MANAGING MAIN SYSTEM WATER DISTRIBUTION

P.S. Rao and *A. Sundar*

Introduction

"Main System" refers to the canal system from the headworks of a storage reservoir or diversion structure down to the outlet where water is delivered to the farmers. In large public irrigation systems, the canal network is complex and comprises the main canals, branch canals, distributaries, sub-distributaries, and minors. (The terminology of primary, secondary, and tertiary canals is also used). The operation of the canal system is governed by a set of rules for allocating and distributing water. The irrigation bureaucracy is responsibte for operating and properly maintaining the canal system.

For over a decade, policy makers, planners and administrators in South and Southeast Asia have been concerned about the poor performance of irrigation systems. Although considerable irrigation potential is being created, there is a time lag before it can be utilized; the yields from irrigated agriculture are relatively low; the problems of waterlogging, salinity and alkalinity are increasing; and there are also other problems of organization and of on-farm development activities below the outlet. However, it soon became clear that improved and more equitable water distribution at the outlets was a prerequisite for increasing the agricultural productivity of the land. Thus, the focus has been shifting to the main system water distribution and improving its performance. Methodologies have been devised for monitoring the performance of large scale irrigation systems. There have also been some attempts by engineers and administrators to improve performance by effecting changes in the main system distribution.

This paper presents, first, a framework for understanding the main system water distribution in a systemic context and focussing on the problems, potentials, and opportunities for improvements. Some evidence is presented of improved performance from changes in main system distribution. Second, a practical typology and description of methods of main system water distribution is described. These are actually used or potentially usable in South Asian systems. And, third, we discuss research priorities for improved distribution in main systems.

Attributes of Characteristics of Main Systems

Input-output concept. The limited objective of the main conveyance and distribution system is to deliver water to the outlets. The water supplies at the outlets should be equitable, reliable, predictable, and reasonably adequate to meet the requirements of the farmers. The system (Fig. 1) has hardware and software components which have complex interactions in them and between them. Water from storage or diversion is the input into the system, and water at the outlets is the output. The system is embedded in and interacts with technological, social, economic, and political environments.

It is important to understand why a system has evolved the way it has and why certain methods of water distribution have become accepted. The design process'of the main distribution system is based on a series of assumptions about crop-water requirements, irrigation requirements (which may be aggregated at some level), rugosity coefficients, conveyance losses, and discharge coefficients. A certain method of system operation is also assumed. In many cases, efforts are never made to test the assumptions and check the conformity between the expected operation as per the design and the actual operation. In the absence of effective feedback to improve the planning and design process, the same assumptions continue to be made.

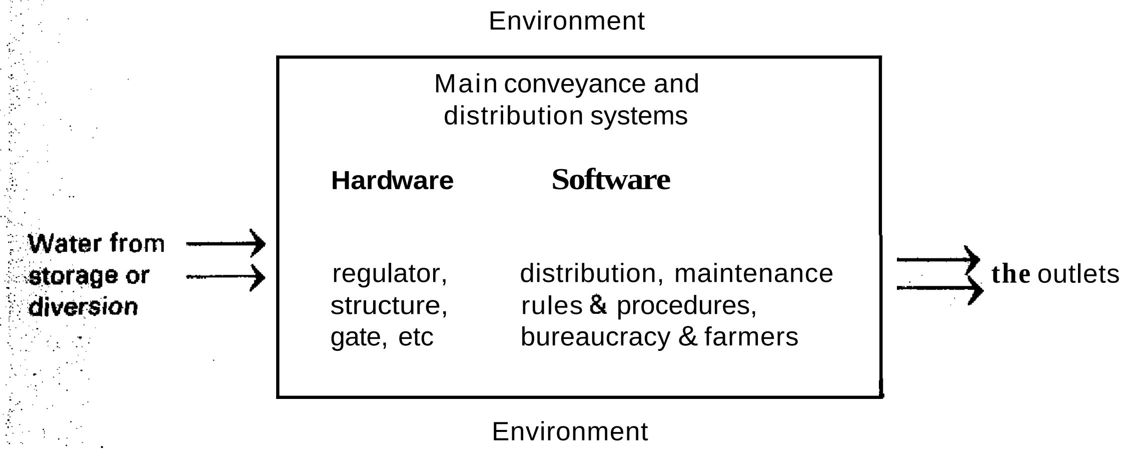

Fig. 1. An input-output concept for main irrigation systems

One way of understanding the complex process in the system *black* box is to investigate the validity of assumptions when the design is applied to real world systems, and to assess the impact on system performance of the errors caused by the assumptions.

