# CHAPTER 8

# Use of a Simulation Model as Part of a Management Information System to Improve the Operations on an Irrigation Canal in Southern Sri Lanka[43]

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## INTRODUCTION

SINCE ITS INCEPTION, the International Irrigation Management Institute (IIMI) has been studying the management of main canal systems. Several studies showed that due to the complexity of their hydraulic behavior these systems are often difficult to control and function under unsteady flow conditions which can prevent the managers from achieving their water delivery targets. Seeking innovative ways of tackling these difficulties, IIMI embarked on a research project to investigate the potential for using new decision-support tools like flow simulation models.

With a view to improving the management of manually operated main canals through the routine use of such tools, IIMI concentrated its efforts on a pilot study in Southern Sri Lanka in the Kirindi Oya Scheme (Figure 8.1).

It soon became clear while designing the framework of this study that the introduction of a simulation tool in this operational environment had important implications in terms of communication needs within the system and availability of real time monitoring data.

A possible approach seemed to be to address the problem as a rationalization of the canal management through the development of a simple Management Information System integrating the simulation tool for specific processing.

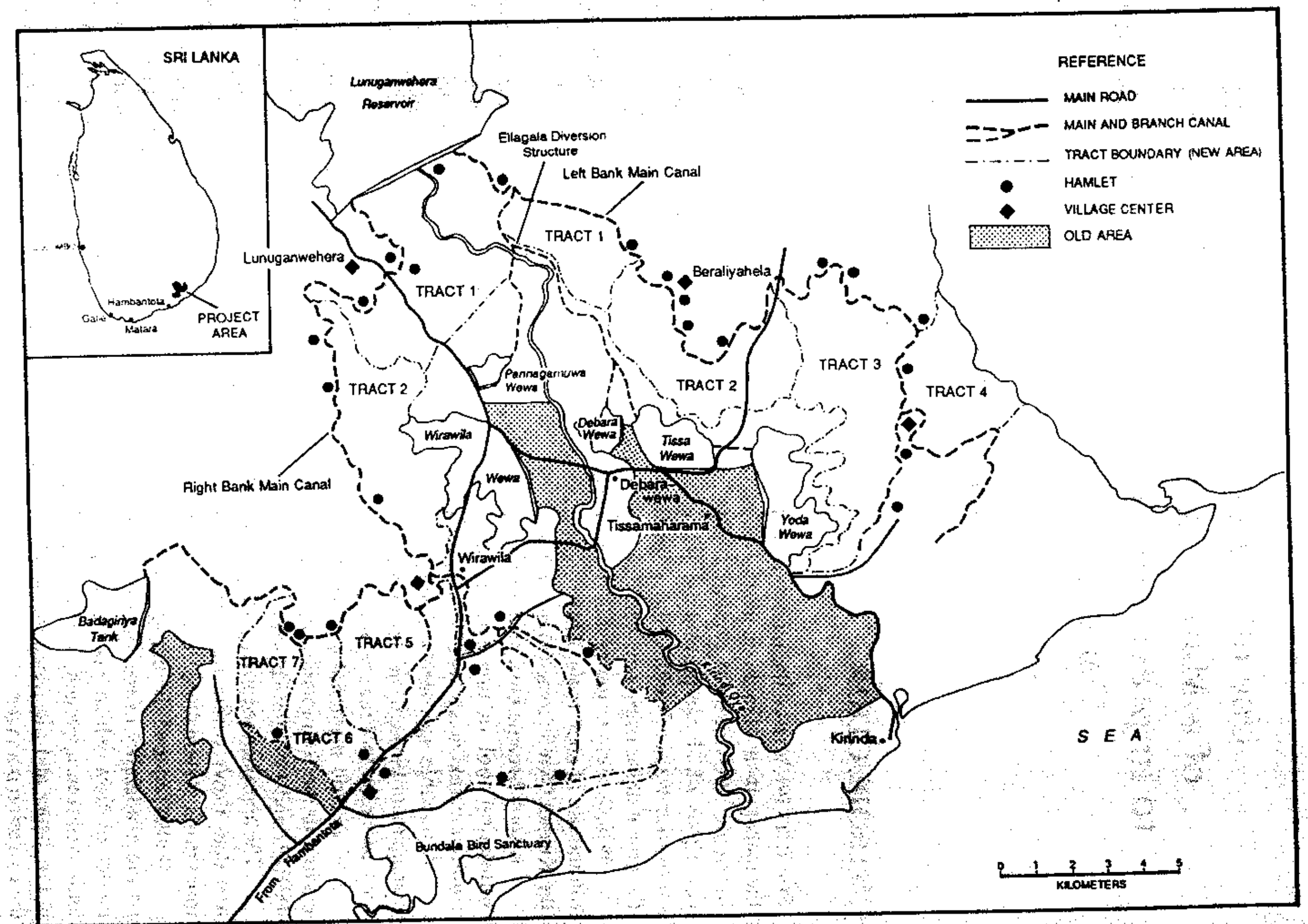
A generic methodology based on system analysis was adopted to diagnose the problems, leading to the formulation of an action-plan to be implemented over two seasons of irrigation: 1991/92 and 1992/93 wet seasons.

The approach required putting some effort into understanding and controlling the information and data flows within the system. This was addressed by the introduction of a rationalized monitoring system (June/July 1991) and the storage of data in a computerized database.

It also required the introduction of some innovations in the decision-making process, based on the availability of real time information and, progressively, the assistance of the simulation model of flow which permits a better understanding of hydraulic conditions. The methods underlying this approach, which will be field-tested during the next irrigation season are presented in this paper and illustrated through the discussion of a particular operational problem faced by the irrigation manager.

43 This paper has benefitted from the constructive comments of Mr. Sarath Wijesekera, Resident Engineer, Right Bank, Kirindi Oya Project, the Irrigation Department of Sri Lanka and Mr. Manju Hemakumara, Research Officer, IIMI.

Figure 8.1. Kirindi Oya Irrigation and Settlement Project.



# OPERATIONAL CHALLENGES

## The Physical System

The Kirindi Oya Right Bank Main Canal (RBMC) is a 30-km long earthen canal. Its design discharge is about 10 $m^3/s$ at the head; its bed width varies from 10 m to 3 m and its average slope is 35 cm per km. The water levels are maintained all along the canal by means of 18 gated cross structures called gated regulators (GR). Water is issued to the secondary network through 42 gated offtake structures (see Figure 8.2). The command area of the RBMC is divided into 4 subdivisions called tracts; its whole extent is in the range of 3,300 hectares (ha), each tract having an area varying from 500 to 1,000 hectares. The water storage at the head is ensured by the Lunugamvehera Reservoir with a capacity of 200 MCM.[44]

The reservoir supplies water to another main canal (left bank) bringing the total command area of the irrigation scheme to approximately 10,000 ha. A severe hydrological deficit in the area makes it difficult for the irrigation agency in charge of the scheme to supply water for ensuring a cropping intensity higher than 100 percent. Even if during the wet season or *maha* (October to March), most of the command area is under cultivation, it is rather difficult to ensure adequate deliveries during the dry season or *yala* (April to August). Thus the operational context of the scheme is one of water scarcity.

## The Managerial Context

The operational management of the scheme is in the hands of the Irrigation Department of Sri Lanka. As given in the organizational setup presented in Figure 8.3, the overall coordination of activities at the main-canal level is performed by a Resident Engineer. His main objective, as far as the water deliveries are concerned, is to ensure that the water stored in the reservoir is used in an efficient way. This implies a careful planning of water releases from the reservoir and a good supervision of the water delivery process all along the conveyance network (main canal, secondary canals, tertiary canals) up to farmers' fields. He is assisted in his tasks by an additional engineer and technical assistants who transmit instructions to and guide the field staff units. A field staff unit, in each tract, comprises one work supervisor and three to four gate keepers.

Until recently the management practices were characterized by a relatively high degree of decentralization, most operations (manual) at the structures being implemented locally according to local objectives (targeted water levels). Overall coordination and inter-tract communication were sought only in cases of severe perturbations along the canal.

