IIMI THE INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

INTER OFFICE MEMORANDUM

To : Program Staff

Copy to : R. Lenton
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From : Hilmy Sally

Date : 8 September 1988

Subject : Kirindi Oya RBMC Simulation Model

Attached herewith please find, for your information and comments, a report describing the field measurement campaign carried out for the calibration of the above model.

**REVISED DRAFT**
(MODCALIB.RPT) Hilmy Sally
8 September 1988

# CALIBRATION OF *THE* KIRINDI OYA RBMC MATHEMATICAL FLOW SIMULATION MODEL

## MENT CAMPAIGN AND PRELIMINARY RESULTS

International Irrig tion Management Institute
Digana Vi lage, via Kandy
Sri Lank

CALIBRATION OF THE KIRINDI OYA RBMC MATHEMATICAL FLOW SIMULATION MODEL

DESCRIPTION OF THE FIELD MEASUREMENT CAMPAIGN AND PRELIMINARY RESULTS

# I INTRODUCTION

IIMI's current research on the operation of "Main Systems" is based on the hypothesis that control of the conveyance and primary distribution of water in main and branch canals could have a profound impact on efforts to improve management at lower levels. In fact an inflexible and unreliable primary water supply regime could negate many of the efforts exerted by irrigation agencies and farmers' organizations to achieve reliable and equitable water supply below turnouts.

Current operational practices in the large canal networks of the rice-based irrigation systems in the humid tropics suggest that there is considerable potential for the development of effective and responsive main system management. Since operational practices are often conditioned by the particular design features for water level control in the main canal, and discharge control at their offtakes, IIMI's research priorities in this area include analyzing the impact of design choices on the management and manageability of main canals.

Such research cannot be easily carried out in the field. Mathematical models that simulate the real system provide a convenient alternative to field research in investigating the behavior of irrigation canals under a variety of design/management scenarios without affecting normal canal operations. For example, such models could be used to assess the impact of any operational maneuver before actual intervention on the field.

IIMI, in consultation with the Sri Lankan Irrigation Department (ID), identified the Kirindi Oya Right Bank Main Canal (RBMC) as an appropriate site for a pilot application of a mathematical flow simulation model. For the implementation of this research project IIMI secured financial assistance from the Government of France, and associated itself with CEMAGREF (National Center of Agricultural Engineering, Forestry and Water Management), a public-sector applied research center in France which is providing additional expertise in computational hydraulics and computer technology.

The object of this paper is to document the field measurement campaign 'carriedout in the Kirindi Oya RBMC with a view to calibrating the mathematical model, The preliminary analysis leading to estimates of some of the hydraulic parameters needed by the model is also described.

# II KIRINDI OYA RIGHT BANK MAIN CANAL (RBMC)

The Kirindi Oya Right Bank Main Canal is fed by the Lunugamvehera reservoir, located on the Kirindi (river) in Southern Sri Lanka and having an active storage capacity of 198 million m3 (MCM). They were both constructed as part of the Kirindi Oya Irrigation and Settlement Project

(KOISP), whose implementation is planned in two phases. The RBMC is meant to irrigate approximately 5000 hectares (ha) of land. The development of a little over half this area was completed in mid-1986 under Phase I of the project.

The RBMC is 32 km long and is designed to carry a discharge of 13 m³/s at its head. The canal is unlined throughout its length and was designed with trapezoidal cross-sections. The cross-sections have however evolved over time into more irregular shapes notably due to erosion and cattle damage. In addition, siltation has occurred in many places on the canal bed.

A total of 33 distributary and field canals take off directly from the RBMC. It is further characterized by the presence of 14 gated cross-regulators, of the undershot type, along its length. The coordinated operation of these regulators (each regulator having from 2 to 5 manually-operated sliding gates) is a key element in achieving effective control of water levels in the main canal, and hence of the primary distribution of discharges into the secondary and tertiary Canals that take off from the RBMC. Ineffective operation of the control facilities could result in unreliable and inequitable water supply.

In the case of the RBMC, effective main canal operation becomes even more critical given that crop diversification is envisaged in the dry season (rice being the traditional wet-season crop). However serious water shortages have so far prevented the satisfactory completion of two normal cultivation seasons. This highlights the urgent need for improved management of the relatively scarce water resource, especially since the existing command area will be doubled after implementation of Phase II scheduled to commence in 1989.

In the context of this relatively water-scarce environment and its particular design features, it is hoped that the use of a mathematical flow simulation model of the Kirindi Oya RBMC would contribute to the identification of alternative management practices leading to improved distribution of water.

