Chapter 11
Mapping the management units

Medium to large irrigation systems usually serve thousands of users. Therefore, there needs to be an efficient organization and sharing of responsibility between the central project management unit and the numerous users.

The partitioning of management and of operation must be done on several grounds:

- homogeneity in the grouping of users and flexibility in providing service to users;
- managerial efficiency, responsibility and professionalism in the definition of the different management levels.

These two rationales can be conflicting and a compromise should be found.

MANAGERIAL APPROACH/MODEL

One of the implicit objectives of irrigation reforms/interventions, such as irrigation management transfer, participatory irrigation management and/or a modernization programme is to identify optimal management units that are likely to yield the best results in terms of performance improvements.

The change is major, from one central management body (an irrigation department) dealing with thousands of individual users, to several layers and units of management with different stakeholders. What is important in this transformation is to make explicit the mission and division of responsibilities among the various actors of the new management setup.

Institutional and water management domains

Irrigation systems can be subdivided into a chain of hydrological water management domains and, thereby, into a chain of water delivery services:

Source – primary canal network – command area water use/demand and allocation

At this level, the water delivery services involved are:

- water acquisition (capturing the water source);
- water conveyance (operation of primary infrastructure to convey water over the CA and its different uses and users);
- water allocation and distribution of the captured water source among the different uses and users (i.e. seasonal water allocations and water rights).

The potential service provider is the irrigation/basin authority, and the potential customers/users are:

- irrigation or users authority (secondary network);
- irrigators (end users);
- nature and nature authorities;
- hydroelectric utilities;
- water supply utilities;
- fisheries, livestock keepers, etc.

Irrigation delivery network (secondary to tertiary)

At this level, the water delivery services involved are:

- short-term scheduling;
- water delivery and operation;
- acquiring water demands (from tertiary level);

TABLE 33
Implicit MASSCOTE managerial model for a large irrigation system

Level and domain	Management unit	Features	Typical size
Water resources management	State responsibility	Regulate water management and ensure that state policy is applied.	Basin
Main system management	Main system agency Autonomous multistakeholders body	A high-level professional agency providing services to local agencies/ users.	20 000 ha and above
Subcommand areas –secondary canals	Local management agency	Professional agency governed by local stakeholders (mostly farmers)	1000–20 000 ha
Local distribution	Farmers and users group	The size of this group is designed to ensure social cohesion within the group.	Fewer than 1000 ha

- acquiring water from primary network;
- delivering water as per agreed delivery service.

The potential service provider at this level is a professional irrigation agency (preferably farmer-owned) and the clients are WUAs at tertiary level and other sector representatives.

Water-use domain

At this level, the water delivery tasks are:

- articulate demand for service and changes therein;
- acquire water from network operator;
- manage and operate water delivery and distribution and use within tertiary domain.

There are many possible options for this management setup, but it is beyond the scope of this paper to propose an exhaustive review of all of them. The important aspect is to make explicit all the ins and outs of the managerial model. The model presented in Table 33 is the implicit model with which the MASSCOTE approach is carried out. However, it is one approach among several.

SPATIAL DIFFERENTIATION OF SERVICE AND MANAGEMENT

As explained in previous chapters, the MASSCOTE mapping exercise in Phase A consists of first mapping throughout the canal system:

- physical features and capacities;
- water balance flows and destinations;
- the service requirements and requirements for canal operations.

This mapping exercise is done considering that the assumption of heterogeneity within the project is the rule and not the exception. The result is an information database that allows consideration of the whole system consisting of numerous units with homogeneous features.

A central question for the management and the cost-effectiveness of operation concerns how far the differentiation should go.

Too much differentiation of the service requirements can lead to a too high cost of operation (or even impractical and incompatible operational demands), while too little differentiation does not respond to the needs for more adapted service. A compromise has to be found between manageability and differentiated service.

In some types of systems, this principle of differentiation can be applied all the way down to the end users. This is the case with pressurized pipeline systems, where the individual farmers can select the service (pressure, discharge and timing) that they think is best for their production conditions.

However, in canal systems, this principle of differentiation is very often limited for practical reasons and cannot be extended down to the level of users, but more often to a group of users or to a low level of the canal system.

This chapter discusses how the whole service area is partitioned into various levels of spatial and management units in order to devise efficient management and operation procedures and better service to users.

The partitioning should aim to identify management units up to the lowest management unit that will be operated with professional staff. The size of these units depends on the agricultural and economic context, but the order of magnitude ranges from one to several thousand hectares.

The number of canal system levels in the partitioning depends on the size of the whole service area. Very large systems, such as those found in the Indus River Basin in Pakistan (more than 400 000 ha below one single intake along the Indus River), requires several different levels in order to reach down to the lowest management unit with professional staff.

RATIONALE FOR PARTITIONING: GROUPING AND SPLITTING

The partitioning of a canal system into manageable spatial units is required for effective decision-making and management, which contribute to improved water service delivery. The main parameters for partitioning into subunits are:

- consistency and responsibility for the main system management;
- cost-effectiveness: too many units = too costly and chaotic; too few units = not responsive enough;
- critical size of the management unit: to allow for the provision of professional staff for operation;
- compactness and sense of ownership for users;
- integration of the concepts of IWRM: may need to incorporate multiple uses and multiple sources.

The process of management partitioning is a two-way process, with two rationales:

- splitting the CA into small units;
- grouping and ensuring a clear responsibility for the main system.

Hence, it is normal that when considering a new partitioning of management it is necessary to consider two actions:

- grouping at the main system in order to increase responsiveness (Figures 58 and 59);
- splitting the CA into professionals local units.

FIGURE 58
Options for partitioning: a single agency serving numerous groups and dealing with IWRM

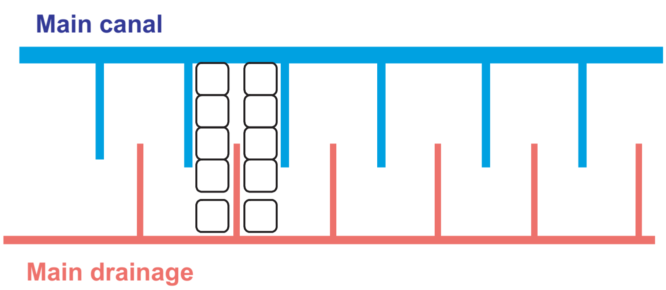
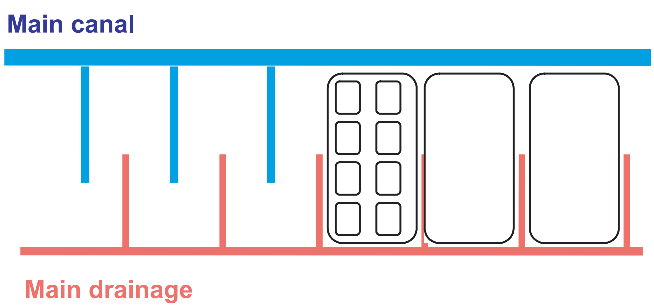


FIGURE 59
Options for partitioning: a main system agency serving secondary agencies encompassing several groups



CRITERIA FOR PARTITIONING

There are many criteria to consider when partitioning a canal system, including social networks and cultural aspects.

Traditionally, canal hierarchy and hydrological units have been used as the basis of partitioning.

However, there are other relevant criteria on which the subunits should be based:

- participatory management and social capital;
- spatial variation and requirement for water services;
- conjunctive water management;
- multiple uses of water;
- drainage conditions.

Canal hierarchy

Large irrigation systems are usually divided into smaller management units called tracks, blocks, subsystems and "casiers", often based on the hierarchy of canals (main, secondary, tertiary, etc.). With a single entity in charge of management, this has often been the easiest way to partition a system into subsystems.

Water management partitioning

As seen in Chapter 2, clear-cut separate management units can initially be defined on the basis of major hydraulic control points where discharge can be regulated, i.e. variations in flow can be compensated for.

Where partitioning along institutional lines, managerial subunits should correspond to the wider partitioning of the service area among: (i) the users (farmer groups, WUAs, etc.); and (ii) main system management – federation/WUAs – farmers group – end users.

In partitioning by type of service, it is necessary to consider the homogeneity of the service to be provided. Areas with different types of service should be as separate as possible. An example of partitioning demand by service in a large project is the NIS, NEPAL. In this case, the canal service mapping was done depending on whether or not there was access to safe groundwater. The results of the mapping determined that arsenic-prone areas should receive the best canal service possible (as seen in Figure 57).

Where partitioning by the hydraulic boundaries of subunits, it is necessary to determine sensible limits *vis-à-vis* the interrelationships between the surface water network and groundwater (irrigation and drainage systems, natural streams).

