow rates are well documented.

Initial system designs may represent a severe constraint to the adoption of new and more flexible operational procedures. Many problems related to inequity and unreliability of water service can be attributed to design and operational procedures, which, if left unchanged, will produce the same results whatever the governance setup. 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 is 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 WRM institutions is therefore compelling.

How farmers responded and why they will always respond in the same manner

Farmers responded to economic changes, poor or inadequate service, insufficient flows for intensive irrigation etc. by trying to achieve required flexibility, reliability and volumes to adopt modern cultivation practices and diversification or freedom in cropping patterns and strategies: illegal water trading within distributaries, tampering of control structures, tapping additional resources, pumping from canals, drains, borrow pits, groundwater etc. If the water distribution rules define a pattern of water distribution that does not match technically feasible and desired goals of the water users, the users will subvert these rules. This will lead to poor water delivery performance and increases in the cost of irrigation to users. Inconsistency in the water distribution rules creates difficulties in system operations that are likely to lead to inefficient and inequitable water distribution performance. Especially inconsistency of rules between various levels: reservoir, main canal, channels is detrimental.

Making water delivery match goals is important. The need for change in response to changing environment, changing agriculture, diversification, etc. requires adapting water distribution rules to changing demands. The users, on the other hand, must accept the limitations on uses imposed by water availability and the features of the system (IWMI Research Paper 12). 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 ISPs and WUAs, to the necessity of improving operations in the upper levels if WUAs are to be in a position to develop applicable rules and procedures, and to the necessity of incorporating at all levels production objectives of the farmers.

An appraisal of initial conditions and performance of the systems to be transferred would allow both a better design and strategic planning of physical improvements together with a definition of the service to be provided both by the irrigation service provider to WUAs and by WUAs to their members, with indications on ways and means to achieve these service goals and improve them in the future, given the forces of change that effect the irrigated sector. To meet the conditions of the future, water delivery from irrigation projects should be more flexible and reliable. Operation rules should be transparent and understood by the users. As for requirements on system operations resulting from IWRM, water rights and the necessity to satisfy different water uses with the same primary infrastructure are not the only issue. Water obligations related to disposal and quality of effluents, other environmental requirements are or will be part of the externalities imposed on system managers in all countries.

Groundwater and IMT

In many parts of the world, groundwater is a major emerging problem. In some areas, overexploitation is posing a major threat to the environment, health and food security. The explosion of groundwater irrigation in some countries is a farmer response to the lack of flexibility and, in the worst cases, the unreliability of the canal irrigation systems. Water recycling and the conjunctive use of groundwater mostly happen as a desperate