## III PRINCIPAL FEATURES OF THE MODEL

### 3.1 Model Structure

The model is designed to run on a micro-computer, type IBM-PC/AT or compatible. It is made up of three software units that can be run either independently or sequentially. They are :

Unit 1 : Topography Unit - This unit enables the user to input and verify all the topographic data pertaining to the canal. The software analyzes this data and generates specially coded files of geometric information that can be accessed for use by the other two units. A notable feature of this unit is that it can accommodate any type of canal cross-section (regular or irregular), including single-bank canals.

Unit 2 : Steady Flow Unit - This unit will calculate regulator and offtake gate openings as well as water surface profiles in the different canal reaches for any steady state scenario of water supply and demand. It also generates initial hydraulic conditions for activation of the Unsteady Flow Unit 3. An optional menu enables the user to impose or modify the hydraulic parameters of the canal (e.g. cross-regulator openings, canal losses, roughness coefficients).

Unit 3 : Unsteady Flow Unit - This unit simulates the unsteady flow conditions that prevail over certain periods of time in response to changes in water supply or demand, and modifications to gate settings. The user will be able to use this unit to assess the impact of different operational procedures (e.g. in terms of water losses or shortages, hydrographs at different points) to effect the transition from an initial steady state to a new one.

A major component of the Kirindi Oya RBMC flow simulation model project is the development of user-friendly conversational procedures so that the model could be used by non-specialized staff. The modular structure of the model will permit future modification or substitution of any of the hydraulic modules. For instance, the incorporation of a regulation module which would allow the inclusion of automatically adjustable control devices could be envisaged at a later stage.

## 3.2 Input Data Requirements

Since the model is a mathematical representation of the real system, it would only be as good as the quantity and quality of the information that is fed into it to describe the reality. The model should thus incorporate, as accurately as possible, all important physical and hydraulic features of the system.

The present model is limited to the first 25 km of the RBMC presently in operation. The input data, both physical and hydraulic, therefore only concerns this stretch of main canal. However the model can easily accommodate eventual extensions by modification of its topography unit.

The physical information was gathered in the course of a topographical survey. This included (a) the locations and descriptions of all cross-regulators, offtakes and other singularities on the RBMC, (b) longitudinal profile of the canal bed, and (c) cross sections of the canal at appropriate intervals (100 meter intervals were used in the RBMC), trying as far as possible to capture all hydraulically significant features.

The hydraulic information required includes (a) roughness coefficients for the different reaches of the canal, (b) head-discharge relationships and discharge coefficients for the offtakes and regulators, and (c) seepage losses along the canal. Estimates of some of these parameters were obtained in the course of this measurement campaign.

# IV FIELD MEASUREMENTS FOR MODEL CALIBRATION

The measurement campaign was carried out by a joint IIMI-CEMAGREF team over a 10-day period in April-May 1988. The ID extended its wholehearted cooperation and support at all stages of the campaign. In carrying out all observations and measurements a primary concern was to cause minimum disruption to normal irrigation activities in the RBMC project area.

## 4.1 Steady Flow Calibration

<u>4.1.1 Water Surface Elevation and Discharge Measurements</u> -- In this phase of the calibration, which was the most time-consuming, an inventory of the status of the RBMC system under given steady conditions of canal water flow and gate settings was taken. ID had undertaken not to alter the main canal discharge nor the gate settings until the end of the calibration campaign. Marks were painted on the gate spindles so that it would be possible to ascertain at a glance if any of these gate settings had been altered.

Water surface profiles in the main canal were computed by measuring water levels at all offtakes, and upstream and downstream of each cross regulator (denoted GR2 to GR15) with respect to temporary bench marks (TBM) of known elevations established at these locations.

The discharges at different points in the RBMC as well as at some offtakes were estimated using an OTT-C31 currentmeter. Gauging in the main canal was performed from 9 different bridges (Br) located at the distances indicated in Table 1[1]. The measured discharges are indicated in upright characters and enclosed in boxes while the figures in italics refer to ID's planned discharges for the period in question.

The openings of all regulator and offtake gates were computed via observations of their respective spindle heights; the relations between gate openings and spindle heights had been established earlier for each gate. Table 2 describes the state of the different offtakes of the RBMC during the calibration campaign. The indication <u>eps</u> (for epsilon) is used to denote an offtake which was for all intents and purposes closed but through which a very small flow nevertheless escaped.

Table 3 summarizes the information contained in Tables 1 and 2, and indicates the discharge values finally chosen for the steady flow calibration of the RBMC model.