Other potential technical partitioning points are:

- well-measured points – these are appropriate for the intake of a subunit as discharge is known accurately;
- spills;
- main entry point of fluctuations (perturbations);
- highly sensitive regulators – these detect upstream changes in the water balance (even small changes) and are good points at which to check the downstream of the subunit;
- storage –allows buffering discharge variations and restarting management downstream.

PARTITIONING WITH IRRIGATION SYSTEM TYPOLOGY CRITERIA

When a typology of irrigation systems is available at the national or state level, then it can be worth using the selected criteria of the typology as the main ones for the partitioning, provided that the typology is driven by the same purpose, e.g. canal operation. This reinforces the consistency of the diagnosis and suggested solutions.

This approach was applied in Sri Lanka, where a generic typology (Renault and Godaliyadda, 1998) was developed for the 64 medium to large systems in the country. A total of 21 criteria were initially examined and scrutinized. These were further reduced to four criteria, and the typology identifies four main types of systems:

- Reservoir and localized storage system: The main source of supply is a reservoir; it has a localized storage (intermediate reservoirs) at system level, single-bank canals (runoff), and no return flow entering the system.

TABLE 34
Irrigation subsystems identified in the KOISP, and suggested operational strategy (Sri Lanka)

Subunit	Salient features for operations	Suggested operational strategy
LBO	Reservoir – double-bank canal – return flow – non-recycled	Controlled volume strategy by monitoring drainage to the sea and acting on reservoir (intermediate tanks) issues.
RBO	Reservoir – single-bank canal – no return flow – non-recycled	Discharge controlled strategy on each subcommand area by monitoring drainage to the river and acting on offtakes. Volume controlled strategy along the main canal.
LBN	Reservoir – single-bank canal – no return flow – recycled into LBO	Volume controlled strategy by monitoring water levels in downstream tanks and acting on issues from the main supply.
RBNT1–2	Reservoir – single-bank canal – no return flow – recycled into RBO – intermediate storage (downstream)	Volume controlled strategy by monitoring water levels in downstream tanks and acting on issues from the main supply.
RBNT5–6	Reservoir – single-bank canal – no return flow – non-recycled – intermediate storage (downstream)	Discharge controlled strategy on each subcommand area (tracts) by monitoring drainage to the sea and acting on offtakes. Volume controlled strategy between downstream reservoir and the main upstream reservoir.

- Reservoir without localized storage system: The main source of supply is a reservoir; no localized storage, with single-bank canals, and without any return flow entering the system.
- Diversion river system: The main source of supply is from a river diversion; it has single-bank canals, with or without localized storage and return flows.
- Return flow system: This type regroups irrigation systems with return flows coming back into the system, having single-bank main canals, fed by a reservoir or diversion and with or without localized storage.

This typology approach when applied to the KOISP led to the identification of five subsystems (average size 2 000 ha) within the service area that can be considered as homogeneous with respect to canal operations. The characteristics of these subsystems are summarized in Table 34 together with some identified possible strategies for improved management.

GROUPING AT MAIN SYSTEM AND SPLITTING FOR LOCAL AGENCIES

Creating a new partition of management units implies a complete reorganization of the CA. There should be no attempt to create local management units unless the main system has been reorganized properly.

In the KOISP, the management setup was inherited from the construction phase with three management units at scheme level: one for the old system, one for the right bank of the new canal, and one for the left bank. In a system that is typically a cascade system, where drainage from one unit is used by units downstream, this division of responsibility proved to be inefficient and counterproductive, leading to high water losses.

The first critical step in the modernization process was to reorganize the management into a single unit by looking at the entire scheme in terms of inflows and outflows. The second step was to delimit units according to the recycling and difficulty of operation.

A similar case was found in the GLBC (Karnataka, India), where the main canal system was divided into three divisions. This partitioning has proved to be ineffective in channelling water to the downstream users, and tail-end users face difficulties in knowing who is responsible for this situation and who they should complain to. In this type of situation, partitioning only for local agencies would not yield the expected results. The first recommendation made to the authority in charge of the system was to create a single unit of management for the entire main system (100 km). An example of the proposal made to the project authority is shown in Table 35 and Figure 60.

TABLE 35
Management levels in the GLBC

Existing management setup	Proposed management setup
GLBC management 3 divisions of 50 000 ha	GLBC management agency Karnataka Neeravari Nigam Limited (KNNL)
3 or 4 subdivisions: 10 000 ha Sectors of 5 000 ha Distributory subcommittees	Local management agencies (stakeholders management) serving water societies where they are active, or directly field group at field channel
WCs (500 ha)	Water societies serving farmer groups
Field channel groups	Farmer groups

FIGURE 60
Example of combined grouping of main canal into one single unit and splitting into 11 local management agencies, GLBC

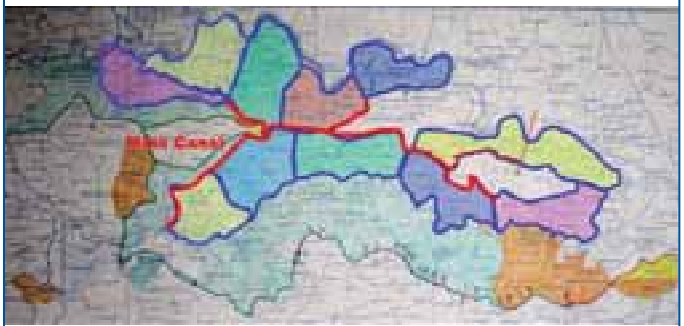
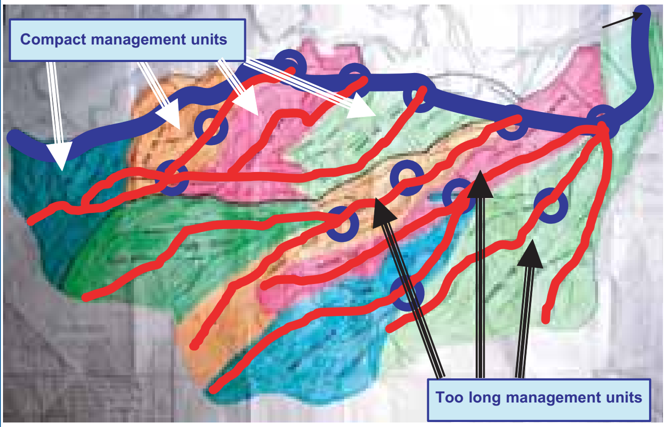


FIGURE 61
Managerial units in the Gohtki Area Water Board, Sindh, Pakistan



DILEMMA BETWEEN COMPACTNESS AND CANAL BELONGING

Determining the right size of subunits for effective management is not an easy task. This can be observed at many projects where WUAs have been created through irrigation reforms and entrusted with O&M responsibilities for parts of systems that for many reasons are difficult to manage. An example in Sindh, Pakistan, illustrates this dilemma (Figure 61). In the northwest of the service area, compact units were originally defined with several parallel canals, while in the south and east, very long managerial units were set up along a single canal. During the implementation of the institutional reforms it was found that the very long units were not effective. There were difficulties for farmers to become organized and to meet regularly because of the travel time involved. It was also difficult for the system operators to operate and manage these systems effectively.

Another example of the size dilemma is illustrated by the NIS, Nepal, where if the criteria of canal belonging (secondary) is applied, it would lead to 22 units, most of them too small to be able to hire professionals.

PROCESS OF PARTITIONING

There are different aspects of partitioning to consider in the process of designing management units. A compromise between hydraulic considerations and social coherence needs to be found. As users are central to SOM, compactness and social coherence should be given precedence in the subdivision of a larger system into smaller manageable units.

There is no scientific or technical knowledge that can give the stakeholders the sense of what kind of partitioning units should be best for the management. However, partitioning of the service area into management subunits should be an iterative process that is technically and socially sound. A proposal for partitioning should then be investigated for both aspects and refined as needed before the validation stage. It should be pilot tested within the project or on representative systems.

AN EXAMPLE OF PARTITIONING IN MANAGEMENT UNITS: THE SMIS, NEPAL

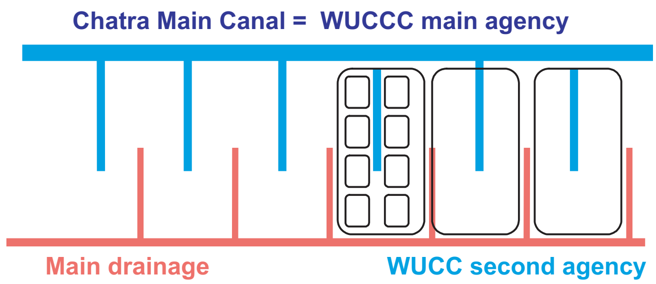
The current management is split into five levels (Table 36). It is believed that too many levels are leading to inefficient management. In fact, it would be best to reduce the number of levels to three.