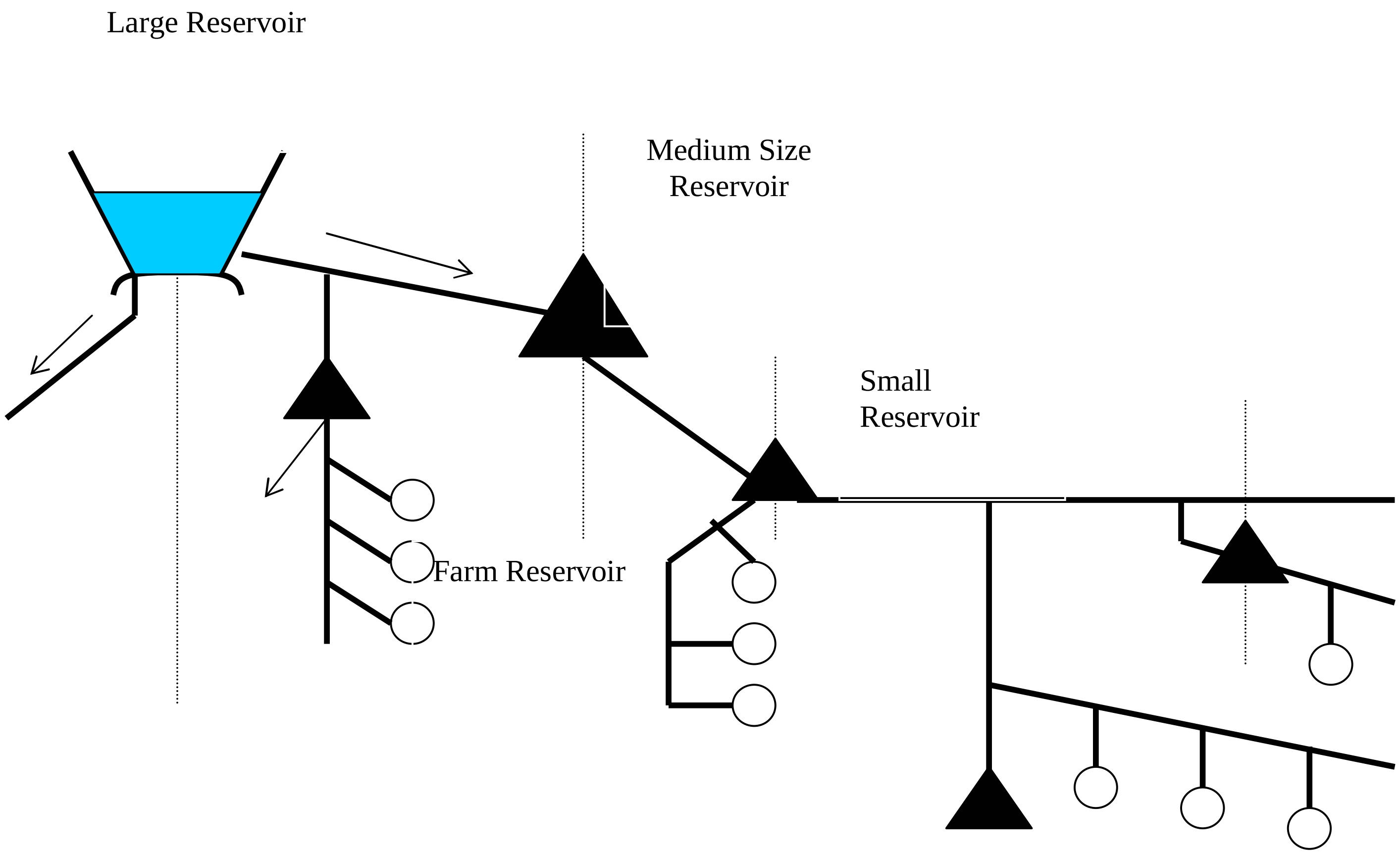


Figure 1: Typical configuration of an irrigation project in Southern China known as " Melon – on – the – Vine"

In this design, reservoirs are natural interfaces between different levels of management: management can be re-started at each reservoir. Operation is therefore highly reliable and flexible. Volumetric water deliveries can be implemented easily between levels.

response from farmers who are unable to obtain their share of irrigation water from the canal, or from systems managers as a way to rectify problems of management capacity and shortcomings of the original design. The benefits to farmers include increased quantity and reliability of water and freedom to choose their crop strategies. Service requirements of the farmers are thus met, where possible, from other sources than the delivery of the main surface systems. It is therefore perplexing that, in spite of an affirmed service orientation, IMT or PIM programs often fail to take into account the actual service needs as expressed by farmers' actual practices and actual water management in the systems. New institutions appear to reflect the stated operations of the canal systems and not the need for combined management of water delivery, drainage, water recycling and conjunctive use. Whether this is a threat to the viability of the water users associations should perhaps be given more attention. From a water pricing perspective, groundwater developers may benefit from groundwater recharge from the canal system without paying for its O&M, with equity consequences in those systems where canal water is the poor farmer's irrigation while groundwater is the rich farmer's irrigation

<u>PIM/IMT and service, in practice</u>

What are the practices through which physical works are planned in PIM/IMT programmes? Particularly in Asia, the most common planning tool is the walk-through. Lack of farmer participation in design and construction has been identified as a problem area in the past and design processes are meant to be more demand-driven (Facon, 2000). The objective is to improve conveyance and reliability and reduce canal maintenance requirements (drop structures, etc.) (Vermillion, 2000, Bruns and Helmi, 1996, FAO, 1998). PRA mapping, transects, of land tenure, farming systems, ecosystems are also tools used on the field, mostly to prepare canal layout designs and identify objectives of rehabilitation/improvement. In practice, a diagnosis of operation procedures is not performed and operational rules and procedures are not really discussed or linked to identified works: they are not related to service or performance goals. As a rule, expectations are low. The initial focus on upgrading is generally on reliability and equity, which are admittedly the first issues to address but there is generally no vision of future requirements. There is no discussion of flexibility, i.e. there is no discussion of the main aspect of service quality.