<u>4.1.2 Canal Losses</u> -- The discharge measurements described in Table 3 are also made use of to compute seepage and percolation losses in each gauged reach of the RBMC. It is assumed that the losses are uniformly distributed over the entire reach. Wherever the offtake has been gauged, the measured discharges are taken into account in the computation. Otherwise it is

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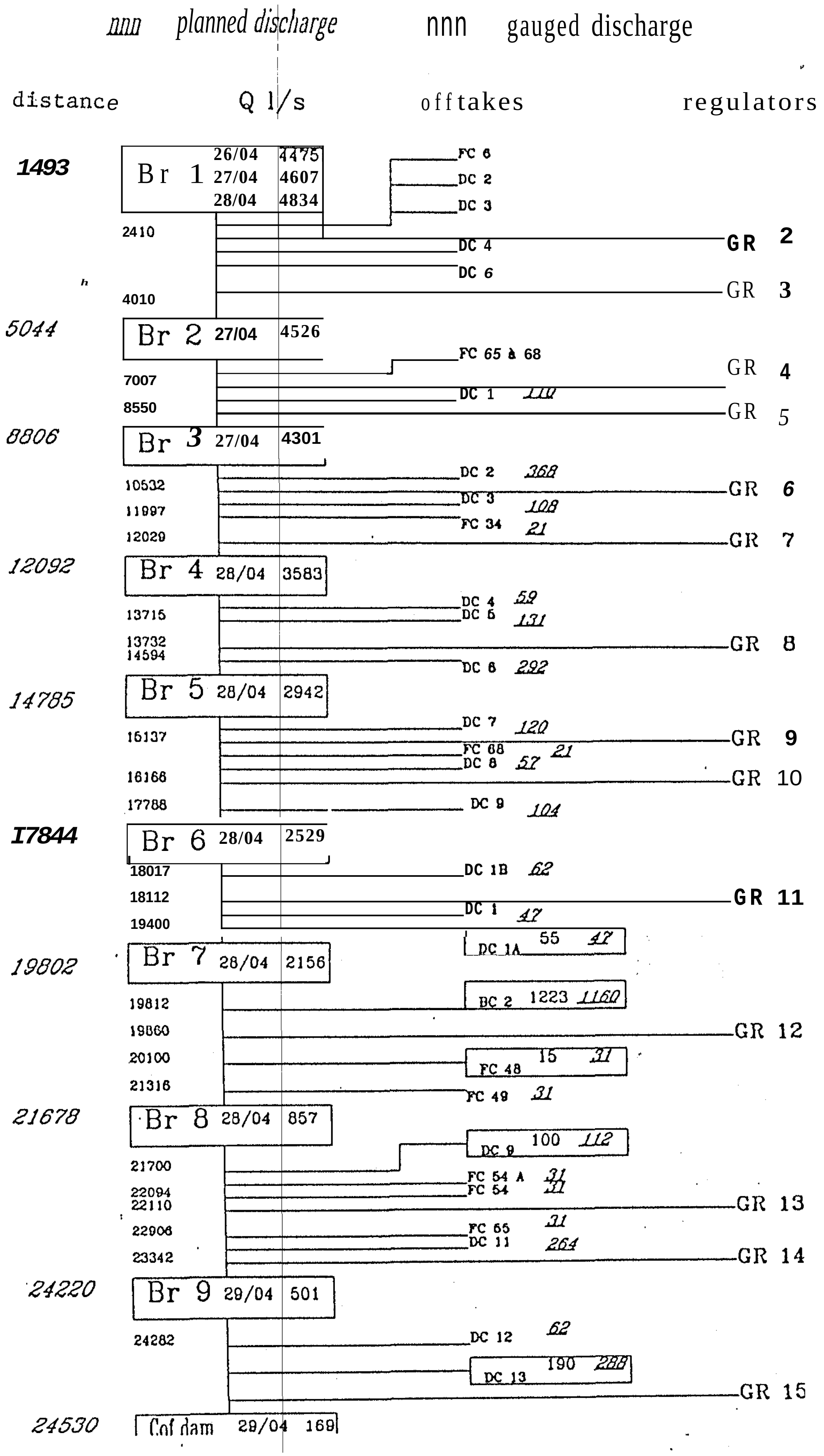
[1] Tables 1 to 5 are adapted from the document CEMAGREF/IIMI - <u>Field Operations Results, Kirindi Oya Right Bank Main Canal</u>, May 1988.

Table 1


nnn planned discharge
nnn gauged discharge
distance
Q l/s
offtakes
regulators
1493 Br 1 26/04 4475
27/04 4607
28/04 4834
FC 6
DC 2
DC 3
2410 DC 4 GR 2
DC 6
4010 GR 3
5044 Br 2 27/04 4526
FC 65 à 68
7007 GR 4
DC 1 110
8550 GR 5
8806 Br 3 27/04 4301
DC 2 368
10532 GR 6
DC 3 108
11997 FC 34 21
12029 GR 7
12092 Br 4 28/04 3583
DC 4 59
13715 DC 5 131
13732 GR 8
14594 DC 6 292
14785 Br 5 28/04 2942
DC 7 120
16137 GR 9
FC 68 21
DC 8 57
16166 GR 10
17788 DC 9 104
17844 Br 6 28/04 2529
18017 DC 1B 62
18112 GR 11
DC 1 47
19400 DC 1A 55 47
19802 Br 7 28/04 2156
19812 DC 2 1223 1160
19860 GR 12
20100 FC 48 15 31
21316 FC 49 31
21678 Br 8 28/04 857
DC 9 100 112
21700 FC 54 A 31
22094 FC 54 31
22110 GR 13
22906 FC 65 31
DC 11 264
23342 GR 14
24220 Br 9 29/04 501
24282 DC 12 62
DC 13 190 288
GR 15
24530 Cof dam 29/04 169