This system is actually functioning reasonably well under stabilized hydraulic conditions (for example, phases of constant water release at the head sluice and fixed water delivery pattern at the offtakes in the case of rice cultivation) but does not allow a proper control of water deliveries by the manager during more difficult phases of management such as changes in head sluice discharge, starting of water issues in one stretch of the canal, rainfall events or intermittent irrigation.

44 Million cubic meters.

*Figure 8.2. Issue tree of the Kirindi Oya Right Bank Main Canal.*

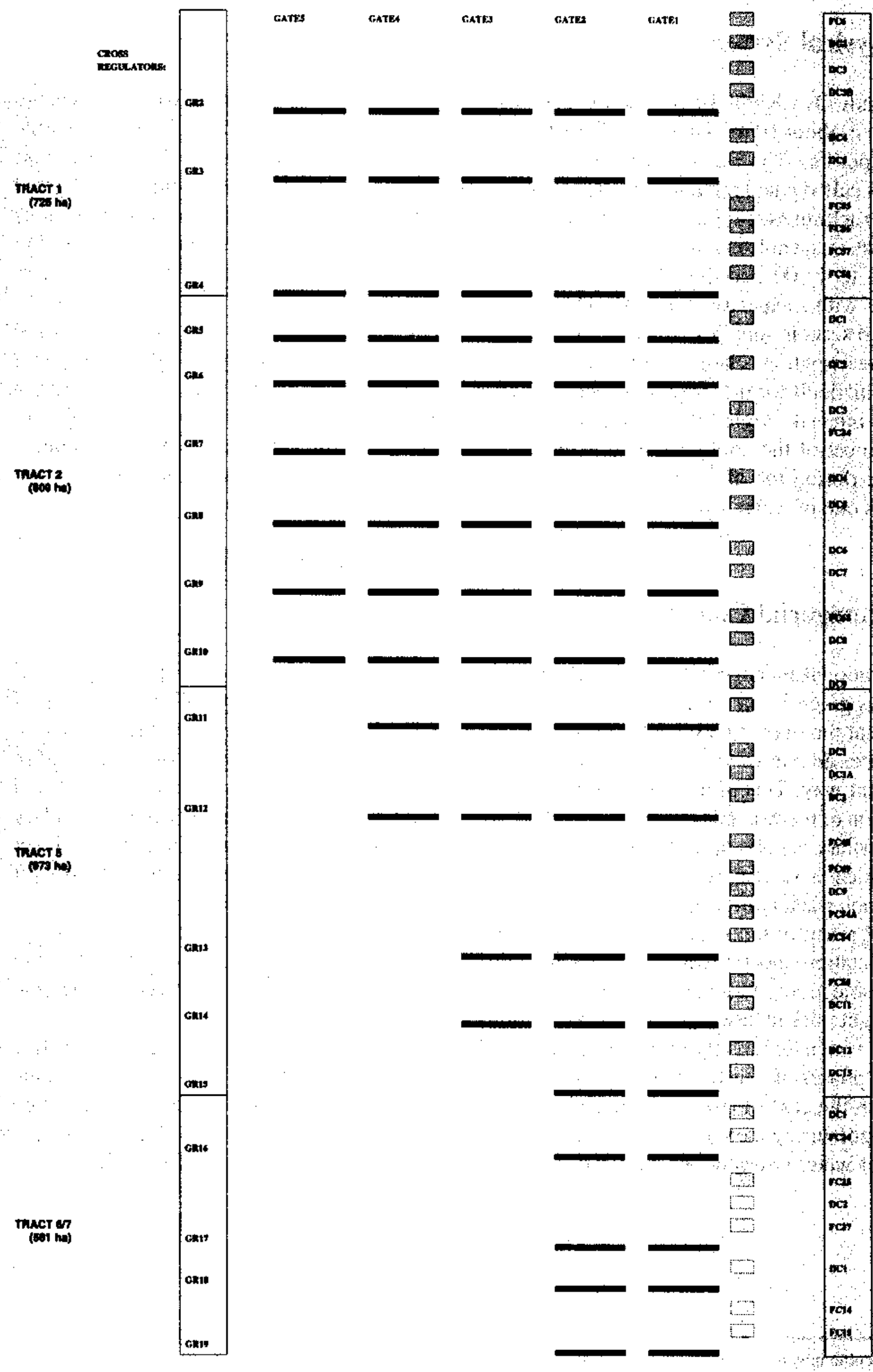
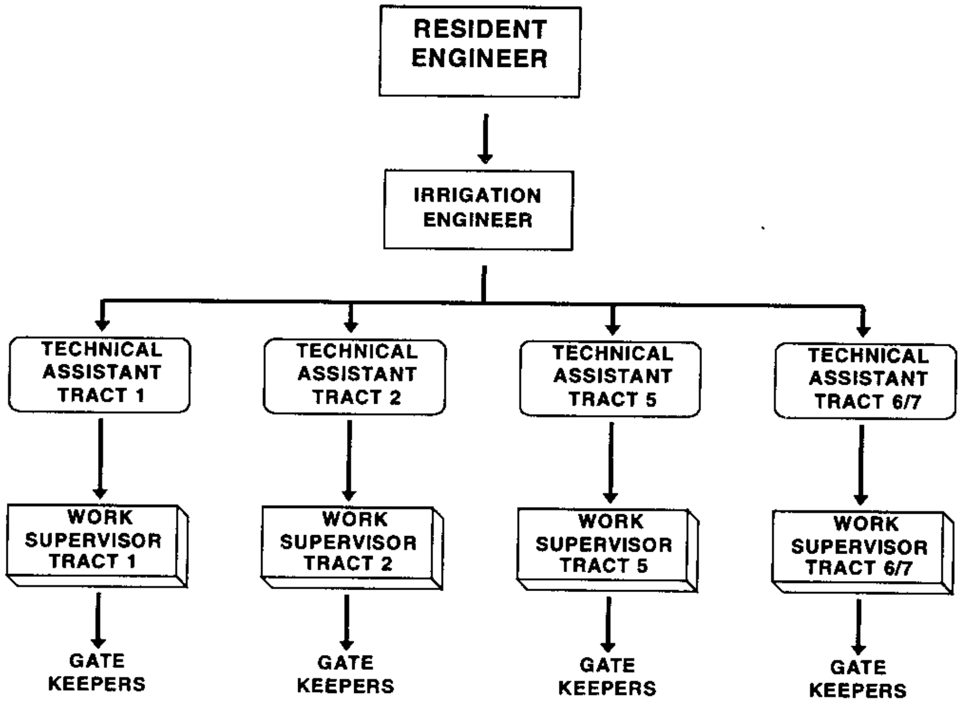


*Figure 8.3. Organizational setup, Resident Office, Kirindi Oya Right Bank Main Canal.*




## Operational Difficulties

This type of operational conditions (intermittent irrigation) has become a challenging concern in Kirindi Oya.

As a tentative response to the water-scarce conditions of the scheme, diversified cropping patterns have been promoted in order to progressively replace rice cultivations with less-water-demanding crops on the well-drained soils of the command area. The water delivery patterns required for these crops imply more sophisticated operational plans (see example in "Illustration of the Decision-Support Approach," page 217).

The generic research question, therefore, to be addressed by IIMI was: How can the planning capabilities of the irrigation canal manager be strengthened in order to ensure a good responsiveness to new and more complex operational scenarios?

The first important requirement identified was to get a better understanding of the hydraulic functioning of the canal. A proper tool to address this issue appeared to be a mathematical flow simulation model enabling the manager to test on a computer any hypothetical operational scenario and foresee the impact of his decisions. Nevertheless, the use of such a tool alone could not fully solve our problem; apart from a good understanding of the hydraulic behaviour of his canal, the manager had to be continuously aware of the present state of his system before making any decision (for example, in case of intermittent irrigation, the water levels in the respective reaches where irrigation is going to start). He also needed systematic guideline procedures to induce tentative operational plans before testing them with the flow simulation model.

All these implications were taken into account by IIMI and CEMAGREF[45] researchers who concentrated their efforts in designing a simple management information system including a simulation model of flow and other decision-support modules. An essential prerequisite for designing this system has been a systematic analysis of the decision-making process.