There is still a significant knowledge gap on the impact of IMT and PIM in general (Vermillion, 1997). However results of recent impact evaluations and efforts to synthesize existing literature allow us to draw general conclusions on the impact of PIM/IMT programmes on the quality of water delivery service. As most of these programmes have included some measure of rehabilitation or upgrading or infrastructure or on-farm infrastructure development, it is often difficult to separate farmers' involvement benefits from other changes such as rehabilitation. Quality of operations and maintenance is often a stated goal of programmes, but most of the evidence is qualitative statements. 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.

In Asia, impacts 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 (Vermillion, 1997, Svendsen et al., 1997, Rabi, 1998, Facon, 2000). The future of farming is seen to depend on diversification of crops and a more commercial orientation (see box).

**RICE**

Rice is not only the staple food, but also a key source of employment and income for the rural population. Rice production must rise over the next generation to meet the food needs of Asia's poor. No major net addition to irrigated rice areas is expected: most of this additional rice will have to be produced in presently irrigated areas. About 70 % of all freshwater resources used are for irrigating rice: efficiency of water use in irrigated rice systems must be significantly increased. The existing strong interdependence between water use in crop production and operation of irrigation facilities elicits the need for pursuing a comprehensive agenda for improving the performance of rice irrigation systems (Bhuyan, 1996). In these systems, rice monoculture is the dominant practice. Diversification of crop production in these areas is desirable to open opportunities for increasing farmers' income from their limited land resources, when profits from rice culture are very low and declining. A diversified agriculture will be more sustainable in the long run. Irrigated agriculture will also have to aim at maximizing return to water rather than to land. Present rice culture systems require more water than most other food crops in terms of food and calorie produced: there is scope for increasing returns from water by growing diversified crops, especially in areas of water shortage. Farmers must be provided with facilities to exercize crop choice options, which is presently lacking in most systems.

Upgrading an irrigation system for rice in the wet season and for diversified cropping in the dry season is complex and requires that any structural or physical upgrading to be done for rice must also conform to the requirements of other crops. Flexibility will become an essential requirement, entailing upgrading of water control, drainage, scheduling of water delivery, etc. of the main system. The on-farm, crop-specific factors could be handled seasonally by the farmers themselves as individuals or as groups. Conjunctive use represents, where available, a convenient solution. Suitable methods of water application to the crops, control of seepage from canals or neighboring rice areas and drainage enhancement will be required.

For rice water management, practices which minimize irrigation inflow are of a direct interest to farmers who see their water supply rationed and have to pay an increasing share of its cost, for managers and developers who also face rationing because of degradation of water resources, dam siltation, transfer to other sectors, etc. and have an interest in minimizing pumping costs, O&M as well as development costs, and for water resources managers who need to plan future irrigation developments with minimum environmental impact from withdrawals or reservoirs. Water saving practices are typically associated with or part of packages to improve agronomic practices and the efficiency of use of other inputs, and therefore play an important role in total factor productivity. They increase water use/irrigation efficiency but also improve water productivity. When implemented properly, they lead to yield increases (in the range of 15-20% in China for intermittent flooding and other methods). The acceptance by farmers of these practices will of course depend on economic factors (Klemm, 1998). Furthermore, they depend on improved water control and management of water at the system level and adequate irrigation (reticulated distribution system) and drainage facilities.

Improvements in O&M of rice schemes through rehabilitation, improvement of irrigation infrastructure for surface irrigation, IMT, modernization, combining to various degrees institutional, organizational and technical changes, have been attempted in the region with mitigated success. Studies undertaken by the World Bank in recent years have evaluated the impact of irrigation projects. A study of 1995 evaluated the design of rice project in the humid tropics and concluded, from the strong degree of resistance of farmers to new design standards and the level of anarchy and chaos observed, that the more reticulated systems, capable of supporting on-demand water delivery, were not appropriate under these climates. A more recent study (1997) assessed the agro-economic impacts of investments in gravity-fed irrigation schemes in the paddy lands of Southeast Asia, to determine whether and how quality of O&M services influences the sustainability of those impacts. The main finding was that, with poor economics and low incomes, these schemes faced an uncertain future. Small-holder irrigated paddy could no longer provide the basis for a growing, or even stable, household economy, driving the young off the farms while the older who stayed behind concentrated on basic subsistence crops, social capital would erode and O&M standards were likely to suffer. Irrigated paddy would not be able to compete with the incomes to be had from other employment opportunities. Improved O&M performance would not rescue them.