Other attributes. The main distribution systems are large in terms of canal length, numbers of control structures, and numbers of people involved. The interactions among elements and with the environment are very complex. They are dynamic in that the demands on the system and its condition changes over time. There are uncertainties associated with the system, the foremost is the hydrologic uncertainty affecting the availability of water.

The allocation and distribution of a scarce and valuable resource tike water is bound to generate competition, conflicts, and corruption. There are many decision makers operating at various levels from the outlet gate up to the headwork. Decisions are made and controls exercised by personnel of the irrigation bureaucrcy and by farmers, formally or informally, legally or illegally. Each control represents a degree *of freedom* for whomever may exercise that freedom.

A Typology of Main Systems and Methods of Water Distribution

Main systems. The interactions among the elements of the system and between the system and the environment, and the problems arising in the system, can vary widely. Classifying the systems may help our understanding:

1. Size of the systems: major, medium, and minor.
2. Climate: humid, arid, and semi-arid.
3. Crop: paddy and non-paddy systems.
4. Bureaucratically administered and managernent-oriented (top-down), and participatory (bottom-up).
5. Traditional communal systems and government or public systems.
6. Storage and non-storage.

Methods **of water** distribution. Several distribution systems have evolved through practice or design to meet specific physical and/or social requirements. They may be broadly categorized as:

1. Rotational **Water** Distribution System **(RWDS or** "warabandi"). Warabandi **is** a rationing **system** used when water supply is insufficient to provide adequate irrigation to **all** the land served **by** the system. In the past, such systems, in north-western India and Pakistan, had no adequate storage and supplies to the canals were unpredictable. The principal objectives of warabandi **systems** are: a high degree of equity in water distribution, and high efficiency **in water** use by imposing scarcity on each user. Each farmer, based on his land holding, gets his share of water according to a schedule, The farmer is at liberty to decide on his own cropping pattern and how to use his share of the water.

Water. from a river or a reservoir is conveyed by a main canal, which feeds two or more branch canals. These operate by rotation and function as the primary distribution system to provide **a** varying supply of water throughout the season. Branch canals supply water **to** many distributaries which must run full supply for eight **day** periods **by** rotation. This **is** the secondary distribution system. Distributaries supply water to watercourses through ungated outlets. The flow **in** water-courses **is** allocated among farmers by a time roster covering seven days (i.e., 168 hours). This is the tertiary distributary system. The water distribution from an outlet, and flowing into a watercourse, is managed **by** the farmers, while the flows in the system above the outlet are managed by the state. Each cultivator's right to a share of water in the water course in guaranteed **by** law and the Canal Act empowers the canal officer to enforce this right for any farmer who institutes a grievance procedure, Every other aspect of managing the system is up to the farmers.

2. Intermittent **flow.** Water delivery **is** fixed according to how much area is served and what crops are grown, but water is not delivered on a continuous basis; the entire system or a portion thereof is closed intermittently. Applications for water are received from farmers who state the crop they wish to grow and the area to be planted. Water is then sanctioned, according to the **crops** and the total demand ***on*** the system. The farmers can propose a proportionate reduction in irrigated area if the demand exceeds the available water. **A** schedule giving turns to different irrigators **is** prepared ***for*** each rotation, and farmers are informed in advance. The rotation interval depends on the watering interval for crops which need large amounts of water, and crops on the same outlets which need **less** water may receive it on alternate rotations.

The system works smoothly as long as the full area demanded by the irrigators for **the** different crops can be sanctioned. However, when the irrigated area ***is*** restricted, there is a tendency for farmers to take more water than authorized for irrigating the curtailed portion. Punishment by imposing penal water rates does not prove **to be** a deterrent.

3. Continuous **flow.** Canal systems from diversion structures or storage reservoirs run continuously during the crop season and serve concentrated areas of paddy-growing commands, The **systems** are designed on the concept *of* ***duty,*** that is, the area that can **be** irrigated by a unit discharge flowing continuously for *the* duration of **the** crop (base period). When **the** farmers are few and the supply is more than the demand (as in the rainy season), the system can be used efficiently if proper drainage at the farm level is ensured. In all continuous flow **systems,** there are problems of inequitable distribution *of* water to head and tail-enders.

4. Demand based. Water delivery to the farm is according to indents received from the farmer. Computer programs can use crop, soil, and climate data to identify the water requirements of a crop at different growth stages. Computer controlled irrigation can determine the individual watering schedules of each farmer, This is perhaps the ideal. An issue to ponder is whether large-scale public irrigation systems, because of their inherent characteristics and limitations, are capable of reaching such goals.