# Observations on the offtakes

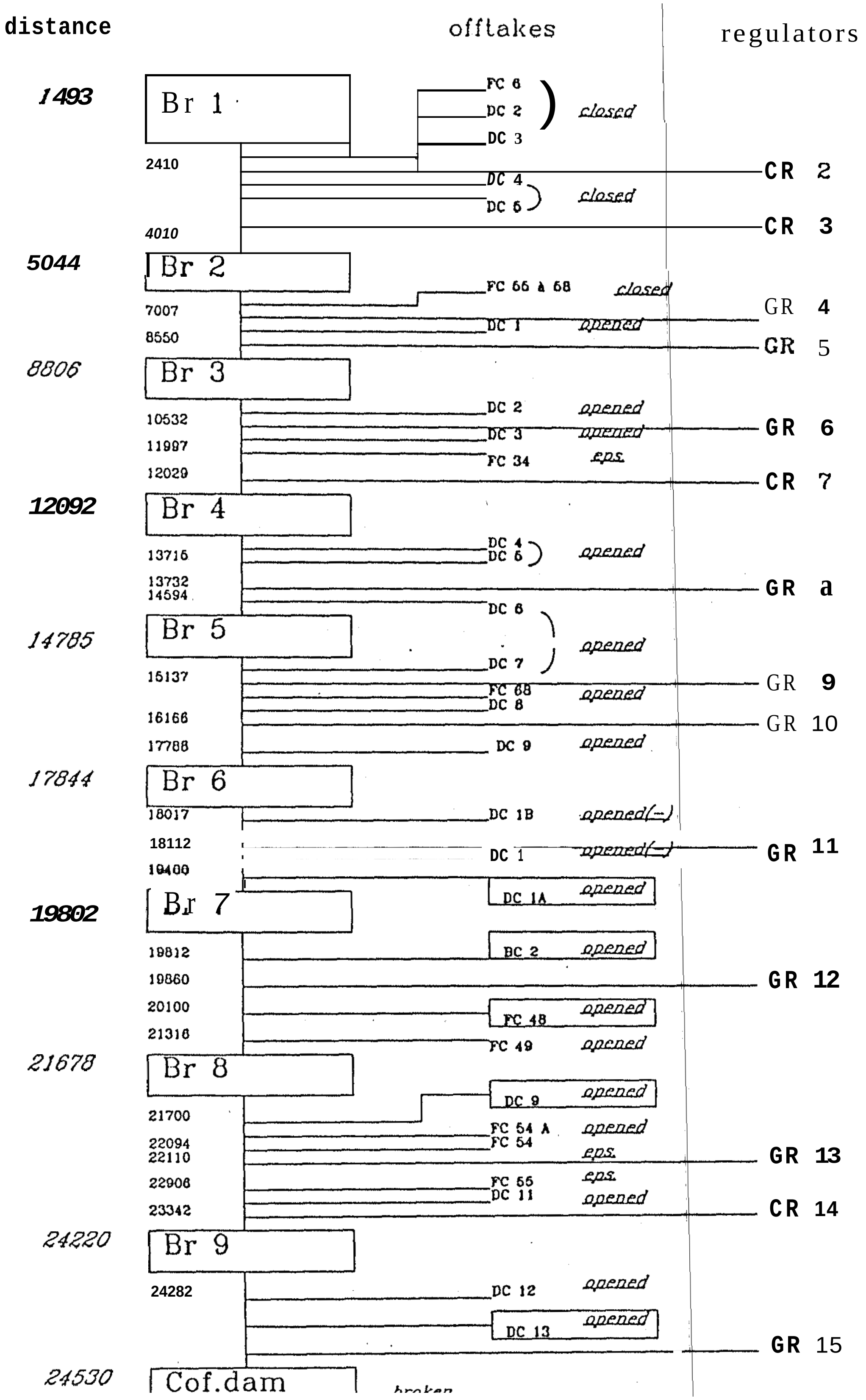
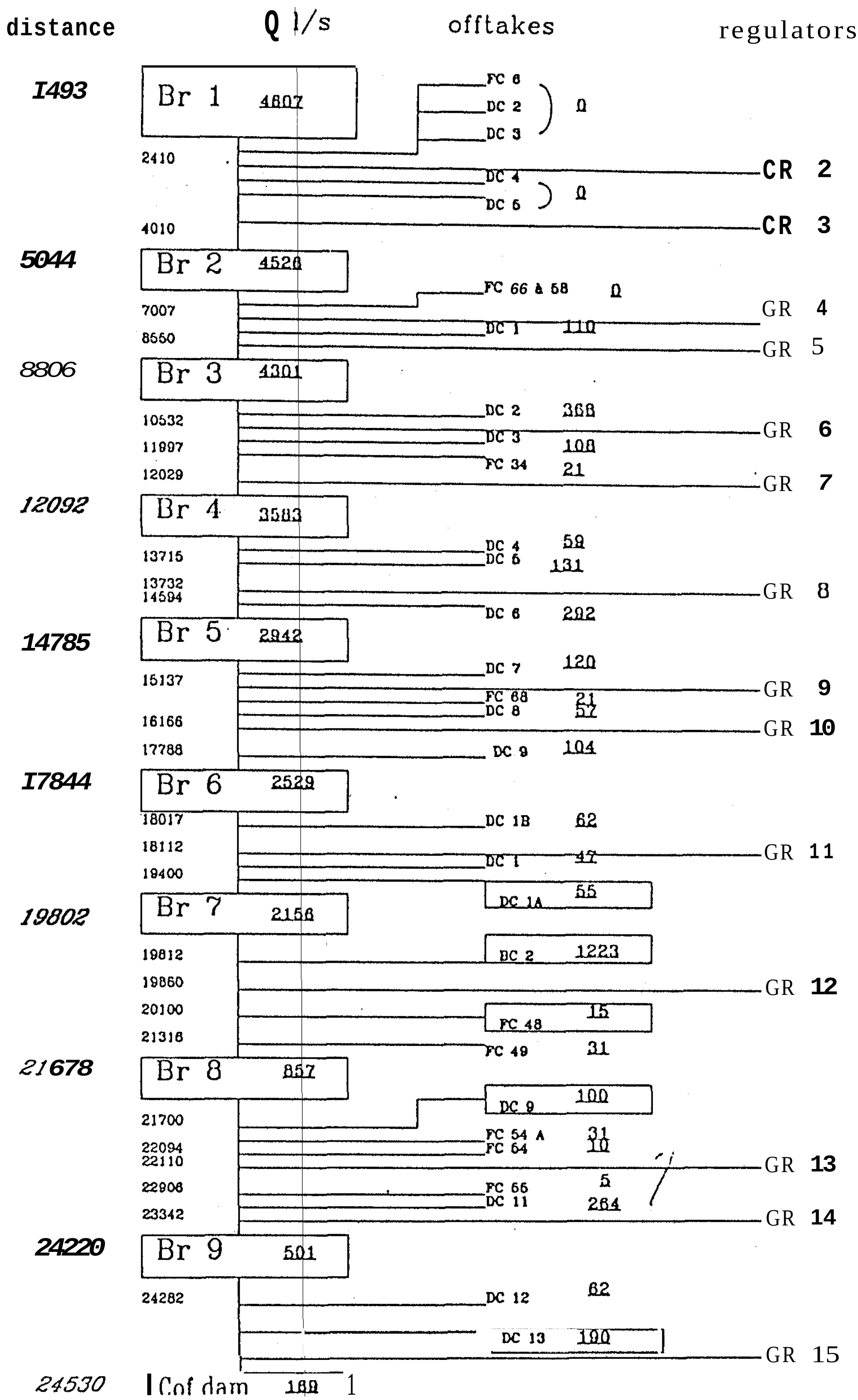