These two studies, combined with the results of the evaluation of modernization projects conducted by IPTRID in 1998, tend to indicate that present project designs or operations are not capable of supporting both economically and technically the intensified, diversified and more water efficient and productive rice production systems which will be required in the future. They also seem to indicate that purely software solutions or mere improvement of operation and maintenance do not deliver the expected results in terms of improvements in performance and yields. They also reveal that many modernization or improvement efforts have been inappropriate, poorly adapted to local circumstances and the specific character of rice-based production systems, and incomplete or fragmentary. Conjunctive is practiced within "modern" irrigation schemes: it may provide a solution but is not available in all places.

Diversification makes irrigation management more complex. The necessity of reengineering irrigation, i.e. 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 (Bruns, 1996) but this is in apparent sharp contrast with actual design processes and their outcomes. Low productivity is also often associated with small farm size, a subsistence orientation, production of low value crops such as grains, inappropriate agricultural policies, a poor natural resource base, and inadequate agricultural services. It is necessary to address these issues or provide assistance through other agencies for production increase, or to subsidize the association. For farmers, the second-generation IMT problem is to increase farm productivity to pay higher irrigation fees and to take advantage of possible improvement in irrigation service quality (Svendsen et al. 1997).

PIM has generally led to modest efforts by farmers to improve management efficiencies and responsiveness. Significant future expenditures loom in the future unless observed under-investment in O&M is halted. It is now recommended to replace periodic rehabilitation with on-going infrastructure improvements jointly financed by government and the farmers, with the objective to improve performance and ensure financial viability and physical sustainability of irrigation. An issue for the sustained success of participatory irrigation management is therefore the availability of financial instruments that allow farmers to invest in the upgrading of their irrigation systems. Decentralized irrigation improvement funds are increasing proposed in IMT programmes.

Type of investment projects

Lending for irrigation has progressively changed over time from a project-specific nature of investments to take the form of sector loans or national/regional in scope projects supporting the objectives of participation and capacity building. These projects often combine a mix of low cost rehabilitation projects and management reforms with attention to improved O&M and user participation. Low cost rehabilitation of irrigation infrastructure, in some cases an investment to catch up years of differed maintenance, cannot correct the deficiencies of the original design, if the causes of deficiencies are not identified through an in-depth diagnosis of the current system. In Asia, where the older public schemes reach 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. 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. The issue is whether basic flaws or constraints can be addressed with a light rehabilitation program and whether not doing so hampers IMT/PIM or jeopardizes the success of reform in terms of sustainability of institutions and financial sustainability.

## 4. TOWARD SERVICE ORIENTATION

Design processes[2]

Performance of irrigation projects is determined by a combination of physical, institutional and policy factors. The gap between potential and actual outcome is strongly related to over-optimistic assumptions of the hydraulic performance at planning stage, and in a number of cases to faulty and unrealistic designs as well as construction. The performance of operation of irrigation systems is influenced by the capacity of the management agency to apply the operational rules defined by the designer. Many designs are difficult to manage under real field conditions. The professional context explains why design irrigation engineers know little about actual distribution processes.

Some of the reasons lie in administrative and behavioral reasons, mostly associated with the lack of experience, effective accountability and feed-back from operation of design engineers, whether in irrigation agencies or in local and foreign consulting firms, in lending policies of financial institutions, in lack of accountability of operators and managers to the users. In countries with large development of irrigation, the state officials have often entrenched engineering practices. The planning, design and construction process must produce a system and conditions capable of accommodating effective management practices. IMT provides an opportunity to correct the administrative and behavioral reasons at the stages of design, construction and operation.

Modern design is the result of a process that selects the configuration and the physical components in light of a well- defined and realistic operational plan, which is based on the service concept. It is not defined by specific hardware components and control logic, but use of advanced concepts of hydraulic engineering, agronomy and social science should be made 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 helps reconcile conflicting expectations between the users, the project manager, the field operators and the country policy objectives. The second step is the planning of an irrigation project is the decision about water deliveries i.e. the frequency, rate and duration of water deliveries at all levels of an irrigation system.