As far as management and operation are concerned, it seems that there is room for two professional levels for the management units. This is what the DOI has adopted in the SMIS with the Water Users Central Coordination Committee (WUCCC) as the professional agency responsible for the CMC supply and for serving the large lower professional agency, the Water Users Coordination Committee (WUCC), one for each secondary canal (Figure 62). In this setup, the WUCCs cover an area of several thousand hectares, and they are responsible for serving smaller units, Water Users Committees (WUCs), of about 300 ha, and they should assume IWRM.

TABLE 36
Existing institutional management setup in the SMIS

	Canal level
Water Users Group	Watercourse
Water Users Committee or Water Users Subcommittee	Tertiary canal
Water Users Committee	Subsecondary canal
Water Users Coordination Committee	Secondary canal
Water Users Central Coordination Committee	System level

FIGURE 62
Management setup in the SMIS



An important issue here concerns the number of second-level agencies (WUCCs).

The partition of the CA into practical management units should be made considering the secondary canals. However, this does not mean that there have to be as many units as there are large or small secondary canals. Other criteria need to be considered, e.g. the size and compactness of the CA.

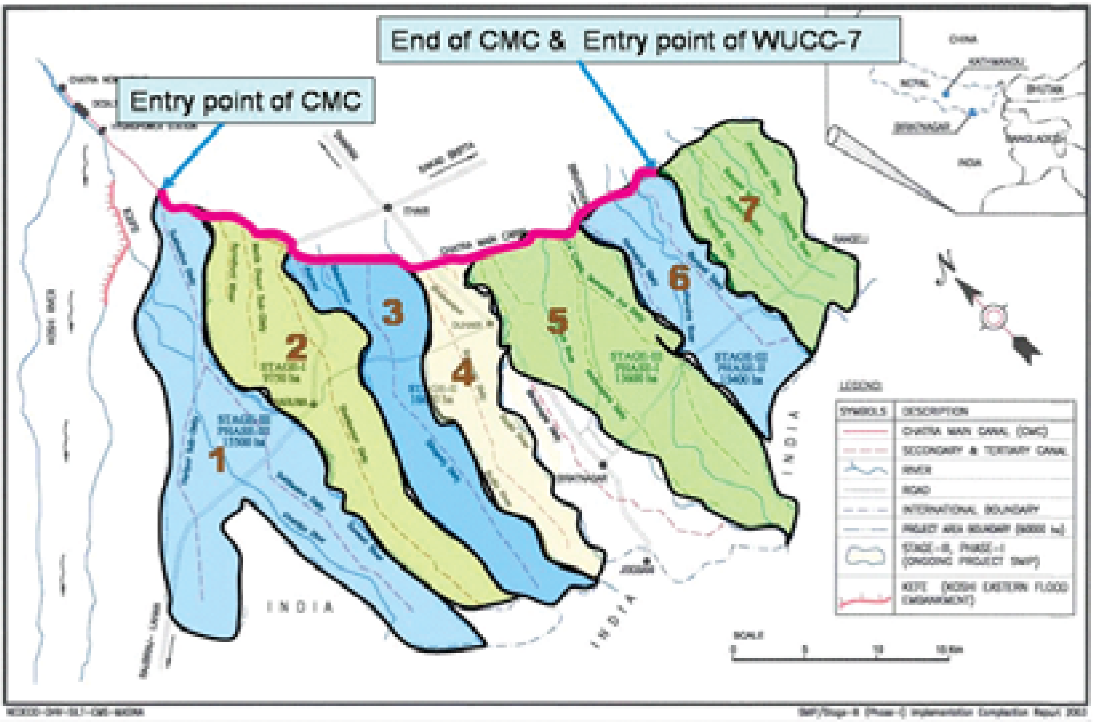
For the moment, the SMIS managers are considering the partitioning on the basis of all secondary canals, including the small ones. Therefore, there would be 20 WUCCs. For the service interface, it is quite reasonable as each WUCC would then have only one offtake point on the main canal. However, FAO believes that this option is likely to create some small units that would not be viable, while others would have a critical mass (area) that would allow the recruiting of professional staff.

The suggestion by FAO is to consider having only seven WUCCs, with many of them having several offtake points on the main canal, but with each of them being large enough to allow strengthened management. Figure 63 maps out what could be the CAs of the second-level units if the entire system were split in seven units, each averaging 10 000 ha.

When considering a partition with seven units, the downstream unit (WUCC-7) would have four medium-sized secondary canals diverting from the CMC. For the purpose of clarity in management, the proposal is to end the CMC upstream of CR11 and to make the WUCC responsible for, and the operator of, the final sections of the CMC. This option would be accompanied by the construction of a measurement weir upstream of CR11 in order to allow the discharge reaching WUCC-7 to be measured. Operation of the four intakes on the CMC should be the responsibility of WUCC-7.

At the tail-end of the system, it is likely that discharge perturbations will affect the delivery at the entry point of WUCC-7. Therefore, the suggestion is to use the main canal as buffer storage in order to compensate for hourly fluctuations.

FIGURE 63
Proposed partition of the SMIS into seven second-level units



Chapter 12
Mapping the demand for operation

Irrigation project managers allocate and spatially distribute resources, resulting in a quality of service and cost of operation. Constraints affecting the quality and the cost of operation are: human resources availability and skills; transport facilities; and communications. Their current status and likely future scenarios need to be assessed properly before engaging in a modernization programme.

As in other activities, it is critical to adjust as much as possible the inputs to the demand. It is assumed that, in general, operational requirements are not distributed homogeneously throughout a given project.

Defining the demand (requirements) for operation involves answering the following questions:

- What service is demanded by the different user groups?
- How do these relate spatially, in time and in operational requirements?
- What service can be offered to the users?
- What is the possible range of service and fees to be considered?
- What mode of operation can be followed and with what precision?
- What perturbations are likely?
- What should be the frequency of checking and intervening?
- Which setup is required in order to monitor the service?
- What are the mechanisms to ensure services are provided and paid for?

The proposed approach outlined in this chapter aims to define the targets and the level of means to be input in operation with considerations on three main drivers: service demand, perturbation and sensitivity.

THE THREE DRIVERS OF THE DEMAND FOR OPERATION

From an operator's or a manager's point of view, canal operations can be perceived as an industrial process. Inputs are transformed into outputs (water delivery to users) by organizing a complex interaction of production elements (canals, structures, storage, etc.). To manage the inputs effectively, managers have to consider:

- The precise service demands and the tolerances allowed by the respective water uses and users – output.
- The impact of decision-making on the output – vulnerability of output.
- The characteristics of the structures involved in the process. Which modes of operation can be achieved? What are the constraints and opportunities? – system behaviour.
- The variability of inputs (water availability and storage) and the frequency and impact of perturbations on the system – input and behaviour.
- The organizational and financial resources available or required in order to achieve the required level of performance – management setup, necessary to keep the process going.
- Requirements of the process setup – rules, transparency, etc.

Assessing the requirements for canal operation needs to be done alongside and in combination with the definition of the service by users and stakeholders. However, canal operation requirements cannot be derived only directly from service demands. The system presents opportunities and constraints that set the boundaries for possible modes of operation. In short, the requirements are to be found in three domains: (i) service demand; (ii) perturbation; and (iii) sensitivity.

The service demand domain refers to the articulated and other demands on canal operation. Many of these demands are interrelated; they can add to or be in conflict with one another. Some of the demands can be seemingly autonomous, as some refer to deliveries, others to canal flows, and others to modes of operation of infrastructure. The integration of these demands enables the definition of spatial and temporal operational scenarios that provide adequate deliveries to vulnerable areas in line with key variables in the service demand domain.

Once the scenarios have been articulated in the service demand domain, the perturbation domain gives the boundary conditions from the supply side. The perturbation domain refers to the frequency and magnitude of perturbation events likely to occur in a subsystem, and it enables evaluations of the stability of the service with respect to the demands. As irrigation systems are subject to continuous modification of flow conditions, from both scheduled and unscheduled events, the required service is not achieved easily. This domain determines the mode of observation, measurement and regulation along the system in order to ensure that the water service is achieved.

The sensitivity domain is characterized by the physical properties of the conveyance and distribution system. The behaviour of irrigation systems under operation and affected by perturbation determines the reaction of the system under non-steady flow with respect to the service demands. This domain sets the precision of control required.