# UNDERSTANDING THE DECISION-MAKING PROCESS

## From Decision Making to Implementation

The different steps sequentially listed below have to be considered as a continuous loop. At any given time, decisions taken for managing a system are based on its present state as well as the experience gained from its past functioning; the monitoring of the implementation and impacts of these decisions becomes the source of experience and support for the next round of decision making. Our tentative list of activities thus includes:

- Working out a water delivery schedule compatible with the available resources (forecasting), and using earlier planning decisions in terms of water allocation and the field conditions (optimization process).

- Obtaining information about the present state of the canal, such as the water levels in the different reaches, and the gate settings at the structures (data collection and management).

- Applying a set of rules and using past experience for designing a tentative operational plan, which can include prediction of the effectiveness of this plan if a simulation tool is available (optimization and simulation processes). This set of rules must explicitly take into account human resource constraints such as those in terms of staff concerned with implementation.

- Transmitting the plan to the field staff (communication).

- Controlling the implementation of the plan and its effectiveness by observing the state of the canal and comparing it with the targets (data collection and management).

- Evaluating the whole process of decision making and implementation to find out weaknesses and potential for improvements (data management and analysis).

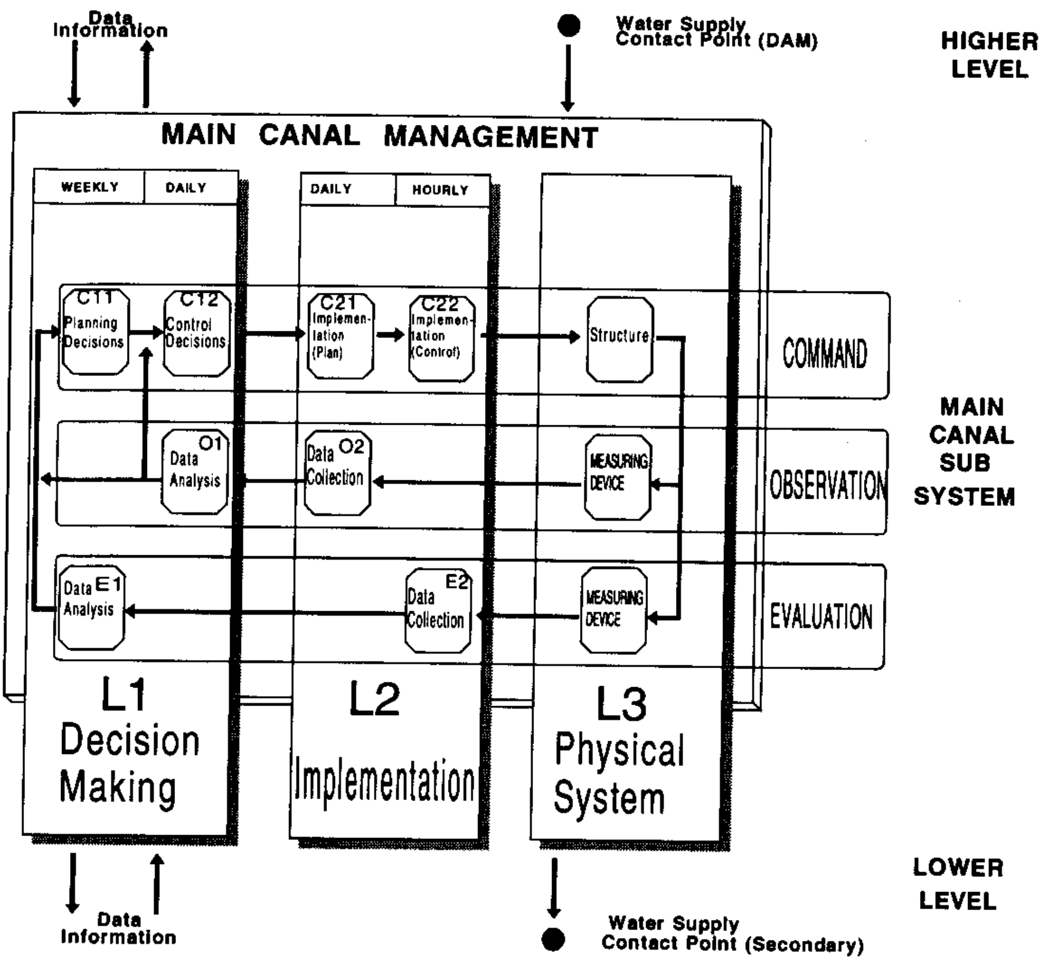
The effective fulfillment of these different steps in a sustainable and systematic way implies the availability of standard procedures and facilities to ensure easy access to field measurements, sharing of decisions with the field staff, control over the gate operations implemented and rapid use of past experiences.

45 Centre National du Machinisme Agricole du Génie Rural des Eaux et des Forêts.

## A Simple Framework for Canal Management

The management process explained above is summarized in Figure 8.4.

*Figure 8.4. Framework for main-canal management.*




As illustrated in the diagram, three main levels have been distinguished to represent the managerial context of the main canal:

1. People in charge of the whole decision-making process and the analysis of data ($L_1$).
2. People in charge of the local implementation process and collection of data ($L_2$).
3. The physical system encompassing the canal, its structure and irrigation water ($L_3$).

Three main functions, command, observation and evaluation, which split into various activities have also been identified.

## Function of Command

$C_{11}$: The decision-making process regarding operational strategies (planning including target setting).

$C_{12}$: The decision-making process regarding real time adjustment and refining of operational strategies (control).

$C_{21}$: Routine implementation of instructions.

$C_{22}$: Handling perturbations at the implementation stage (local analysis).

## Function of Observation

$O_2$: Collection of data (water levels, structure state).

$O_1$: Observation of the hydraulic state and behaviour of the system.

## Function of Evaluation

$E_2$: Collection of data (operations implemented, time and amplitude).

$E_1$: Analysis of the performance of the water delivery process and estimation of potential improvements.

Any attempt at improving the management process as a whole must take into consideration the complete sequence of activities involved, leading to subsequent intervention where it is needed.

At the field level, the most important issues are to establish and sustain a reliable data collection network and ensure timely communications between the field staff and the center of decision making.

At the decision-making level, the most important issues are to develop a simple and efficient data storage and retrieval system as well as quick and systematic procedures for analyzing these data and generating relevant information for making decisions. The availability of relatively cheap computer technologies offers new opportunities to deal with these issues efficiently. Database management software, spreadsheets or specific applications such as simulation models can be integrated into simple and modular management information systems.

This approach is being tested in Kirindi Oya where changes have been introduced at both field level and manager level as described in the following section.

# IMPROVING THE DECISION-MAKING PROCESS

## Data Collection and Communication

First, the existing system for data collection and communication in Kirindi Oya was improved by replacing the earlier practices (delays in feedback to the decision center, manual filing) with systematic and timely procedures.

Basic data on water levels and gate openings are now collected at all structures operated along the main canal, including gated regulators and offtakes. These data are read and recorded twice a day by the gate keepers who send them to the work supervisors.The data are recorded in a standard form which is handed over by the work supervisor to the resident engineer on the same day. Water level readings are converted into discharges and stored along with the raw data in a computerized database. The main problems faced at this stage are to ensure reasonably accurate data collection and reliable discharge computation which imply careful calibration of the structures. In terms of communication between the decision maker and the field staff, a key improvement has been the daily contacts between the resident engineer and the work supervisors.

## Computerized Decision-Support Tools

Second, different prototype computer modules have been developed and integrated to help in fulfilling the tasks described as $L_1$ ($C_1$, $O_1$, $E_1$). These modules comprise the database (Dbase III files, and entering and request procedures), the simulation model of flow, RBMC developed by CEMAGREF, and spreadsheets (Lotus 1-2-3).

One of the main constraints in developing this tool has been the need to interface the various modules to ease the transfer of data and results between them. Nevertheless, the facilities provided by the use of standard software enable any programmer to arrive at a reasonable degree of integration. A brief description of the tool developed is given in Annex 1. At this prototype stage, the intention was not to program a comprehensive commercial package but rather to give an example of a modular approach likely to be reproduced by other developers.