A water delivery schedule does not necessarily imply a specific design. A rigid schedule of water deliveries to the farm turnouts may use modern irrigation hardware and computerized decision support systems to make the water deliveries reliable and equitable, but a project designed for rigid rotation through simple non-adjustable structures or for proportional distribution cannot be operated for flexible water distribution.

To a large extent, the layout, original design criteria and standards used for an irrigation project limit the options for its rehabilitation and modernization. In extensive irrigation projects with the objective of thinly spreading water, the design capacity decreases from upstream to downstream. Traditional delivery systems have no or little flexibility built into them and do not attempt to match water deliveries to crop needs. In responsive irrigation projects, the design capacity increases when moving downstream to accommodate the need for flexibility.

[2] Most of the material in this section also originates from the FAO publication under preparation: Design, Policy, Management and Performance of Irrigation projects: Emerging New Modernization Procedures And Design Standards

Key elements of sustainable service oriented I&D management

Sustainable service oriented irrigation and drainage management can be characterized by the following (Malano and van Hofwegen, 1999):

- It is output-oriented: the cost of the service provision is based on well developed operation and asset management programs
- It involves users to determine levels of service and the associated cost of service
- The irrigation and drainage organization should be able to recover the cost of service provision either from direct consumers or from subsidies
- It relies on an appropriate legal framework that provides protection for users, the organization providing service and the general interest of society

The level of service consists in a set of operational standards set by the irrigation and drainage organization in consultation with irrigators and the government and other affected parties to manage an irrigation and drainage system. It must emerge from an extensive consultation process. It should become a series of norms (targets) against which operational performance is measured, be revised on an on-going basis to respond to changes in irrigated agriculture and requires careful consideration of the cost associated with specific levels of service. A strategic planning and management approach is recommended. The formulation of level of service specifications is the central decision for strategic planning and future operation and management. For existing irrigation and drainage schemes, Malano and van Hofwegen recommend that the following process could be applied:

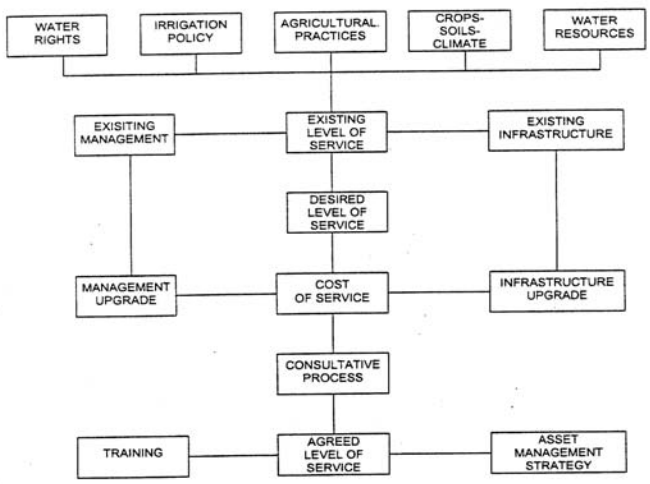


Figure 2: Decision-making process in service-oriented organizations

In service-oriented water management, the decision on the level of service against the cost for providing this service, from Irrigation Service Provider (ISP) to WUAs and WUAs to users, and the service relationship can be expressed through service agreements which are the foundation of an asset management strategy and managerial capacity upgrading programs. These are translated into financial plans. Service agreements contain details on the level of service to be provided by the organization, the obligations of customers and the organization and the process for resolution of conflict should these arise. Service agreements may be a modality to force a negotiation on service levels when water tariffs are introduced or revised and initiate a process towards a transformation of top-down irrigation agencies by providing accountability and transparency.

Management of irrigation systems

Each level of service, to be achieved, depends on operational parameters. Requirements in terms of flow control systems and human resources must be clearly understood and planned for. It is also necessary to understand the internal mechanisms of irrigation systems, and to provide selective enhancement of those internal mechanisms, if irrigation project performance is to be improved. These "details" are so important that it has been argued that investments must be based around specific actions to improve them, rather than deciding on the framework for detail improvement only after the investment is approved (FAO, 1998).