The assessment of the requirements for canal operation should include all these overlapping domains. The technical, organizational and financial boundary conditions can be set in this overlay, and compromises will have to be made.

WATER DELIVERY SERVICE, PERFORMANCE AND FLOW CONTROL

Water delivery service, flow control and performance are intrinsically linked. This can be illustrated through the example of a delivery structure (offtake) by looking at the service and operational requirements. For a delivery structure (Figure 64), the water level in the parent canal (H_{us}) conditions the head through the structure (the difference between the upstream and downstream water levels) and, thus, the discharge (q) through the gate once the gate opening is set.

Fluctuations in the water level in the parent canal generate variations in head and discharge through the gate. As described in Chapter 6, for a sensitive offtake, a small fluctuation in water level will generate a high variation in discharge, whereas for a low-sensitive offtake, water levels may vary strongly without significant variations in discharge q. Following Chapter 6 (that showed a clear link between acceptable variation of discharge, sensitivity and control of water depth), the discharge service delivered at this point can be defined by:

$$\text{Service}_{\text{target}} = q \qquad \mapsto \text{Tolerance}_{(q)} \quad = +y\% \text{ and } -z\%$$

where y and z are tolerance factors considering, respectively, adequacy and efficiency of performance. Adequacy and efficiency are basically opposite to each other – where one is high, the other is low. Values for y and z are not necessarily the same. For example, a high value for y might be tolerated (surplus), while the value for z (deficit) must be kept lower in order not to penalize the user too much (Figure 65).

Assuming there is no adjustment to the setting of the gate, fluctuations result from the variation in the water level in the parent canal. The variation in discharge depends on the sensitivity of the structure and the head variation: Perturbation or Head variation H → Sensitivity → Perturbation of discharge Q.

Where the structure is submerged, the downstream conditions also influence the discharge. A correction for downstream submergence can be brought into the computation of the sensitivity indicator. However, most of the time, the correction is not needed.

By inverting the equation of sensitivity, the precision required for water-level control in the parent canal (ΔH_{us}) is computed as:

$$\Delta H_{US} = \frac{Tolerance(Q)}{S} \qquad (18)$$

where: S is the sensitivity of the offtake; and tolerance on discharge (Q) is y and z percent (Q is a typical abbreviation for discharge/flow rate).

H_{us} in the parent canal should be controlled in such a way that discharge is maintained within the defined limits of ($Q + y$ percent; $Q - z$ percent). This service objective can then be converted into a control objective at this particular point of the canal.

Equation 18 expresses the tolerance with which the water level in the parent canal at this particular structure is allowed to fluctuate. This in turn has to be converted into control targets at the nearest downstream regulator. Control of water levels along the canal is the result of the combined effects of the hydraulic properties of the canal section, regulator characteristics and periodic operation of cross-regulator structures. The precision with which target water levels are controlled at cross-regulators (ΔH) is an indicator of operational performance directly influenced by management.

FIGURE 64
Linking service and control through a delivery structure

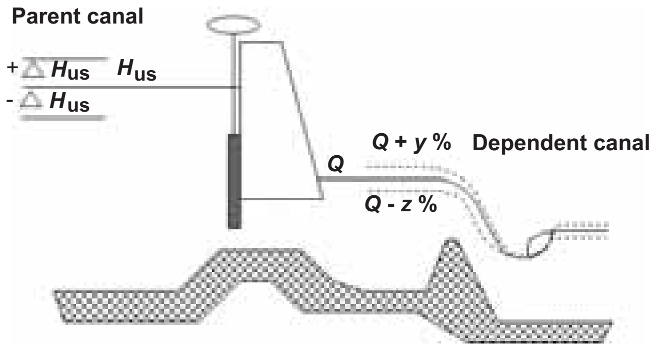
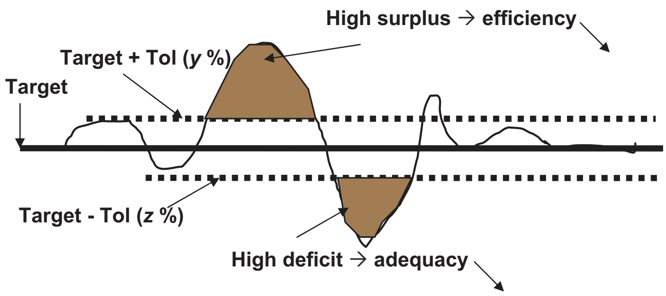


FIGURE 65
Adequacy and efficiency as related to tolerance limits



THE SERVICE DEMAND DOMAIN

The service demand domain refers to opportunities, constraints and impacts of operation at different scales of space and time. Service demands set by users or other stakeholders can be affected positively or negatively by canal operation. Some demands are more vulnerable to operation than others. Vulnerable periods might be transplanting of rice or flowering of fruit trees. Inversely, areas or periods of low vulnerability are only affected slightly by low-quality operation.

Service demands with high vulnerability need more weight in evaluating scenarios. However, both demands and vulnerabilities have to be considered in the service agreement. Demands and vulnerabilities (and thus levels of tolerance) for the different water uses should have been discussed by the users while defining the service.

The service demand domain refers not to the setting of vulnerabilities but to the responses to these demands. It aims to address which modes of operation can deliver a good service to most of the demands in the area in a cost-effective and efficient manner. Hence, service demands extend beyond the confines of irrigation water for crops and include consideration of larger-scale water management impacts.

Some of the wider aspects of water management that should be mapped as areas of vulnerability include those discussed in Chapter 11:

- water quality;

- recycling of irrigation water;
- water harvesting and conjunctive management;
- soil and water salinity and waterlogging;
- multiple uses of water;
- health impacts.

To these should be added: location within the system. The impact of operations of structures located at the head of the canal system is greater. Therefore, location is included in the vulnerability analysis.

The study of each aspect of the service demand domain leads to an assessment of the aggregate demands for canal operations, as well as areas of vulnerabilities. On the basis of this assessment, the service provider can lay out the contours of an operation plan. The rationale is that highly vulnerable areas require a high-quality water service while a lower quality service may suffice for less vulnerable areas. The spatial and temporal characteristics of the service demand domain can be converted into operational scenarios with specific water service targets that can be measured partly with water supply performance indicators, such as adequacy, efficiency, dependability, timeliness and equity. However, some demands do not relate to deliveries (e.g. health impacts, safety, and canal operation efficiency). They relate more to the mode of operation rather than the quality of delivery.

THE PERTURBATION DOMAIN

Open-channel irrigation systems are hydraulically complex. In general, system operation is reduced to controlling water levels at cross-regulators in an attempt to maintain stable water levels and, hence, discharges at offtake structures. However, steady water-level profiles hardly ever occur in irrigation systems owing to upstream inflow variations and the compounding effects of operational interventions within the system. Hence, even where all the gates are set appropriately, operation is a never-ending challenge, and control structures have to be adjusted continuously in order to meet demands.

A perturbation at a given location is defined as a significant change in the ongoing discharge. Flow changes may originate from planned changes in delivery or arise from unexpected or transient changes. Perturbations of the latter category are more difficult to manage accurately because they cannot be anticipated precisely.

Managing perturbations has two basic objectives:

- ensure passing variable flows without adversely affecting deliveries;
- ensure that the perturbation is managed properly, by compensating for a deficit of water if the perturbation is negative, or by storing the surplus if it is positive.

To achieve these objectives, there are two options:

- Set up an infrastructure in such a way that perturbations are dealt with automatically, e.g. the surplus is diverted automatically towards areas that can store or value the water.
- Detect the perturbations and have a proper set of procedures for the operators to react.

For analysis, the perturbation domain is divided into two components: (i) generation; and (ii) propagation. These can also be termed “active” and “reactive” processes (Chapter 3).

The active and reactive processes can be analysed in three constituent parts:

- the causes of perturbations, such as return flows, illicit operation of structures, and drift in the setting of regulators;
- the frequency of occurrence;
- the magnitude of perturbations experienced.

The causes of perturbations are to a large extent determined by the network properties of the canal system. Determining static properties are: the source of supply;

hydraulic layout and variability in discharges; interconnections with other networks, such as drainage; unregulated return flows, etc.; and the number and type of offtakes and regulators. A second cause of perturbation is the operation of the irrigation regulation system itself. The operation of offtakes and regulators generates transient conditions in the network, just as any obstruction of flow, withdrawal and rejection, either planned or illicit. The complexity of the distribution setup and the control mechanisms for diversion and abstraction have a significant influence on the level of perturbation.