Table 3

## Final Discharge Values



assumed that the targeted discharge is being delivered it the offtake.

Consider a reach 1-2 with n offtakes:

```
|==========|========|=================|====  =====|==>
           |        |                 |
Q1         q1       q2       . . .    qn          Q2
```

$$\text{Loss} = \frac{(Q_1 - q_1 - q_2 - \ldots - q_n - Q_2)}{x_2 - x_1}$$

where $Q_1, Q_2$ = Discharge at upstream and downstream ends of reach 1-2

and downstream

method

was performed. The

given in Table 4. In

reach Br8-Br9 the sum of the outflows is greater than the inflow, possibly indicating that the target discharge in DC11 remains unsatisfied. On the other hand, unusually high losses seem to occur in reach Br9-COFDAM which could mean that the actual discharge in DC12 exceeds the target value.

It will be observed that there is a wide range of variation in the losses obtained for the different reaches. This reflects the variation in

.e. whether it is built

irely above the natural

. The losses would be least

. Table 5 gives a

anal sections of the RBMC.

The weighted mean value for RBMC losses, taking into account the values obtained between Br 1 to Br 8. is 0.046 l/s/m (or 2.44 cusecs/mile).

$m^3/s$ (or 40 cusecs) over the 25 km

regulator GR15, which corresponds tc

in the simulation model.