Management of irrigation systems in a business and service oriented mode is also a complex operation. It requires advanced managerial skills and the ability to process and interpret large amounts of data. A feature of modern design and operation is often the minimization of the collection of large amounts of data for statistics while information needed for operation increases. Water requests and water deliveries have to be recorded and matched with conveyance capacity, seasonal water allocation and total water availability. Water deliveries have to be converted into financial transactions. Payrolls and financial assets have to be managed as well as stocks, spare parts, vehicles and construction equipment. Maintenance programs have to be implemented and closely followed (Facon, 1997). Modern information and management systems are imperative to assist managers in performing efficiently their tasks. These tools can be used irrespective of changes in management structure, but the needs will also be felt by WUAs. The availability of management support tools can be seen as a means to facilitate their taking over their new managerial responsibilities.

Design and operation for IMT.

Management of a relatively large system is generally divided between various units. The locations of the interfaces between these levels have an important influence on the way the system is operated and its hydraulic performance. If management of the main system has to be divided between units, the interface should be located at hydraulic “breakdowns” such as reservoirs. The trend is to transfer the management of large sections of irrigation systems to large user associations. The contractual approach to bulk supply provision or irrigation service provision may require changes in hardware and operational rules at the interface between the management levels.

Precise, but user-friendly, control of flows and measurements of volumes is needed. Reforms often include the establishment of water rights and trade of these rights, and the pricing of water on a volumetric basis. The design of irrigation projects should take these reforms into consideration. A rigid system with fixed distribution structures is not compatible with water trading. Measurement and control are required where trading is expected to occur. The canal network layout should also be designed to be integrated with not only the roads and drainage system, but also with the multi-level of management. Existing layouts typically exhibit a confusion of hierarchical levels (see figure 3).

Economic appraisal methods are important. Conventional economics use high discount rates for future costs and benefits and fail to show the importance of maintenance in sustaining the life of a system and the livelihood of farmers. A project with a low initial cost, which deteriorates quickly and is dependent for continued survival on timely and properly funded maintenance, or with high operation costs is preferred to one that is constructed to need less maintenance or lower operation costs as it appears cheaper. Such a project may not sustainable unless governments keep a policy of subsidizing irrigated agriculture.