With the availability of the decision-support tools as well as improved communication between the decision maker and the field, the decision-making process as detailed earlier can be performed in a more systematic and efficient way. Next, in this paper, this process will be put into the perspective of a typical management problem faced by the irrigation manager in Kirindi Oya during the season yala 1991.

# ILLUSTRATION OF THE DECISION-SUPPORT APPROACH

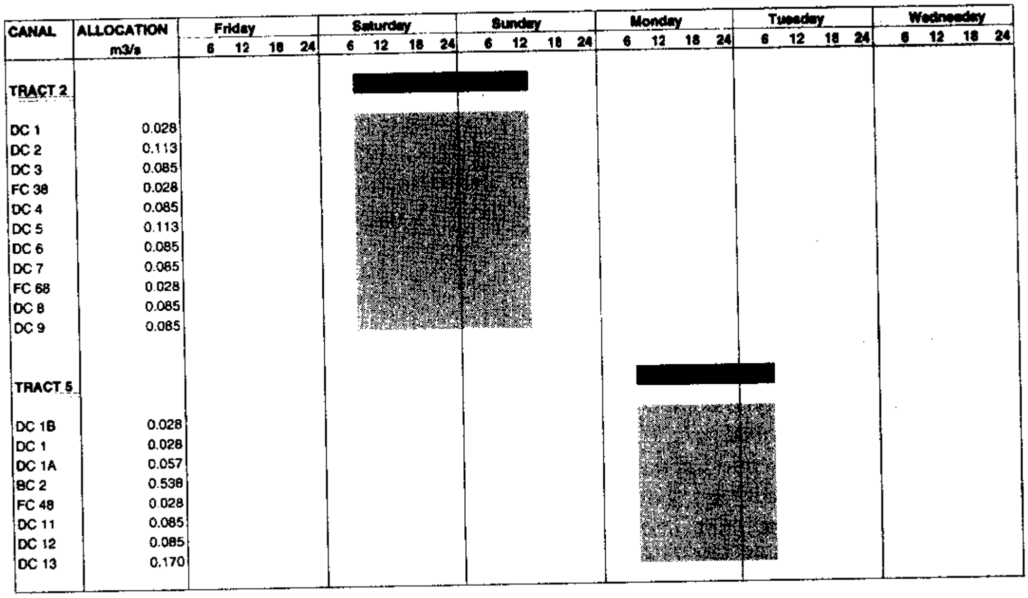
As an example of operational difficulties arising due to the crop diversification, the water delivery pattern implemented during the yala 1991 season is considered. Tracts 2 and 5 were under cultivation (pulses, chilies, onions) and the agreed schedule of water delivery was as in Figure 8.5.

This water issue pattern was new to the irrigation staff whose experiences referred mostly to rice cultivation. The questions raised were mainly:

- What would be an optimal pattern of water issues at the head sluice?
- How to operate the gated regulators in a coordinated way?

The operational concerns underlying the questions were the need to fill certain stretches of the canal prior to the start of water deliveries in case of a drop in water level between these issues, and the relative difficulty of ensuring a smooth transition of water deliveries from Tract 2 to Tract 5.

*Figure 8.5. Water delivery schedule during 1991 dry (yala) season.*




The decision-making process of the manager (activity $C_{11}$) before commencing the water issues of Tract 2 is described next. While the main steps of his analysis will be given here, the corresponding numerical results will be presented in the annexes. These results have been obtained *a posteriori* and have not been field-tested because most of the tools used were not yet available during yala 1991.

The manager first assesses the present state of the canal, paying special attention to the water levels in the reaches of Tract 2 (filling requirement); this is easily obtained by using the database (Activity $O_1$: observe water). He will then follow the process described as command operations in Annex 1, to work out the optimal main sluice issues pattern as well as an adequate sequence of gate openings to achieve his targets in terms of water levels at the gated regulators and discharges at the offtakes.

This process is detailed below:

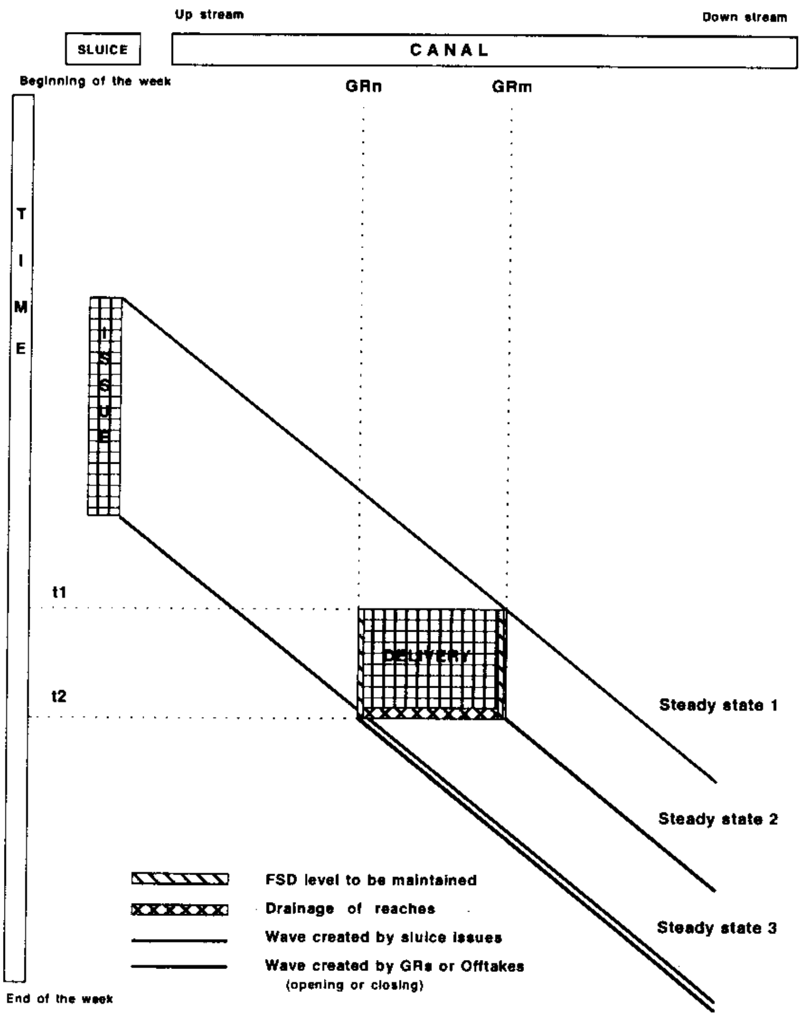
As mentioned earlier, before testing any operational plan with the simulation model, the manager has to combine his own experience with the use of simple decision-making modules (hydraulics optimization) to design a reasonably appropriate tentative plan and to avoid time-consuming, trial-and-error simulations.

The first module, based on the initial water levels in the canal and topographical data, gives information concerning the approximate time needed for filling the reaches in the parts of the canal where irrigation is going to start. Rough information about adequate gate settings at the gated regulators to fill the reaches in a coordinated manner is also provided (Annex 2).

The second module, based on the consideration of the water delivery schedule and the use of linear transfer functions roughly modeling the water propagation along the canal (diffusion and lag times) provides a first tentative plan for the water released at the main sluice (Annex 3).

Based on the water issue pattern at the main sluice and the water delivery schedule, the propagation of water along the canal is studied in order to provide some guidance concerning the time and amplitude of gate settings required to achieve the targets. This analysis is mainly done manually by studying a simple chart presenting a summary of the expected water delivery pattern. Some steady flow simulations are also used to generate indications about the optimal amplitude of gate openings required during the different stabilized phases of the water issues (Figure 8.6).

*Figure 8.6.*



Having following these three steps, a tentative operational plan for all gate settings along the canal (see Annex 4) is then available to be tested and evaluated by means of an unsteady flow simulation. Water levels and discharges at any point of interest along the canal are computed by the model and the results are evaluated in terms of achieved water deliveries at the offtakes and water level fluctuations in the main canal (Annex 5).