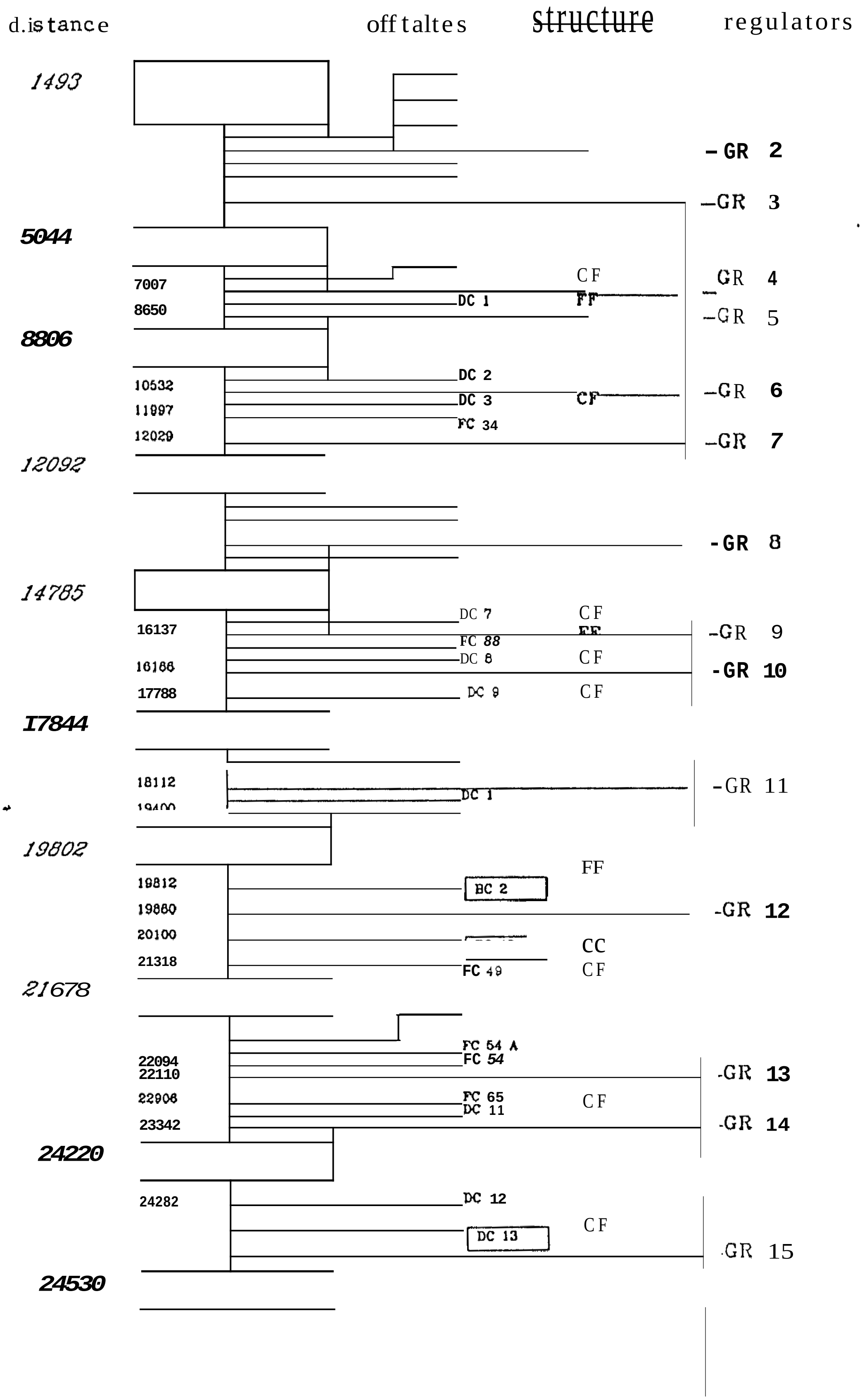
To conclude this section, we would like to emphasize that the loss values obtained at this stage are only approximate. But they nevertheless give some indication of canal losses in a situation where there was hardly any information available previously. The approximate nature of these results is due to the uncertain offtake discharges; the discharges $q_1$, $q_2$, ... etc. were not directly measured at all the offtakes. In the computation of losses it was assumed that the ungauged offtakes were delivering flows equal to their respective targets. This is perhaps not always true, as evidenced by the unusual results obtained in reaches Br8-Br9 and Br9-COFDAM. More reliable estimates of canal losses would have been obtained if discharge