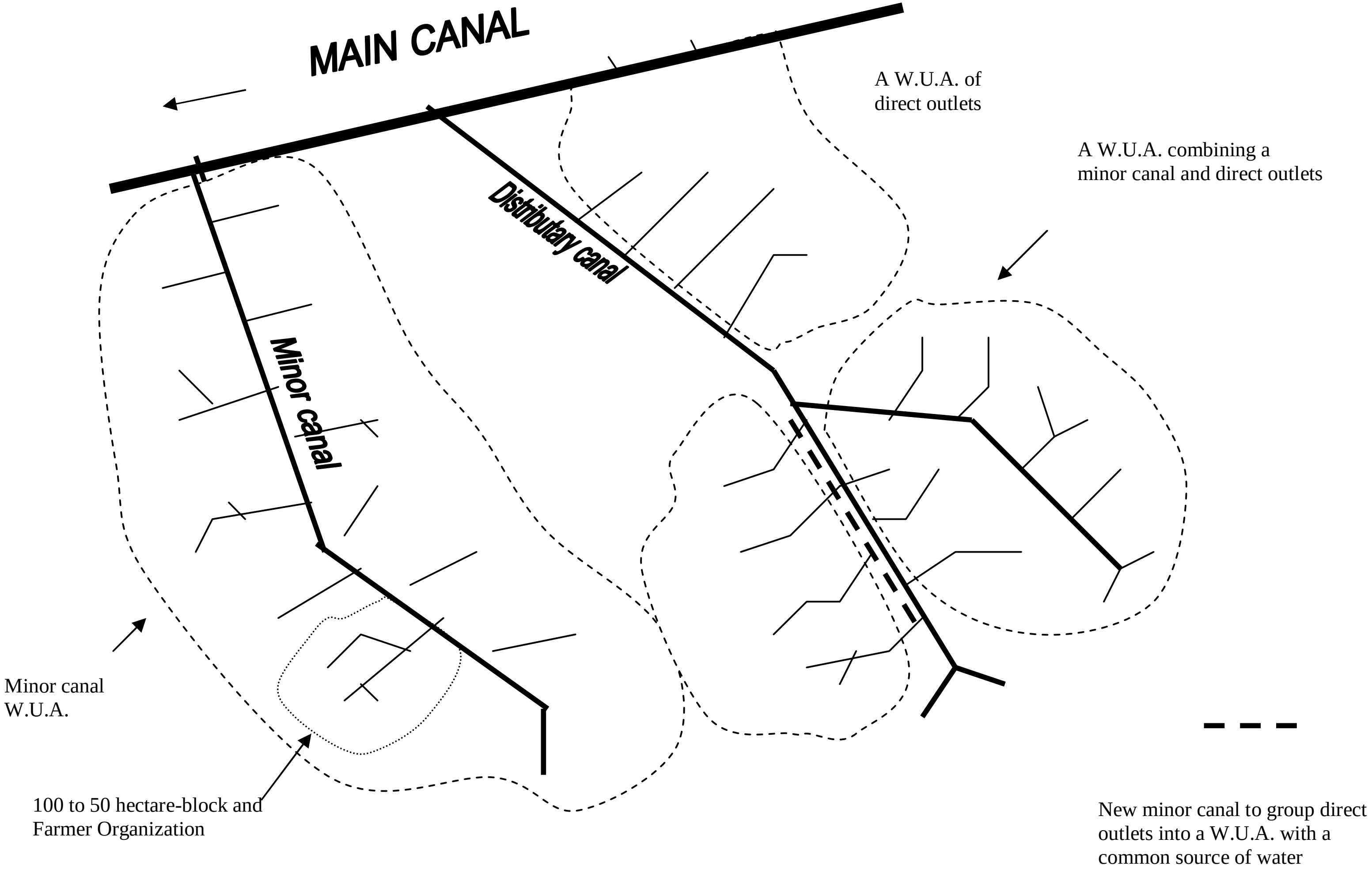


Figure 3: Typical configuration of irrigation systems with poor hierarchy of water management levels

**Chaos and anarchy: how water is controlled and measured - some recent travel notes**

Makhamthao-Uthong canal, RID Region VII, Thailand. This 103-km long canal is designed for FSL of 30 m3/s. A diversion weir across the Chao Phraya river controls water levels at the gated canal intake. Due to variations in water level, the flow regime varies from free flow to submerged flow: water supply may drop from 30 to 17 m3/s unexpectedly. Canal structures follow a typical USBR design. Operators receive gate stroking instructions at the cross-regulators which are meant to provide both water level control and flow control for the supply of the downstream areas (a hydraulic impossibility). The X-regulators are not calibrated. For years, the project has been collecting data at three X-regulators that show that flow rates, as one moves downstream, decrease from 30 m3/s to 8 m3/s then jump back to 16 m3/s at the tail end. There is no flow measurement at secondary offtakes. Operations are based on rotation between sections of the main canal and between upstream and downstream sections of secondaries. Farmers cannot maintain water levels in the paddy fields with this 12-15 days rotation and all have pumps to scavenge water from canals, drains, ponds or to pump from shallow tubewells. RID project staffing is rather high (150 ha/O&M staff). Annual budget is about US$ 27.5/ha for O&M, of which about 66% is for staff salaries (US$ 18.2/ha). No water charges are collected from the farmers but they spend between 10 to 35 US$/ha in pumping costs per dry season.

Cam Son-Cau Son irrigation system, Red River Delta, Vietnam. This 24,000 ha scheme is supplied by a regulating reservoir and a diversion weir and branches out into three main canals (sluice gated intakes). The Irrigation Management Company operating the canal does not know how much water goes into the system, into each main canal and into each secondary. There is no water measurement at any level. The IMC computes theoretical cropping patterns and irrigation schedules and instructs gate operators at the main canal intakes to operate the gates to maintain a water level target downstream, set according to a rating curve established by the designers 20 years ago. This curve may be based on normal flows for the design X-section of the canals. Flow regime is however not normal and the X-section has been decreased through siltation. Water levels fluctuate rapidly with an amplitude of over 25 cms due to poor geometry of the structures. Irrigation blocks downstream are supplied typically by several gated offtakes on the main and several secondary canals. Operators open/close the gates of the offtakes but farmers operate the gates themselves too. There are service contracts between the IMC and the communes or cooperatives in the system. The seasonal tariffs vary according to the reliability of supply and whether farmers have to lift water to their fields or not. The criteria for satisfaction is not based on deliveries but on comparison of rice yields among different areas.