Main System Water Distribution: Objectives, Criteria, Performance Standards

The objectives of irrigation management are comprehensively stated in terms of efficient use of resources, equitable distribution, environmental stability, and human welfare. The performance of an irrigation system may be evaluated according to these criteria.

Objectives of main system water distribution. Delivering irrigation water at various levels down to the outlet or turnout through minors, distributaries and canals, is the objective of the main system. The criteria for evaluating the performance of the main system should, therefore, concern the various measures of water delivery and compare the *actual performance* with *the* performance *expected as per the design.*

Measures of water delivery. Delivery measures include: quantity of water delivered, and frequency and reliability of supply. Performance indicators for a water distribution system can be formulated, measurements can be made on a sample basis, and performance can be evaluated at various levels.

Standards of performance. Currently there are no performance standards for various systems. Therefore, it is necessary to establish expected standards for a well-designed and well-maintained system operated according to some well-defined procedures in a given environment. This can be done only through extensive research on various systems.

Assessment of Problems in Main System Water Distribution

The management of main system water distribution is a relatively neglected research field and, at present, ?here are not many empirical studies of acceptable quality available for comparative analysis. There is need for studies of problems related to main system management, especially about the technical aspects of the physical system, including planning, design, operation and maintenance, and performance evaluation.

Problems arise in large public gravity systems from unclear objectives. Fundamental problems relate *to* the role of public systems, and the conflict between the goals of management and those of the private beneficiary farmer. To the system manager, water is generally the limited resource. He attempts to derive the maximum benefit from the limited and variable amounts available to a command area and served by the existing canal system. Thus, he is interested in attaining maximum benefit per unit of water carried in the system. To the farmer, on the other hand, land is usually the limited resource and, hence, each individual wants to maximize his benefit from the limited land he holds. His objective is to obtain maximum benefit per unit of land, and he attempts to get as much water as he can for irrigating his land.

The smooth operation of a large public system requires the elimination or reduction of this environment of conflict. This can be done by rejecting the concept of meeting the total crop water requirements for every farmer. Management's clearly stated objective must be to supply equitable, predictable, and reliable quantities of water at stated intervals to farmers. And the water allocated to each farmer should be less than his full requirement so that he is induced to obtain maximum effciency in its use. In this way, the objectives of the individual farmer and that of the system as a whole will coincide.

Problems arising at planning and design stages. Misunderstanding and lack of clarity also exist regarding localization and the desire to enforce cropping patterns by executive fiat. Another important assumption is that farmers will irrigate during the night as well as during the day,

Some other design deficiencies are: 1) outlets which are too small to supply the designed discharge, 2) outlets which are not located properly, 3) sluices or outlets which come directly from the distributary instead of from a minor, 4) the assumption that duties at the heads of all distributaries will be the same irrespective of channel length, 5) the assumption that seepage and operational losses will be lower than they actually are, and 6) not providing drainage facilities even where they are necessary.

Testing the system for acceptable performance in its ability to deliver water at various points as per the design is not a standard practice in many irrigation departments.

Problems arising from construction phasing. During early construction stages, storage facilities provide abundant water to the first reaches of canals that are complete. This often results in over irrigation in the head reaches. When the entire canal system is completed. there is insufficient water for tail-enders.

Problems of operation and maintenance (O&M). Operation and maintenance of irrigation systems is not given a high priority. There are no manuals for O&M. Adequate measurements are not made for effective monitoring and management. Communication systems are weak. There is no organized feedback from the beneficiaries to the management. Maintenance grants are very inadequate.

The situation is further compounded by the complex operations that involve many controls and many people - both farmers and irrigation agency personnel. The interactions of the water distribution system with the social and political environment also play a part in O&M.

Research Priorities

Potential for improvement. The potential for improving main system water distribution is widely accepted and convincingly demonstrated by actual interventions. (Some examples are given in the full text of the paper).

Issues for Research and Priorities.

1. Awareness and Commitment. How can we increase the awareness, desire, and commitment of national governments to improve the performance of irrigation systems and, therefore, of main water distribution systems?

2. Objectives, criteria, and indicators of performance. What objectives underlie planning, designing, and operating main water distribution systems? What criteria and indicators can be used to evaluate system' performance?

3. Design conformity. What operating policies and operational plans are assumed in designing a water distribution system? If the system is operated as designed, can it deliver the required quantities of water at distributary, minor, and outlet levels? If deficiencies exist, can they be remedied and the system improved to the standard assumed in the design, and at what cost?

4. Studies on operation of the system. Comparative studies should seek answers to questions like: How is the system actually operated in the field and during times of scarcity? Are the operational plans and procedures understood by farmers and officials? What measurements are made and what information collected for use in operating the system? Who really makes the operational decisions at various levels? What roles do farmers and officials play in system operation and how do they formally and informally interact? How does the socio-economic and political environment influence system operation and with what impact?