# Computation of Canal Losses

| Bridge | Q(l/s) | Relative Distance (m) | Discharge (l/s) | Length (m) | Mean losses (l/s/m) |
|---|---|---|---|---|---|
| Br 1 | 4 607 | 1 493 | | | |
| | | | 0 | 3 551 | 0.023 |
| Br 2 | 4 526. | 5 044 | | | |
| | | | DC1 110 | 3 762 | 0.031 |
| Br 3 | 4 301 | 8 806 | | | |
| | | | DC2 368<br>DC3 108<br>FC 34 21 | 3 286 | 0.067 |
| Br 4 | 3 583 | 12 092 | | | |
| | | | DC4 59<br>DC5 131<br>DC6 292 | 2 693 | **0.059** |
| Br 5 | 2 942 | 14 785 | | | |
| | | | DC7 120<br>FC 68 21<br>DC 8 57<br>DC 9 104 | 3 **059** | 0.036 |
| **Br** 6 | 2 529 | 17 844 | | | |
| | | | DCI B 62<br>DCI 47<br>DCIA *55* | 1 **958** | 0.107 |
| Br 7 | 2 156 | 19 802 | | | |
| | | | BC 2 1223<br>FC 48 15<br>FC 49 31 | 1 876 | 0.016 |
| Br 8 | 857 | 21 678 | DC 9 100<br>FC54A 31<br>FC 54 10<br>FC 55 5<br>DC 11 264 | 2 542 | aberran. DC11 targetted discharge might be unsatisfied. |
| **Br** 9 | **501** | 24 220 | | | |
| | | | DC 12 62<br>DC 13 190 | 310 | aberrant DC11 targetted discharge might be esceeded. |
| COF-DAM | 169 | 24 530 | | | |

Table 5

FF: canal completely above terrain CF: partly above CC: complete below terrain



measurements had been performed at all the offtakes, or if all the offtakes had been closed. ID has agreed to let us carry out measurements under the latter conditions (i.e. flow only in the main canal with all offtakes closed) sometime during this Maha cultivation season.

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re

pa

va

over time (e.g. weed growth). The roughness coefficient (in the form of the

s

ion gradient.

The standard Manning-Strickler equation for open-channel flow was utilized to estimate the roughness coefficient:

$$Q = K \cdot A \cdot R^{2/3} \cdot \sqrt{i}$$

where
- $Q$ = Discharge
- $K$ = Strickler coefficient (= 1/Manning's n value)
- $A$ = Cross section of flow
- $R$ = Hydraulic Radius = A/P, with P = wetted perimeter
- $i$ = Bed slope (=0.0003)

The cross section and wetted perimeter have been accurately measured only under the bridges, which are however not representative of the real flow sections in the canal reaches bounded by the bridges. The canal cross section and the wetted perimeter were therefore each assumed to be 10% greater than their respective values measured under the bridges.

Direct application of the Manning-Strickler equation yielded values of K for the different locations. The computation was performed only at bridges located sufficiently upstream of any cross-regulator where a reasonably uniform flow regime could be assumed to prevail. The results are indicated in Table 6.

Table 6

| Location | Q (l/s) | A (m²) | $R^{2/3}$ | Strickler K | Manning n |
|---|---|---|---|---|---|
| Br 1 | 4607 | 12.75 | 0.968 | 22 | 0.045 |
| Br 2 | 4526 | 11.28 | 0.913 | 25.4 | 0.039 |
| Br 3 | 4301 | 11.50 | 0.945 | 22.9 | 0.044 |
| Br 4 | 3583 | 10.91 | 0.913 | 20.8 | 0.048 |

It should be emphasized that the above values of roughness coefficients are only preliminary estimates. The final values to be adopted in the simulation model will be known once the calibration computations are completed. This involves adjusting the value of the roughness coefficient until there is reasonable agreement between the computed and observed water surface elevations (cf. section 4.1.1), whilst at the same time ensuring that there is conservation of the volumes of water being conveyed in the different canal reaches.

However the Strickler roughness coefficients obtained (between 20 and 25), though only indicative of the final value, are substantially less than the value assumed at the design stage, 40. This implies that the canal roughness is higher than what was originally assumed, leading to a proportional reduction in canal carrying capacity.

4.1.4 Calibration of Cross Regulator -- The calibration was carried out at cross regulator GR3, where IIMI had installed automatic data logging equipment to continuously monitor water levels in the RBMC and in the nearby DC5 distributary canal. The object of the calibration was to determine an appropriate coefficient of discharge for the regulator gates. The value obtained will be considered to be representative for all the regulators.

*GR3* is a 5-gated regulator. For a given combination of gate settings, measurements of water levels upstream and downstream of the cross regulator were made with respect to the top of the side check walls (corresponding to the Full Supply Depth--FSD). The spindle heights were also noted, from which the relevant gate openings could be derived. Adjustments to gate settings were made such that, as far as possible, the same opening was maintained at each of them. It was however not possible to make adjustments to one of the gates which remained blocked.