Ciamis, East Java, Indonesia. The 6,600 ha system consists of a river diversion weir, a primary canal of design 9m3/s capacity branching out into three main secondary canals. Secondaries are equipped with cross-regulators (sluice gates) for water level control to the gated tertiary outlets. A tertiary network of canals has been developed, equipped with division boxes. There is supposed to be an outlet for each 30-ha block. Most of the block outlets are not used and there is a large number of informal offtakes on the tertiaries. On-farm infrastructure is inexistant. According to staff, scheme water supply is usually sufficient throughout the year. Dry season water supply can however be reduced but overall, rotation among the tertiaries, which is triggered when available flows are below 50%, is rarely implemented. There is an official cropping pattern and irrigation schedule, based on double rice cropping and proportional allocation of available flows. Tertiaries are supplied with constant flows calculated according to the irrigation schedule. In practice, the irrigation schedule is not respected and system operators respond to requests for increased flows downstream. They meet daily and the policy seems to be to increase if possible primary canal flows to respond to the demand and, in case of conflicts, they either review overall allocation or impose a rotation. According to staff, the secondary offtakes are all used for flow control and the X-regulators are used for both water level control and flow control (an hydraulic impossibility). Tertiary outlets are used for flow control. There are Parshall flumes for water measurement throughout the system but they are not used at the tertiary level. Operators try to provide "maximum flows" and use "experience" and feedback from farmers for estimating required flows. Gates at secondary outlets and X-regulators are very poorly operated. Operators claim that they operate the gates properly but that farmers move them. Farmers indicate that they do not respect the cropping pattern throughout the system because of delays in water supply. This results in excessive staggering of the crops, which creates a problem for water management at block and system levels.

## 5. CONCLUSION

The level of chaos (difference between stated policies and actual policies) and of anarchy (subversion of policies) in the formal irrigation systems in Asia, which comprise the great majority of irrigated areas with the exception of certain countries (Afghanistan, Nepal, Laos), is usually 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;
- Exporting of design concepts outside of their area of validity;
- Difficulty to control and operate the systems;
- Layouts with confused hierarchies;
- Serious flaws in operation strategies;
- Inconsistencies between operating rules at various levels;
- Inconsistencies between operating rules and farmers' requirements;
- Changes in farmers' requirements not reflected by changes in system policies;
- Poor quality of water delivery service to farms;
- 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 water pricing system will require substantial efforts to restore water control throughout the irrigation systems and establishing water measurement at all levels. Water measurement devices are generally lacking and, where they exist, are seriously flawed. Common sense would dictate that a condition for a water pricing system to work would be that stated operation policies and distribution rules become the same as actual operation and distribution, and that these are consistent with farmers' requirements. IMT/PIM in theory would provide the opportunity to achieve this but a review of past and present IMT/PIM programmes in the region suggests that these usually fall short in a crucial area: the decision-making process leading to the decision on system operation strategies and service and performance objectives.

The establishment of water pricing systems may not lead to substantial water savings in irrigated systems as a proper analysis of project water balances and river basin water accounting suggests that project and basin efficiencies are usually already quite high in closing river basins. Some authors also suggest that, on the one hand, present administrative rules for water allocation already allocate water efficiently to higher value uses and that water tariffs would need to reach unacceptably high levels to influence farmer behavior. However, the introduction of water pricing would be particularly welcome if it forced a negotiation between ISPS and individual users or WUAs of service levels to be provided and at what cost. The establishment of service agreements as described above is a promising avenue. Monitoring and evaluation of system performance and achievement of service standards would require the development of water measurement systems consistent with service standards and the basis for the calculation of water tariffs (either on a volumetric, flow-rate/duration or area basis or combination of these methods). However, this will typically require a departure from existing design standards and operating rules, serious attention to all details of system hardware and software, and more than cosmetic rehabilitation or installation of gauges.

Further work is needed on interactions between design standards, operation strategies, service level and water pricing. Volumetric delivery/pricing at the tertiary level is an achievable medium-term objective for gated systems provided that they are modernized (Vietnam, Thailand for instance). Systems based on proportional flow division may well limit options to flat-rate area-based or crop-based irrigation charges if users cannot have control over water deliveries and pre-empt long-term goals of volumetric water pricing.

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