The position in the network is a determining factor in frequency and magnitude of occurrence of transients and partially explains the well-known “head/tail” issue in irrigation systems. In general, deviations from planned water deliveries are larger and occur more frequently in the tail-end of a system. This is linked directly to the number and operational characteristics of upstream structures. Slight deviations in the head-end are amplified owing to however minor management errors at all nodes. Furthermore, once the gates have bee set, the sensitivities and flexibilities of structures determine whether perturbations are attenuated or amplified and, thus, spread throughout the system.

Perturbations are expected whenever a change in the distribution takes place. Therefore, the scheduling and distribution policy (on-demand, arranged demand, or rotation) is a key determinant of frequency of occurrence of perturbations. The greater is the flexibility of the service being provided, so the greater the frequency of changes in flows in the canal system will be. Proper consideration of the impacts of service flexibility on the perturbation domain is essential in order to identify the specific operation modes and structure characteristics required for acceptable performance.

THE SENSITIVITY DOMAIN

An important consideration for canal operation is the sensitivity of structures and their impact on the propagation or attenuation of transient flows that enter the canal system. The sensitivity domain analyses the behaviour of structures and subsystems during the propagation of transient conditions. It aggregates sensitivity analyses (Chapter 6). In the absence of operational interventions, the evolution of perturbations through the subsystem shows a decay curve integrating the conveyance sensitivity of the reaches and associated structures.

A QUALITATIVE APPROACH TO MAPPING THE DEMAND FOR CANAL OPERATION

The three domains outlined above must be combined in order to map the demand for canal operations. The rationale is straightforward: the higher the service demand, perturbations and sensitivity, so the higher is the demand for canal operation. This can be captured in the relationship: demand for operation = service × perturbation × sensitivity.

There are some exceptions to this generic equation, e.g. where high criteria do not lead to high demand. This is the case when highly sensitive structures (reach or offtakes) are used to divert high perturbation towards areas that will not be penalized by either a surplus of water or a temporary shortage.

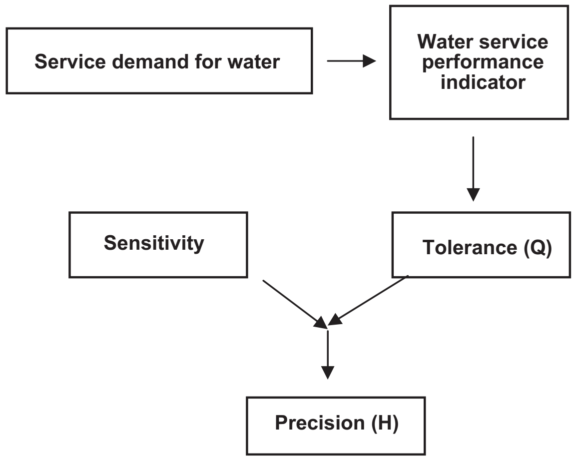
A simple way of aggregating the three domains into canal operation demand is through multiplying primary indicators ranking from 1 to 4, as shown in Table 37.

TABLE 37
Adding the primary indicators in order to evaluate canal operation demand

	Service demand	Perturbation	Sensitivity		Product	Canal operation demand
Low	1	1	1		from	1–4
Medium	2	2	2	➔	1	4–16
High	3	3	3		to	16–27
Very high	4	4	4		64	27–64

The service is classified from low to very high (1–4); 1 is for a low service, it could be a service to drought-resistant crops in areas for which an alternative source of water is also available in the

FIGURE 66
Functional relationships between the vulnerability, sensitivity and characteristics of the service



event of emergency, while 4 could be a service to sensitive crops in areas for which there is no alternative source of water. Perturbations are also classified from 1 to 4 according to their frequency and magnitude. For the purpose of consistency with the other primary indicators sensitivity is reclassified as follows, 1 when sensitivity indicator (S) (Chapter 6) is 0.5 or less; 2 when it ranges between 0.5 and 1; 3 for S between 1 and 2 and 4 if S is higher than 2. Similarly the aggregated demand is reclassified as Low for a product between 1-4, medium between 4 and 16, high between 16 and 27 and very high between 27 and 64.

QUANTIFYING CANAL OPERATION REQUIREMENTS

More precise and quantitative indicators for operation can be derived from the service demand domain. The process should consider both water deliveries for irrigated crops and water management in a broad perspective. Here in this analysis, only primary indicators are considered, namely: adequacy, efficiency and timeliness. In order to facilitate analysis, it is preferable to convert performance indicators into tolerance with respect to targets. Thus, irrigation performance for adequacy and efficiency can be summarized by a function expressing that the discharge at a given location should be maintained between target -*z* percent and target +*y* percent:

$$\mathrm{Tol}(Q) = {}^{+y\%}_{-z\%} \qquad (19)$$

where: *z* expresses the capacity of the area to accommodate water shortage (*z* is strictly related to the adequacy indicator and incorporates concerns about the deliveries); and *y* expresses the capacity of the subsystem to accommodate a surplus of water (positive perturbation). A similar equation can be proposed for timeliness.

The relationship between water service, irrigation performance indicators and operation targets illustrated above for a simple case can be generalized, as shown in Figure 66. This relationship indicates that the required precision of structure operations is the product of the tolerance on delivery and the sensitivity of the structure.

The demand for operation can be derived from the previously outlined relationships by converting the tolerance on discharge to either a tolerance on controlled water depths or some other structure setting. The link between operation and irrigation performance can be established through generic relationships:

$$\text{Service Demand}\begin{Bmatrix}\text{Irrigation requirements}\\ \text{Water management}\end{Bmatrix} \Rightarrow \text{Demand} \Rightarrow \text{WSPI} \Rightarrow \begin{Bmatrix}\mathrm{Tol}(Q)\\ \mathrm{Tol}(T)\end{Bmatrix} \times \{\text{Sensitivity}\} \Rightarrow \begin{Bmatrix}\mathrm{Tol}(H)\\ \mathrm{Tol}(\text{Setting})\end{Bmatrix} \qquad (20)$$

The relationships in Equation 20 express the idea that the water supply indicator is the result of the product of the tolerance in operating the infrastructure and the sensitivity of the structures themselves (Table 38).

PERTURBATION MANAGEMENT

Ultimately, the assessment of the operational requirements is a mixture of both quantitative and qualitative approaches. The objective of a qualitative approach is to identify the properties of subsystems that influence potential operational strategies significantly. All the above-mentioned properties have to be weighed, and they can be combined to classify the requirements for operation as low, medium or high.

This classification can lead to a more appropriate distribution of efforts for operation within the project. The objective of a quantitative approach (i.e. set targets and tolerance levels) is to specify the service agreement in operational targets so that it can be used for monitoring and control.

TABLE 38
Examples of sensitivity, tolerance and control precision

Sensitivity of the structures (S) (m^{-1})	Tolerance for discharge (α) (%)	Precision of control (ΔH_{us}) (m)
0.5	±10	±0.2
Low sensitive	±20	±0.4
1	±10	±0.1
Medium sensitive	±20	±0.2
2	±10	±0.05
High sensitive	±20	±0.1

An important aspect of canal operation is the management of perturbations (fluctuations of flows). The objective is to increase water management efficiency (e.g. of rainfall harvesting) while minimizing the effect of perturbations on the deliveries. This process combines the opportunities for perturbation management (storage facilities or efficient use of water surplus) and the probability and magnitude of occurrence:

$$\text{Perturbation}\left\{\begin{matrix}\text{Opportunities for}\\ \text{perturbation management}\end{matrix}\right\} \times \left\{\text{Perturbation}\ \begin{matrix}\text{probability}\\ \text{magnitude}\end{matrix}\right\} \Rightarrow \left\{\begin{matrix}\text{Operational modes}\\ \text{Frequency}\end{matrix}\right\} \qquad (21)$$

This allows the determination of the appropriate mode and frequency of operation depending on the expected frequency of perturbations, as illustrated in Figure 67.

The frequency of operation/checks can be summarized as: Frequency (check/operation) = Frequency of perturbation × Magnitude of perturbation × Sensitivity regulator.

MAPPING THE DEMAND FOR OPERATION: AN EXAMPLE

The mapping of the demand for operation can be illustrated through the example of the KOISP, where the methodology led to ultimately four classes of demand for services (Figure 68).

Perturbations

Four subsystems are supplied by a reservoir, hence minor fluctuations in the main inflow are expected. However, three major canals are only single-bank canals and therefore susceptible to perturbations resulting from runoff during rainfall events. One subsystem (Left Bank Old [LBO]) is a return-flow subsystem; hence, discharge within the CA fluctuates with return-flow variations.