If considered as satisfactory, the plan is stored in the database and proposed for implementation; if not, the decision maker can revise it according to the weaknesses detected by looking at the simulation results and retesting it as many times as needed.

Most of the printed supports obtained by applying this process to our operational scenario have been presented in the annexes. The final plan described in these annexes would ensure satisfactory water deliveries.

The implementation of the plan (activity $C_{21}$) then needs to be carefully monitored (activities $O_2$, $E_2$) to allow proper control in case of perturbations (activity $C_{12}$) and, of course, a complete *a posteriori* evaluation (activity $E_1$).

## CONCLUSION

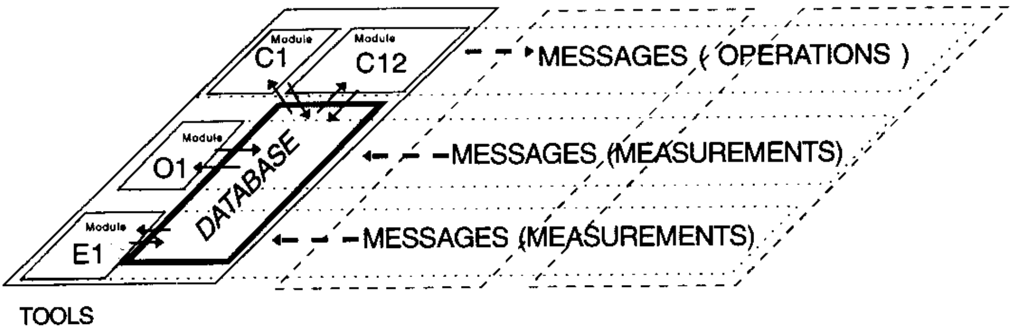
Several lessons have been already learned from the research conducted in Kirindi Oya; others are expected after full implementation of the decision-support package during the next irrigation season. The most important of these is probably the evidence that any attempt to improve the decision-making process of an irrigation manager has to be done with full awareness of the technical and managerial constraints relating to the data collection and communication systems in use. A sustainable introduction of decision-support tools implies upgrading the existing setup as a prerequisite condition.

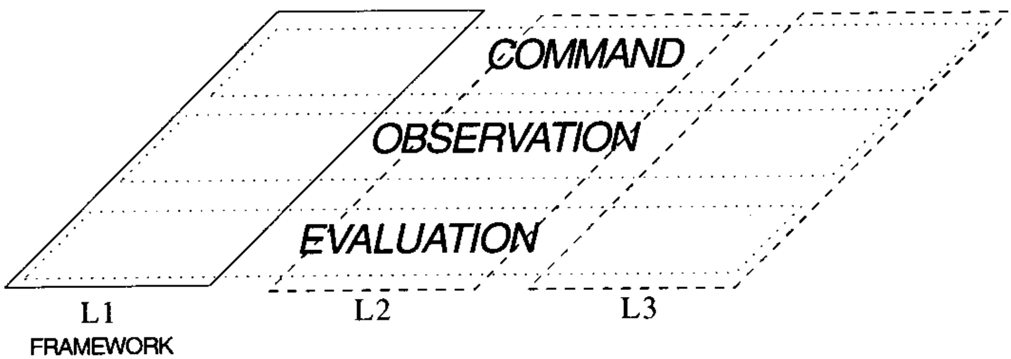
A second aspect relates to the nature of the proposed tools. It is probably worthwhile to insist again on the absolute necessity to make these tools modular, easily interfaced with simple database management software and leaving some room for customization by the manager. Within this context, computerized information, simulation and optimization techniques have certainly a key role to play in future improvements likely to occur in the management of main canal systems.

# Annex 1

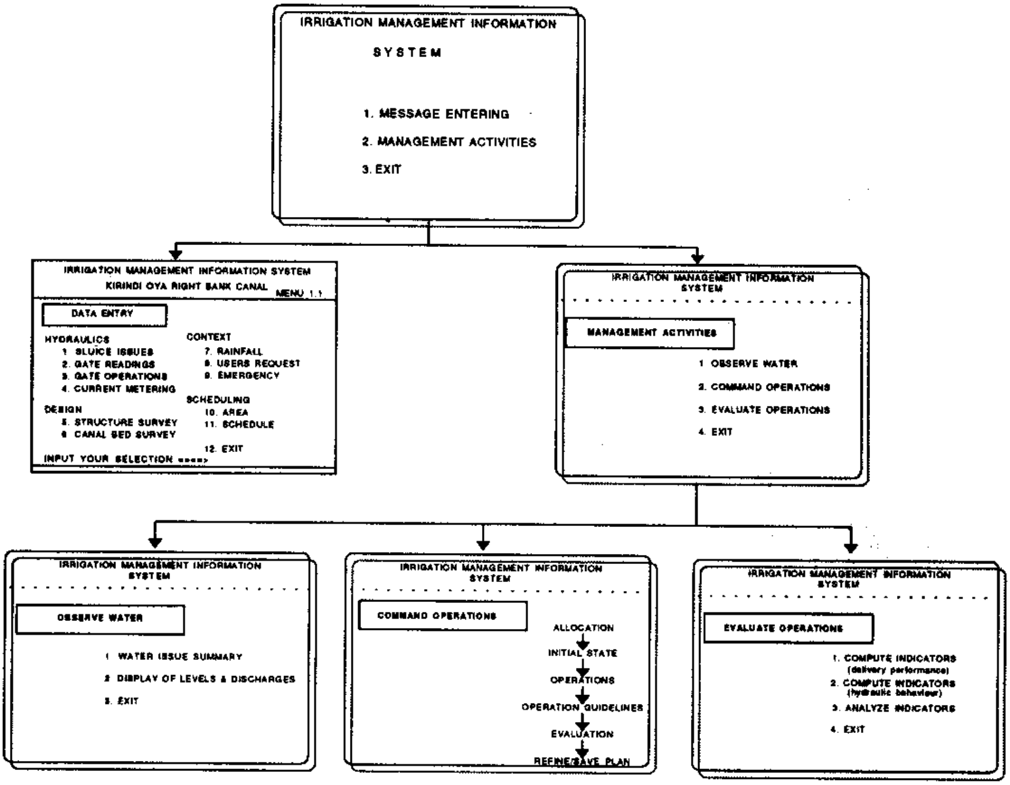
## Simplified Layout of the Management Information System

Various modules can be developed for assisting the decision-making process, derived from the framework representing the management process:



The first main menus of the prototype tool are as follows:



# Annex 2

## Module Filling Phase

A filling phase is a transitory period of canal functioning during which one or several reaches (stretches between two gated regulators) have to be filled in order to increase the water levels. This occurs, typically, when the manager has to start the deliveries along a branch of the canal which has been kept dry or at low water levels previously. The inputs and outputs of the spreadsheet module used for managing such phases is given below. The main information needed is the set of initial water levels measured upstream of the gated regulators (recorded with reference to the targeted water level or full supply depth [FSD]). As a result, an indication of the time needed for filling Tract 2 (12 hours) and approximations of suitable gate openings at the gated regulators are obtained:

**POND STATUS:**

| | GR2 | GR3 | GR4 | GR5 | GR6 | GR7 | GR8 | GR9 | GR10 | GR11 | GR12 | GR13 | GR14 | GR15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| input: UPSTREAM WATER LEVEL / FSD: (m) | 0.00 | 0.00 | 0.00 | -0.93 | -0.96 | -1.26 | -1.23 | -1.08 | -1.00 | -1.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| VOLUME / VOLUME FSD: (m3) | 0 | 0 | 0 | 12793 | 16342 | 17104 | 21621 | 16150 | 10658 | 15951 | 0 | 0 | 0 | 0 |