5. Studies on maintenance of the system. What criteria can be used to define the level of system maintenance? How can resources be raised for maintenance? What are the maintenance roles of farmers and officials? What conditions are conducive to obtaining good maintenance?

6. Others. Case studies, the role of communications and communication technologies, and research methodologies are additional areas for research.

MAIN SYSTEM MANAGEMENT DISCUSSION: A SUMMARY

De Cock's supporting paper on Water Management in the Office du Niger gave an account of significant water savings (20%) in the Sahel Canal system through a concept for controlling water releases that required no new construction. Constant demand-driven downstream volume was regulated manually by observers who communicated daily by radio or telephone. The targe size of the Sahel Canal permitted. adequate on-line storage; the only investment required was an initial topographic survey and a mathematical model. The impressive results of this example stimulated e lively discussion of the French *School,* and the pros and cons of demand-driven systems in general.

Do Asian engineers learn about French systems in their formal training? Are these systems rare in Asia because they are ill-suited to Asian conditions or because they are not widely known7 Wade pointed out that downstream control is the rule in North Africa where it generally applies to the main system; at the local level it reverts to upstream control.

Several participants suggested that IIMI carry out research on the comparative advantages of upstream vs. downstream control under various environmental and political conditions, Downstream control using automatic gates is successful in countries with strong, authoritarian governments. Could these systems, which are easily tampered with, also work in South and Southeast Asia? Clearly there is an element of historical chance which determines the system adopted. Bottrall discussed India's Chambal Irrigation System which flows between the states of Rajasthan and Madhya Pradesh. Although the environmental conditions are identical in both states, each operates according to different distribution principles.

The warabandi system of India and Pakistan brought out several comments. Wade noted that warabandi systems are relatively simple to administer but are inherently infiexible. How serious a problem is this in terms of water wastage? Interest was expressed for comparative research on regulation technology. Planners need to know the options, observed Moore. "Engineers who design the systems," noted Walter, "need to know the objectives: should they design for ease of management, for simplicity of maintenance, or for maximum performance?"

Ait Kadi noted that the greater capital investment required for downstream control must be weighed against the more intensive management required by some systems for upstream control. This raises the question of the relationship between system design and institutional arrangements. As Saldanha put it, "When we talk of system management, we cannot talk of management isolated from the bigger organization to which it belongs." Managers need incentives for accountability, and technical, financial, and manpower support. "And if the manager doesn't get that support from the bigger organization, what is the use of his trying to develop more creative and effective methods of distribution?" One approach to improved irrigation management, suggested Huppert, is to look outside irrigation at management approaches that could be applied to irrigation systems or agencies.

While all participants agreed on the need for comparative research studies, they debated the methodology for comparing one system with another. System performance means different things to different people; until performance is better defined, how can two systems be compared? Should performance be limited to physical measures, such as water loss efficiency *or* agricultural productivity? Rao suggested that performance evaluation must be tied to clearly defined objectives. The concept of production performance vs. management performance arose as a related issue: "We can't assume that because a canal performs well in terms of physical measures, its management also performs well." Moore noted, "a canal might be designed *so* well that it performs adequately in spite of poor management."

What then is meant by improving the performance of managers? Should Performance be limited to efficient use of water, or does it also include efficient personnel management? Groenfeldt suggested that so long as the marginal productivity of irrigation staff is not negative and the physical performance of the irrigation system is not adversely affected, the issue of superfluous staff should not be IIMI's concern. Carruthers argued that inefficient management of people necessarily involves an opportunity cost which could in theory be applied elsewhere.

At what level are performance indicators needed? Do we want to compare the performance of irrigation sectors in different countries or different systems within a region? Saldhana suggested that our primary task is "to improve the management of specific irrigation systems and the capacity of managers and planners." Wade argued for a more macro-perspective: "We need to be able to measure effects if we're going to make prescriptions. If we're going to talk about performance above the system level, it means indicators that can compare the performance of whole irrigation sectors at the national level."

One of the key factors in improved system Performance is improved communications. Chambers cited the installation of a new communication system along the Nile. Radio signals will link solar-powered monitoring stations to computers in Cairo and Aswan to regulate the entire irrigation network from Aswan to the Mediterranean. Boonyok outlined some of Thailand's options for improved communications. A communications system, observed Rao, should be thought of "as a linkage between an information system which flows up and a control system which flows down." Coward cautioned that communication technology is only useful if it is integrated into the management organization of an irrigation system.