Network

Three subsystems do not include recycling and, therefore, should be operated carefully because drainage flows are truly lost to the sea. On the other hand, the Right Bank New (RBN) canal ends in a downstream reservoir, which might compensate for any errors in operation. Thus, for each subsystem an analysis of the impact of the operational performance can be carried out.

FIGURE 67
The functional relationships between the vulnerability, perturbation and operational modes

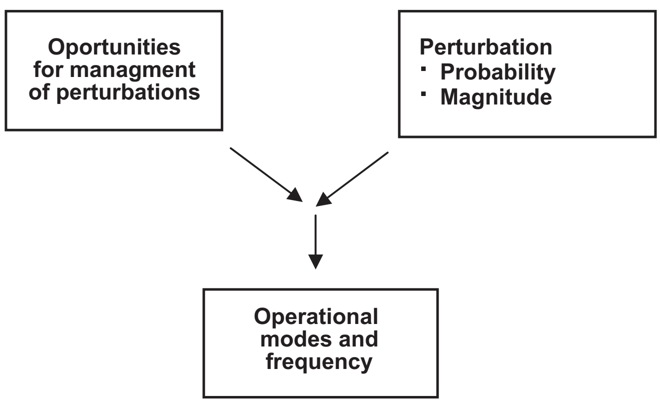
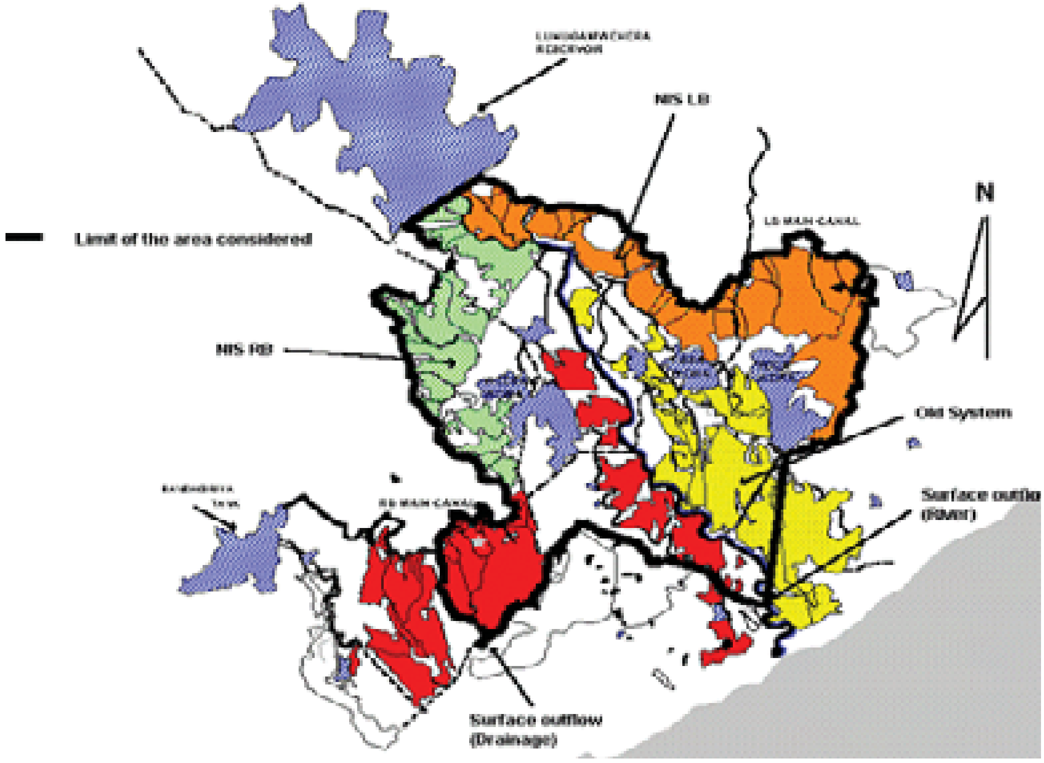


FIGURE 68

Application of demand approach in mapping canal operation for a rice-based system in Sri Lanka



Note: High demand = red; low demand = green.
Source: Renault and Makin, 1999.

Sensitivity

The sensitivity of offtakes distinguishes the RBN (medium sensitive, average S = 1.3) from the LBN and RBO canals, which are classified as highly sensitive (average = 2.4 and 2.2, respectively). This means that the same level of precision in water depth will generate discharge deviations two times greater in the LBN and RBO than in the RBN.

Analysing resources allocations vs demand for operation

As a transitory phase between the approach of the demand for operation and the design of improvement options, it can be a very useful exercise to specifically confront the current allocation of resources and practices throughout the system with the demand for operation. This yields to identify gaps and distortions and allow proposing improvement options by simply reallocating the efforts in operating the system.

This exercise is illustrated through the same example of KOISP, looking more specifically at the main canal of the right bank. The initial allocation of operators along the Right Bank Main Canal (RBMC) was made on a tract basis: 4 operators for tracts 1 and 2; 5 operators for tracts 5; and 3 operators for tracts 6 and 7 considered as a single unit (Table 39). The area served by each tract appears to be rather similar (850–1 000 ha), while the area served by a single operator varies (213–300 ha). The density of structures per operator is also quite constant. These figures show that the current mobilization of efforts is somewhat homogeneous with respect to the area served and the structure density.

Figure 69 plots the number of gate operations at cross-regulators. It shows that, although not constant, variation is limited. For tracts 1 and 2, the variation is between

TABLE 39
Allocation of resource and efforts along the RBMC, KOISP, Sri Lanka

Tract	No. of gate operators	Area served (ha)	Area per operator (ha)	Number of regulators	Number of offtakes	Structures per operator	Class of demand for operation
1	4	851	213	3	10	3.25	Low
2	4	868	217	6	10	4.00	Low
5	5	1 005	200	5	14	3.80	Very high
6–7	3	896	300	4	8	4.00	Very high

30 and 38 per season. For tract 5, it is higher (mean = 44) and more variable (33–52). For tract 6–7, the mean is 38 but the range of variation is high (20–60).

The average number of operations per offtake is more variable, it decreases from 60 per season for tract 1, to 34 for tract 5 (Figure 70). This reflects a significant variation in the quality of operation, which is confirmed by the analysis of the variation in water depth variation upstream of each offtake and the resulting discharge variation (Figures 71 and 72).

The paradox of the then practice along the RBMC was that operation was more frequent where the flow was more stable than in the upstream reaches.

FIGURE 69
Number of gate operations at cross-regulators, average for 6 seasons, RBMC, KOISP

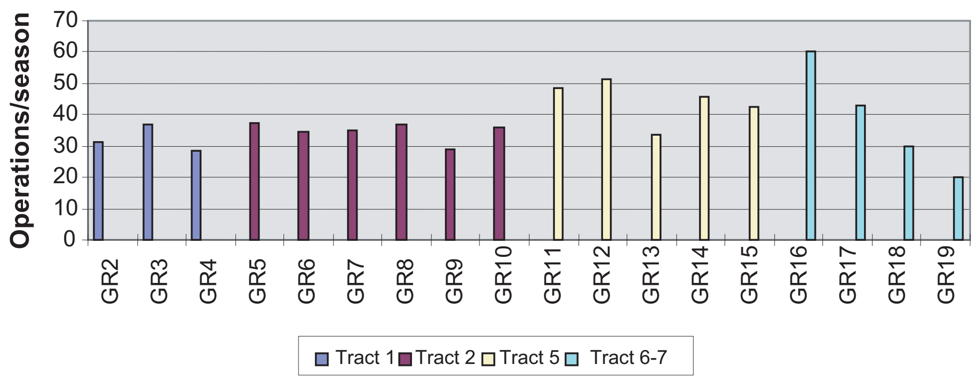


FIGURE 70
Number of operations per offtake, average for 6 seasons, RBMC, KOISP

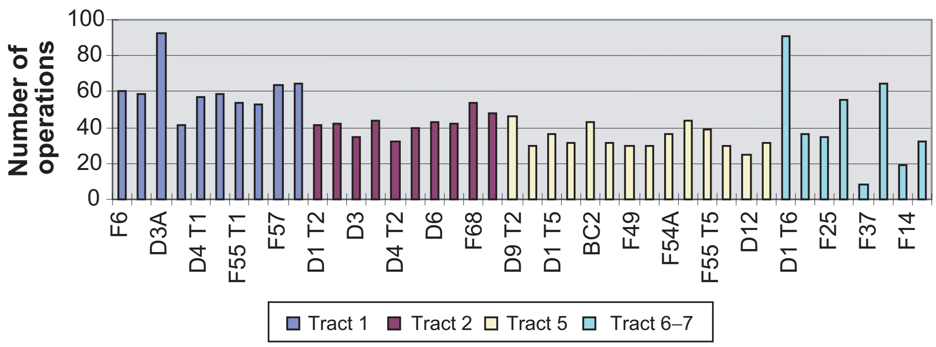


FIGURE 71
Seasonal standard deviation of upstream water level at offtakes, maximum, minimum and average for 6 seasons, RBMC, KOISP