**FILLING LAGTIMES:** [ =Tfill ]

| | | | |
|---|---|---|---|
| input: INFLOW MSLUICE DISCHARGE (m3/s): 2.80 | input: INFLOW DIVERTED UPSTREAM : | 0.00 | input: INFLOW NEEDED DOWNSTREAM : 0.00 |

| | GR2 | GR3 | GR4 | GR5 | GR6 | GR7 | GR8 | GR9 | GR10 | GR11 | GR12 | GR13 | GR14 | GR15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME BY REACH: (h) from main sluice: | 0.0 | 0.0 | 0.0 | 1.5 | 1.5 | 2.0 | 2.5 | 1.5 | 1.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| reach only: | 0.0 | 0.0 | 0.0 | 1.5 | 1.5 | 1.5 | 2.0 | 1.5 | 1.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| FSD NEEDED AT: (h) | | | | 6 | 6 | 6 | 6 | 6 | 6 | 6 | | | | |

| | TRACT 1 | TRACT 2 | TRACT 5 | TRACT 6,7 |
|---|---|---|---|---|
| TIME BY TRACTS: from main sluice: (without lagtime) | 0.0 | 12.0 | 0.0 | 0.0 |
| cumulative: (h) | 0.0 | 12.0 | 12.0 | 12.0 |

**GATE SETTINGS DURING FILLING PHASE:** [ =Wcoord ]

| TRACT BY TRACT | GR2 | GR3 | GR4 | GR5 | GR6 | GR7 | GR8 | GR9 | GR10 | GR11 | GR12 | GR13 | GR14 | GR15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| estimated opening: | | | T1 | 0.84 | 0.72 | 0.54 | 0.35 | 0.21 | 0.12 | 0.00 | | | | T5 |
| during: | 0.0 H for TRACT1 | | | | | | | | | 1.00 | | | | |
| | 12.0 H for TRACT2 | | | | | | | | | | | | | |
| | 0.0 H for TRACT5 | | | | | | | | | | | | | |

| WHOLE CANAL | GR2 | GR3 | GR4 | GR5 | GR6 | GR7 | GR8 | GR9 | GR10 | GR11 | GR12 | GR13 | GR14 | GR15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| estimated opening: | | | | 0.84 | 0.72 | 0.54 | 0.35 | 0.21 | 0.12 | 0.00 | | | | |
| during: | 12.0 H | | | | | | | | | | | | | |

# Annex 3

## Module, Main Sluice Issue

The main hydraulic factors to be considered to release water at the main sluice are:

- The time of propagation of water (lagtimes).
- The phenomena of diffusion (attenuation of discharges peaks).
- The phenomena of storage/drainage in the various reaches due to gated regulator operations.

Given the targeted discharges at the offtakes and the main hydraulic conditions of the scenario (low or normal water depth and low, average or high base discharge), a rough estimation of the main sluice issue pattern is computed by considering the inverses of simple linear transfer functions calibrated *a priori* for each stretch of the canal according to the type of hydraulic scenario studied. The interface of the spreadsheet used for this purpose as well as the proposed pattern corresponding to our operational situation are given below:

### INTERFACE

- THIS SHEET ALLOWS YOU TO COMPUTE AN APPROXIMATION OF THE MAIN SLUICE ISSUES SATISFAYING YOUR OBJECTIVES:

* ROUGH LINEAR INVERSION
* INCLUDING SEEPAGE LOSSES
* INCLUDING FILLING PHASES

(AS DEFINED IN T1C2VOLM.WK1)

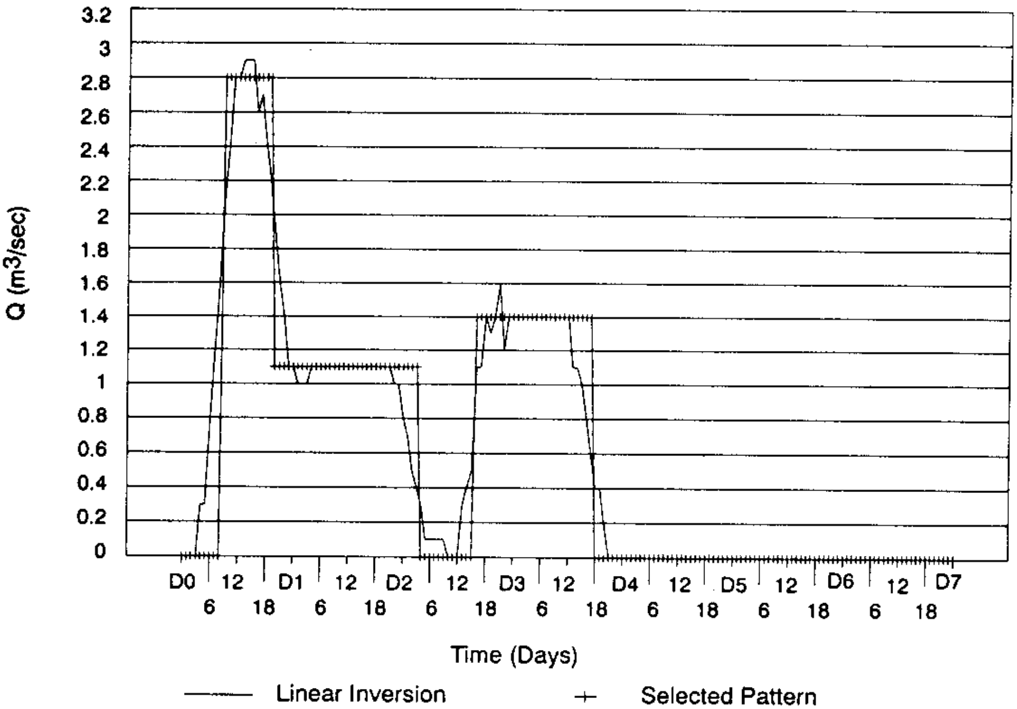
RUN THE MACRO \O AND COME BACK TO THE BASIC DATA BLOCK BELOW IN ORDER TO FINALIZE YOUR MAIN SLUICE ISSUES.

MAIN SLUICE ENVISAGED OPERATIONS AND EVALUATION:

VOLUME NEEDED: 364217 M3
VOLUME PROPOSED: 368640 M3

| NBOP: | ! | DAY: | HOUR: | DIS.: (M3/S) | ! |
|---|---|---|---|---|---|
| 1 | ! | 0 | 0 | 0.00 | ! |
| 2 | ! | 0 | 9 | 2.80 | ! |
| 3 | ! | 0 | 20 | 1.10 | ! |
| 4 | ! | 2 | 4 | 0.00 | ! |
| 5 | ! | 2 | 16 | 1.40 | ! |
| 6 | ! | 3 | 18 | 0.00 | ! |
| 7 | ! | 6 | 0 | 0.00 | ! |