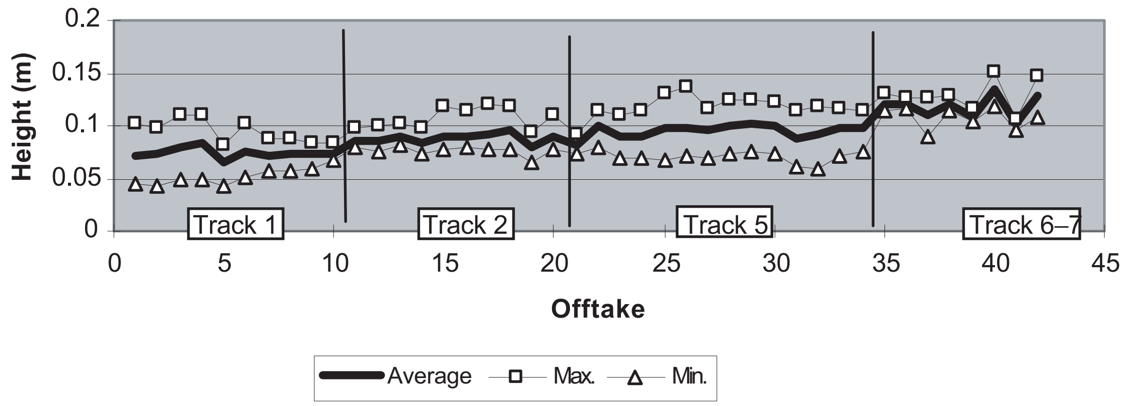
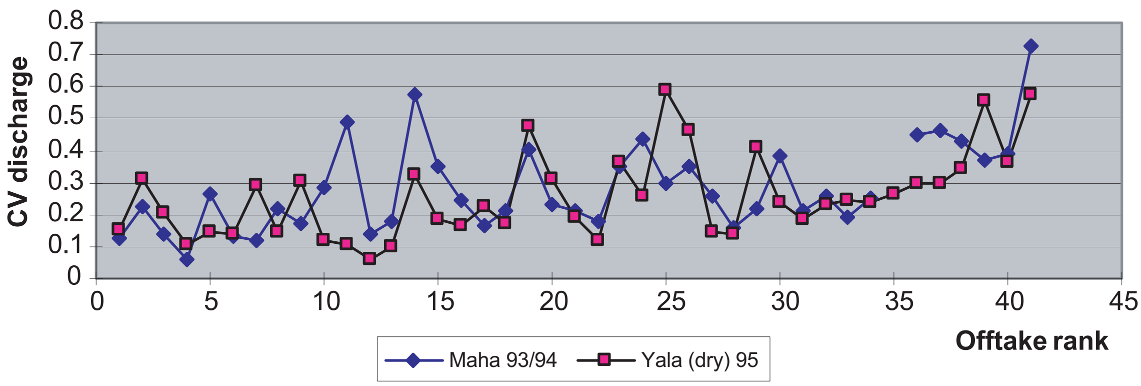


FIGURE 72
Discharge variation along the RBMC, KOISP, coefficient of variation



The analysis of the human allocation and of the interventions along the RBMC shows that the density of staff and interventions should be reversed in order to take into account the decreasing quality of the services downward. The need for re-allocating the resources is further reinforced when considerations on the demand are included (see Table 40). Upstream reaches are low-demanding whereas downstream reaches are high-demanding for operation mainly because they do not have recycling facilities, and the surplus/drainage is lost or even has a negative impact on some coastal lagoons.

TABLE 40
Classification of the demand level for operation in the KOISP, Sri Lanka

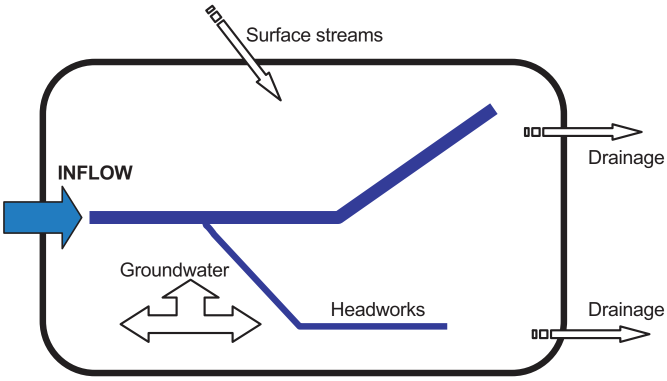
Subsystem	Tracts 1 & 2 of RBN	LBO	LBN	RBO	Tracts 5 & 6–7 of RBN
Vulnerability	Low	Low	Low	Very high	Very high
	Recycled	Return-flow RF	Recycled	Non-recycled	Non-recycled
Water service at secondary/tertiary canal headworks	Low	Low	Low	Very high	Very high
	Tol $Q = \pm 20\%$	Tol $Q = \pm 20\%$	Tol $Q = \pm 20\%$	Tol $Q = \pm 5\%$	Option PA (3) Tol $Q = \pm 5\%$
					High
					Option RO (4) Tol $Q = \pm 10\%$
Sensitivity of SC/TC headworks structures	High	Very high	Very high	Very high	High
	1.3	(not measured)	2.4	2.2	1.3
Precision	Low	High	High	Extremely high	High ±4 cm for Option PA (3)
	±15 cm	10 cm as an indication	±10 cm	±2.2 cm	Medium ±8 cm for Option RO (4)
				Unrealistic	
Perturbations	Low probability	Low probability	Medium probability	High probability & magnitude	High probability & magnitude
	Low magnitude	Low magnitude	(high-sensitive offtakes & single-bank canal sections)	(no water depth control; single-bank; improved operational procedures)	(improved operational procedures)
Operation mode and frequency	Low frequency	Medium frequency	High frequency checking of sensitive offtakes	Note: a specific control project will have to be designed for RBO, including some rehabilitation and/ or modernization works.	High frequency FBC(2) from drainage outlets
	FBC(2) from downstream tank	FBC(2) from drainage outlets	Low frequency FBC from downstream tanks		Precise control of level
					Improved operational procedures
Class of demand	D1	D2	D3	D4	D4
	Low	Medium	High	Very high	Very high

Chapter 13
Improving subunit operation

Once the management and operation partitioning have been defined, the next stage is to identify modernization improvement options for each subunit (Figure 73) based on: (i) water management; (ii) water control; and (iii) canal operation (service and cost-effectiveness).

A comprehensive approach needs to be carried out at each unit in order to ensure that the constraints and opportunities have been identified properly.

FIGURE 73
Sketch of a subunit within the CA



Improvement in canal operation is carried out for the purpose of cost-effectiveness in servicing users. The objective might be to better serve users according to their demand and at a reasonable cost.

In theory, modernization does not necessarily means improved water delivery service to users, but rather the best compromise between service and cost that has been agreed upon with the users. In practice, modernization often goes with improving the service, but this is more the result of remedying the previously poor management performance in delivering services.

ANOTHER ROUND OF MASSCOTE FOR EACH MANAGEMENT UNIT

Each subunit defined previously must be considered as a separate system for which, ideally, another round of MASSCOTE analysis should be made in order to focus on the specific constraints and opportunities of the subunit. The idea is to specify and produce for each subunit:

- A water management strategy: What is the rationale for water management in the CA of this particular subunit? What are the procedures to deal with all the scheduled and unscheduled water fluxes (rainfall, runoff, drainage, groundwater, canal water surplus, etc.)?
- A service strategy (allocation – scheduling – delivery): What are the specific rules of services to downstream users, considering the constraints of the resources and services provided by the upper level (main system)?
- An operation strategy: What are the main rules used to convert the WDP into operation plans and to deal with perturbations?
- Operational procedures for ensuring scheduled deliveries and addressing unscheduled interventions.

Ideally, at the subunit level, the MASSCOTE approach should lead to the proposing of several technical options to the users. The users should decide on the targets and techniques.

TYPES OF IMPROVEMENTS

Improvements in canal operation techniques can result from different types of interventions. The two major types are:

- Adjusting operation to the demand: Within a management CA (served area) and considering one canal operation technique, this consists in better adjusting inputs for operation to the demand for services and to the constraints for operation. Used alone, this should be considered as a "minor change".
- Improved canal operation techniques: This consists of significant changes in the techniques in order to respond better to the current demand for service.