MAIN SLUICE ISSUE

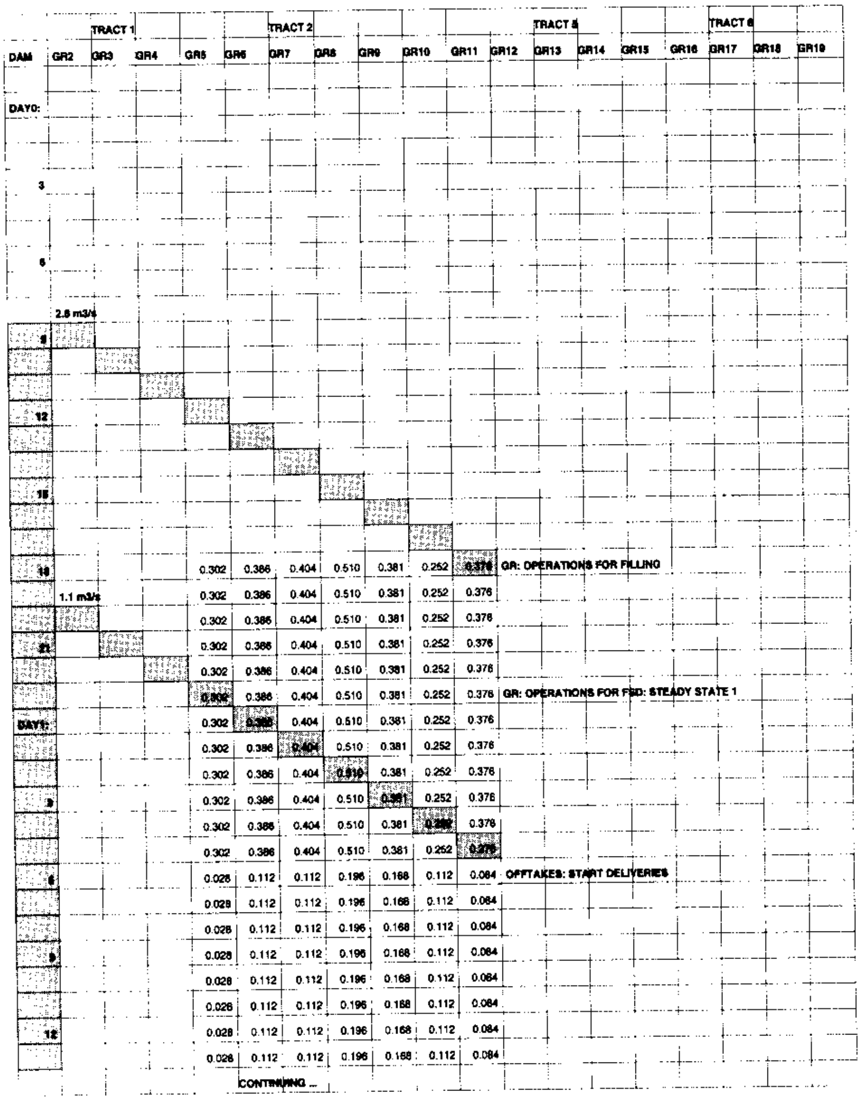



On the graph, the final pattern of water release chosen is made of 2 phases of continuous issues plus an initial increment at a higher discharge in order to fill Tract 2. Tract 5 will be filled by draining Tract 2 after its delivery period (the water levels are kept low in the portion of canal commanding Tract 2 once the delivery period is over).

# Annex 4

## Proposed Operational Plan

After the various aspects relating to the filling phases and the main sluice releases are studied, the objective of the manager is to find out an appropriate sequence of gate settings at the gated regulators and the offtakes. A partial printout of the chart used for this purpose is presented below with the first operations resulting from the manager's analysis. The numbers indicated below each gated regulator (GR) represent the total demand in the reach upstream of this GR in $m^3/s$ (demand for filling or deliveries at the offtakes).



A set of rules allows the manager to work out his first strategy regarding the timing of gate operations. Using the wave chart, the following method can be applied:

a. Locate the periods during which the water level has to be controlled (FSD) at the gated regulators.

b. Locate the periods during which the gated regulators are fully open (in case of drainage of certain reaches after deliveries).

c. Locate the wave propagation:

- created by main sluice issues
- created by the opening of certain gated regulators
- created by the closing of offtakes (end of deliveries)

The speed of the waves (slope of lines in the chart) is roughly provided by the analysis mentioned in Annex 3 (in this scenario, approximately 1 hour per reach).

The first set of rules then becomes:

1. Adjust gated regulators before establishment of each FSD period.
2. Adjust gated regulators if a wave crosses a FSD period.
3. Adjust gated regulators in case of a severe wave liable to cause overtopping.

An indicative amplitude of the gate adjustment needed is then searched. This can be achieved for the 3 cases mentioned above using the steady state unit of the simulation model which can provide an optimal set of gate settings given:

- The delivery pattern at offtakes.
- The discharge in the main canal (estimate in case of drainage waves).
- The targeted water levels at the gated regulators.

The tentative operational plan is then finalized (see standard printouts for Tracts 2 and 5 below). The operations are given in the format, day/hour/amplitude, and can then be tested with the simulation model of flow.

The RBMC software allows neither the hydraulic computations under dry bed conditions nor tolerate supercritical flow conditions. It is thus difficult to simulate an operational scenario which implies very low main sluice discharges. In this example, the issues at the main sluice have been kept to a minimum rate of 0.5 $m^3/s$ to compensate for the seepage losses along the canal for the two intermediate phases even if a complete closure would have been appropriate.

**RBMC WATER DELIVERIES - PROPOSED OPERATIONAL PLAN - TRACT 2** **WEEK: YALA 91**

(DAY/TIME/amplitude)

| | | OP 0 | OP 1 | OP 2 | OP 3 | OP 4 | OP 5 | OP 6 | OP 7 |
|---|---|---|---|---|---|---|---|---|---|
| M.Sluice | | .500 | 00!0900!2.8 | 00!2000!1.1 | 02!0400!0.5 | 02!1600!1.4 | 03!1800!0.5 | 04!1200!0.0 | |
| D 1 | | .000 | 01 0600 0.05 | 02 1200 00 | | | | | |
| GR 5 | G1 | 1.50 | 00 1800 0.84 | 00 2300 0.38 | 02 1200 1.5 | | | | |
| | G2 | 1.50 | 00 1800 0.00 | 02 1200 1.5 | | | | | |
| | G3 | .000 | | | | | | | |
| | G4 | .000 | | | | | | | |
| | G5 | .000 | | | | | | | |
| D 2 | | .000 | 01 0600 0.08 | 02 1200 00 | | | | | |
| GR 6 | G1 | 1.50 | 00 1800 0.72 | 00 2300 0.30 | 02 1200 1.5 | | | | |
| | G2 | 1.50 | 00 1800 0.00 | 02 1200 1.5 | | | | | |
| | G3 | .000 | | | | | | | |
| | G4 | .000 | | | | | | | |
| | G5 | .000 | | | | | | | |
| D 3 | | .000 | 01 0600 0.10 | 02 1200 00 | | | | | |
| F 34 | | .000 | 01 0600 0.06 | 02 1200 00 | | | | | |
| GR 7 | G1 | 1.50 | 00 1800 0.54 | 00 2300 0.11 | 02 1200 1.5 | | | | |
| | G2 | 1.50 | 00 1800 0.00 | 02 1200 1.5 | | | | | |
| | G3 | .000 | | | | | | | |
| | G4 | .000 | | | | | | | |
| | G5 | .000 | | | | | | | |
| D 4 | | .000 | 01 0600 0.12 | 02 1200 00 | | | | | |
| D 5 | | .000 | 01 0600 0.14 | 02 1200 00 | | | | | |
| GR 8 | G1 | 1.50 | 00 1800 0.35 | 00 2300 0.02 | 02 1200 1.5 | | | | |
| | G2 | 1.50 | 00 1800 0.00 | 02 1200 1.5 | | | | | |
| | G3 | .000 | | | | | | | |
| | G4 | .000 | | | | | | | |
| | G5 | .000 | | | | | | | |
| D 6 | | .000 | 01 0600 0.07 | 02 1200 00 | | | | | |
| D 7 | | .000 | 01 0600 0.11 | 02 1200 00 | | | | | |
| GR 9 | G1 | 1.50 | 00 1800 0.21 | 00 2300 0.02 | 02 1200 1.5 | | | | |
| | G2 | 1.50 | 00 1800 0.00 | 02 1200 1.5 | | | | | |
| | G3 | .000 | | | | | | | |
| | G4 | .000 | | | | | | | |
| | G5 | .000 | | | | | | | |
| F 68 | | .000 | 01 0600 0.16 | 02 1200 00 | | | | | |
| D 8 | | .000 | 01 0600 0.37 | 02 1200 00 | | | | | |
| GR 10 | G1 | 1.50 | 00 1800 0.12 | 00 2300 0.04 | 02 1200 1.5 | | | | |
| | G2 | 1.50 | 00 1800 0.00 | 02 1200 1.5 | | | | | |
| | G3 | .000 | | | | | | | |
| | G4 | .000 | | | | | | | |
| | G5 | .000 | | | | | | | |
| D 9 | | .000 | 01 0600 0.09 | 02 1200 00 | | | | | |

**RBMC WATER DELIVERIES - PROPOSED OPERATIONAL PLAN - TRACT 5** **WEEK:** **YALA 91**

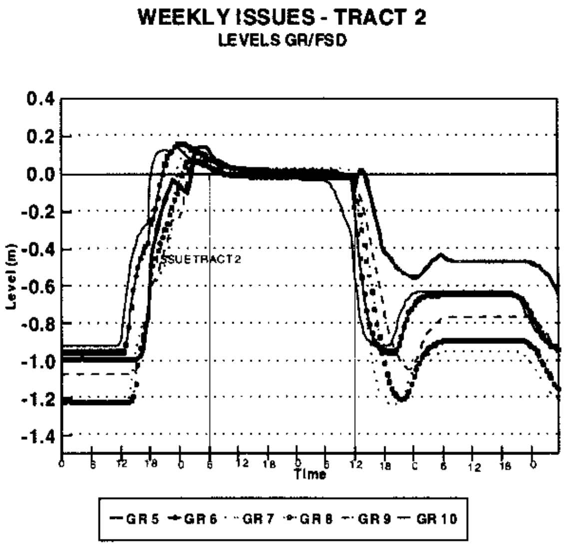
(DAY/TIME/amplitude)

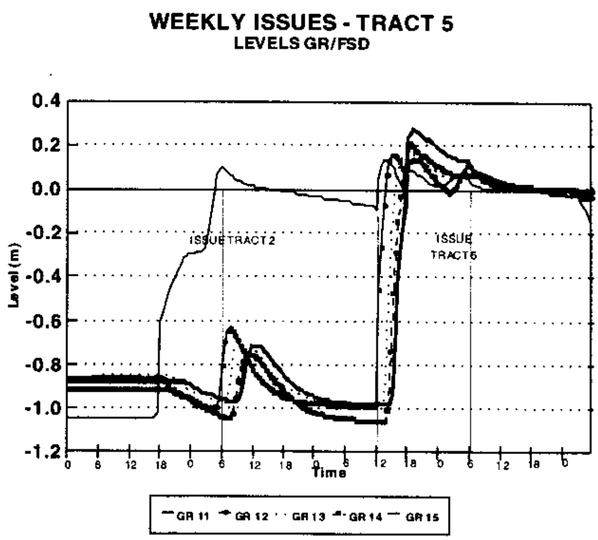
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | OP 0 | | OP 2 | | OP 4 | | OP 6 |
| | .500 | 00I0900I2.8 | 00I2000I1.1 | 02I0400I0.5 | 02I1600I1.4 | 03I1800I0.5 | 04I1200I0.0 |
| D 1B | .000 | 03 0600 0.05 | 04 0600 00 | | | | |
| | 1.50 | 00 1800 0.04 | 02 1200 1.00 | 02 1800 0.10 | 03 0600 0.36 | 04 0600 1.5 | |
| | 1.50 | 00 1800 0.00 | 02 1200 000 | 04 0600 1.5 | | | |
| | .000 | | | | | | |
| | .000 | | | | | | |
| D 1 | .000 | 03 0600 0.06 | 04 0600 00 | | | | |
| D 1A | .000 | 03 0600 0.18 | 04 0600 00 | | | | |
| BC 2 | .000 | 03 0600 0.38 | 04 0600 00 | | | | |
| | 1.50 | 02 1200 1.00 | 02 1800 0.13 | 04 0600 1.5 | | | |
| | 1.50 | 02 1200 0.00 | 04 0600 1.5 | | | | |
| | .000 | | | | | | |
| | .000 | | | | | | |
| F 48 | .000 | 03 0600 0.06 | 04 0600 00 | | | | |
| F 49 | .000 | | | | | | |
| D 9 | .000 | | | | | | |
| F 54A | .000 | | | | | | |
| F 54 | .000 | | | | | | |
| | 1.50 | 02 1200 1.00 | 02 1800 0.21 | 04 0600 1.5 | | | |
| | 1.50 | 02 1200 0.00 | 04 0600 1.5 | | | | |
| | .000 | | | | | | |
| F 55 | .000 | | | | | | |
| D 11 | .000 | 03 0600 0.08 | 04 0600 00 | | | | |
| | 1.50 | 02 1200 1.00 | 02 1800 0.12 | 04 0600 1.5 | | | |
| | 1.50 | 02 1200 0.00 | 04 0600 1.5 | | | | |
| | .000 | | | | | | |
| D 12 | .000 | 03 0600 0.15 | 04 0600 00 | | | | |
| D 13 | .000 | 03 0600 0.18 | 04 0600 00 | | | | |
| | 1.50 | 02 1200 1.00 | 02 1800 0.05 | 04 0600 1.5 | | | |
| | 1.50 | 02 1200 0.00 | 04 0600 1.5 | | | | |

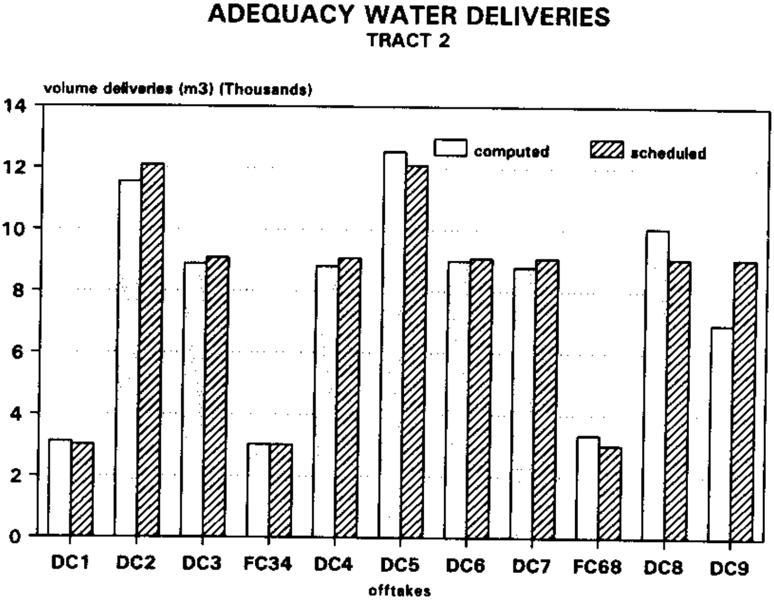
# Annex 5

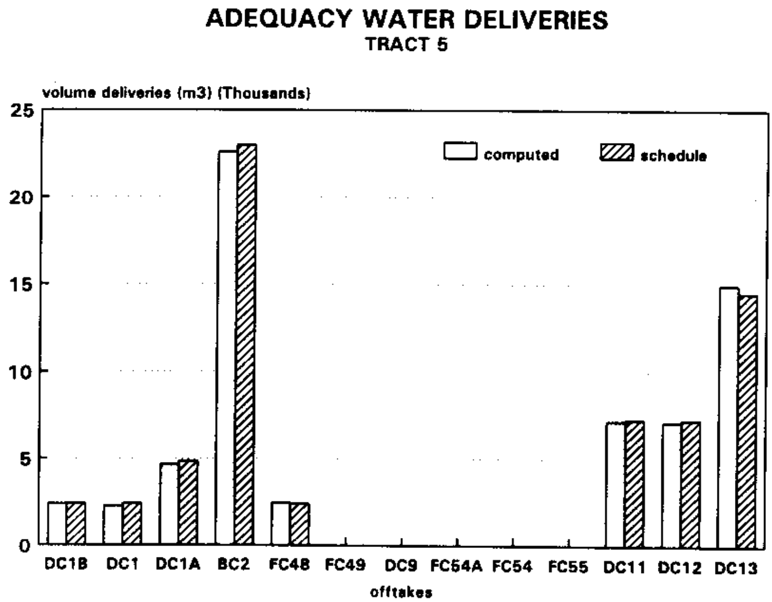
## Evaluation of the Proposed Operational Plan

The fluctuations of water levels at the gated structures and the gap between targeted and achieved discharges at the offtakes have been kept as relevant criteria for evaluating the operational plan. The evaluation, accomplished after using an unsteady flow simulation, is summarized below by means of 4 graphs:






The operational plan adopted proved to be acceptable even if some improvements could be introduced. For instance, the transition phase between the Tract 2 and Tract 5 deliveries reveals a significant increase in water levels along Tract 5 which could be minimized by limiting the drainage of Tract 2. The method presented is in fact largely suboptimal and leaves room for various alternatives which can be tested by the manager.