OBJECTIVES OF IMPROVEMENTS

Operational improvements should aim at specific objectives such as:

- improve water delivery services to agriculture users;
- raise the performance of operation in delivering services from one level to the next lower level, with a particular focus on the indicators that ranked low in the RAP exercise;
- optimize the cost of operation;
- raise the cost-effectiveness of existing procedures.
- improve water management and water productivity (maximize the conjunctive use of water);
- integrate the multiple uses of water (IWRM).

The overall goal of implementing a MASSCOTE approach is to enhance current operational practices (making them more efficient or cost-effective) or to implement a new and improved strategy.

These improvements are to be sought through one or a combination of the following options:

- allocating existing resources and inputs in a more cost-effective and responsive way;
- optimizing the organization and the operational modes;
- changing the operational strategy;
- investing in improved techniques and infrastructure.

MODES OF IMPROVEMENT

Addressing the capacity issues

The first option for the technical interventions is to plan specific interventions to reduce or eliminate the capacity problems identified in Step 4. This can result in a long list of issues and possible interventions and may not lead to a consistent framework. It is necessary to prioritize the interventions. In addition, it is also necessary to check that these interventions are consistent with the overall operation strategy. However, this is also an opportunity to identify simple interventions that can yield significant results without major investments and without major changes in the procedures. As such, this kind of intervention can be "visible" and help restore trust between managers and users.

Table 41 provides an example of the issues and options identified for a main canal system in India.

Improving the current operation strategy

The objective of improving canal operation procedures is not to change the strategy but to improve the efficiency by setting new targets, refocusing operators on specific tasks, and optimizing the use of resources for operation, considering all aspects and functions of operation:

- scheduled, unscheduled, safety and information;
- transport, control, diversion, storage, etc.

TABLE 41
Capacity issues and proposed options along GLBC main canal

Capacity along the main canal	Issues	Options
Carrying capacity of the system	Localized reduced section.	Restore the sections.
Measurements at the border between management units.	Rating curve calibration not made.	Regular calibration.
Measurement skills	OK, but too frequent manual recording.	
Functioning of CRs	Not operated.	
Remote monitoring (including rainfall data in the command) along main canal	Density of rain gauges insufficient.	Add automatic rain gauges.
Escape capacity / recycling and measurements	Purposely leaking. No measurements.	
Buffer storage in, along and off the canal	No buffer storage.	Investigate online and offline storage to improve water supply downstream.
Sensitivity of the cross-regulators and offtakes	CR not operated (low sensitive). Offtakes low sensitive with few exception.	Special treatment of the sensitive offtakes: physical changes where possible or specific operational procedures.
Seepage accommodation	Quantification of seepage is inaccurate. Accommodation is quite OK throughout the CA except downstream along the Biligi branch.	
Special structures	One syphon with reduced capacity.	
Communication system (road and telecommunication)		
Regulating capacity of Dhupdal weir		

These types of changes can include modifications regarding the frequency of monitoring and adjustments of cross-regulators. For example, in the KOISP system in Sri Lanka, different practices (derived from those currently in use) have been investigated. The current practice is a fixed frequency of operation at twice per day (interval of 12 hours) at the cross-regulators with the aim of maintaining water at FSL. Most cross-regulators in canals in Sri Lanka are mixed-type, i.e. composed of a central undershot gate (or gates) and side weirs. The crest of the weir defines the FSL. Results of the simulations carried out showed that the current practice is not far from the optimal for the conditions of this system. A slight improvement can be expected if the frequency of operation is increased, reducing the interval to six hours during daytime hours.

Changing/optimizing the strategy and organization of operation

Changing the operational strategy can be a way to improve performance sometimes without major physical changes in the infrastructure. In this context the strategy can be simply defined as a structured way to set objectives for water services and practical ways to achieve them. For instance there are many systems in Asia which are set for dry conditions targeting water deliveries to users only but not geared for wet conditions. This strategy is obviously leading to loosing lots of water during the rainy season. Another strategy would then be to target both the water service to users while harvesting and storing as much as possible rainwater within the command area. This strategy change is illustrated below through some examples.

Example of a volume-controlled strategy for managing inflow changes

Operational strategies to integrate the management of water-level fluctuations along a canal with the objective of providing stable deliveries and being able to store the positive fluctuations have been investigated in Sri Lanka. Different strategies for operation, based on the salient physical features identified in the irrigation subsystems of Sri Lanka were tested for various techniques of volume control, targeting the optimal management of possible storage or the effective use of water (Renault, Godaliyadda and Makin, 1999).

These strategies were:

- Systematic oversupply some offtakes serving return-flow or re-use subsystems to be used as a “compensation storage” in case of temporary shortage downstream;
- undersupplying some offtakes to create on a rotation basis a capacity to absorb water surplus;
- wedge storage management by lowering the water level below full supply level to allow runoff to be stored along the canal in case of rainfall events.

The potential for improving the performance of water management using these techniques was first evaluated successfully in hydraulic simulations based on the right-bank main canal of the KOISP. All the options were presented and discussed with the users. Ultimately, they decided to select the on/off option.

IMPROVEMENT IN WATER MANAGEMENT

Using the RAP external indicators as a basis, the goal is to increase water productivity and water uses by: (i) maximizing water harvest; (ii) minimizing losses; (iii) managing perturbations (management of surplus); and/or (iv) by consolidating the control of flows throughout the service area. Although this final aspect is both critical and challenging, it should be a major goal to incorporating (or re-incorporate) into the management and operation all withdrawals that are either legal or illegal but tolerated, such as water lifting from the canals through pumps and illegal outlets along the main canal.

Canal pool storage (wedge) management can also in some circumstances compensate for small volume (time × amplitude) fluctuations.

Water measurement at key points plays an important role in improving canal operation, service delivery, and water management. A sound water measurement programme in the project helps in the following ways:

- improving transparency in water delivery service in terms of discharge and volume to an individual farmer or a group of farmers;
- ensuring equitable water allocation and distribution;
- accounting for water (water balance) in order to minimize adverse environmental impacts, such as waterlogging and salinity;
- negotiating service contracts;
- conserving water by restricting oversupply, which in turn can prevent deep percolation and runoff;
- providing the farmers with good information, on the basis of which they can take important farm decisions about cropping patterns, cropping intensities, irrigation scheduling and frequency, fertilizer use, labour, etc.;
- enabling proper billing for water usage (where water charges are based on the volume of water used, or where managers want to introduce volumetric pricing).

IMPROVEMENT IN WATER CONTROL

Based on the diagnosis provided by the internal indicators of the RAP, the goal would be to improve the control of water levels and discharges. This can be achieved by putting in place appropriate water control structures and setting proper operational procedures. Revised operational procedures should take into account improved modalities of operation (targets and modes) through reduced tolerance on H and reduced tolerance on discharge variation.

The first step is to set new achievable performance targets, and the second step is to define technical options for achieving these targets.

IMPROVEMENT FOR COST-EFFECTIVENESS

Operation accounts for a major share of the total cost of irrigation management. Some options for improving the cost-effectiveness of canal systems are:

- reduce the frequency of adjustment (where labour is expensive);
- reduce the sensitivity – upgrade sensitive structures (offtakes and regulators) (Plate 31);
- automate some structures (where labour is expensive);
- develop an effective information management system (for targeted interventions);
- replace gated regulators by automatic or fixed regulators.

Plate 31 shows an example where side weirs could beneficially replace gates of sensitive regulators – reducing the sensitivity and the needs for adjustment.

Plate 31
Building side weirs on gated regulators.

CONJUNCTIVE USE OF WATER

Conjunctive use of surface water and groundwater is important for:

- improving overall water resource management, maximizing the use of water for both quantity and quality;
- improving the service to users by buffering the fluctuations of one source by another one.

INTEGRATED WATER RESOURCE MANAGEMENT

Agriculture and ecosystems are often the two main users of water (be it rainwater or irrigation water). Often, within an irrigation project, water contributes significantly to uses other than evapotranspiration of field crops. For example, in the KOISP, water consumption from rice evapotranspiration accounts less than one-quarter of the mobilized water (Chapter 8). Provision of multiple services in the context of integrated water resource management could, for the operation of irrigation systems be considered both a constraint and an opportunity. It is a constraint because the services are diverse, sometimes conflicting and this made more complex the task of operating the infrastructure. At the same time it is an opportunity to share the cost among various users/beneficiaries and therefore alleviate the burden of farmers in sustaining the irrigation system.