Since all offtakes upstream of this regulator were closed during the measurement campaign, the main canal discharge was not affected by changes to gate settings. It was only possible to conduct this experiment for one value of steady discharge during this present field measurement campaign. However measurements corresponding to five different gate settings were made for this particular discharge. It is however hoped to repeat this operation for at least two other steady state discharge conditions.

This particular experiment was performed on 26 April 1988 when the main canal discharge was 4.475 $m^3/s$. The different gate openings effected that day, expressed in terms of area of opening, are shown in Figure 1.

Measurements were undertaken only after allowing time for the upstream water level to regain stability following a gate adjustment. Although over two hours had elapsed between successive sets of gate adjustments, examination of the water levels recorded by the data logger upstream and downstream of the regulator *GR3* that day (Figure 2) indicates that complete stability had in fact not been attained at the end of each set of adjustments. This clearly demonstrates the wealth of useful information that can be obtained from the continuous data logger records.

The flow actually passing through the regulator gate openings was

# GR3 – GATES OPENING

26-04-88 00H00 to 28-04-88 00H00

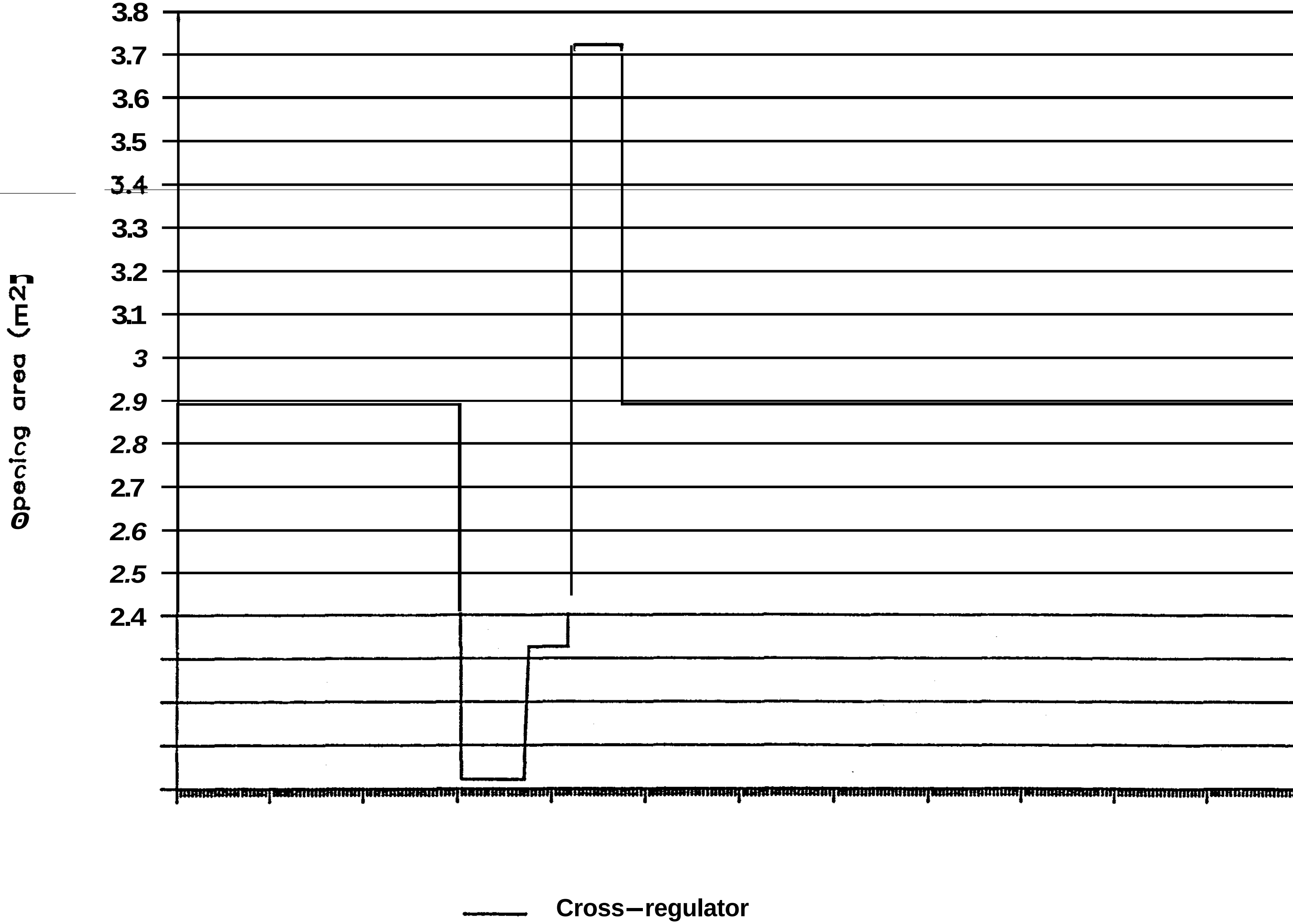
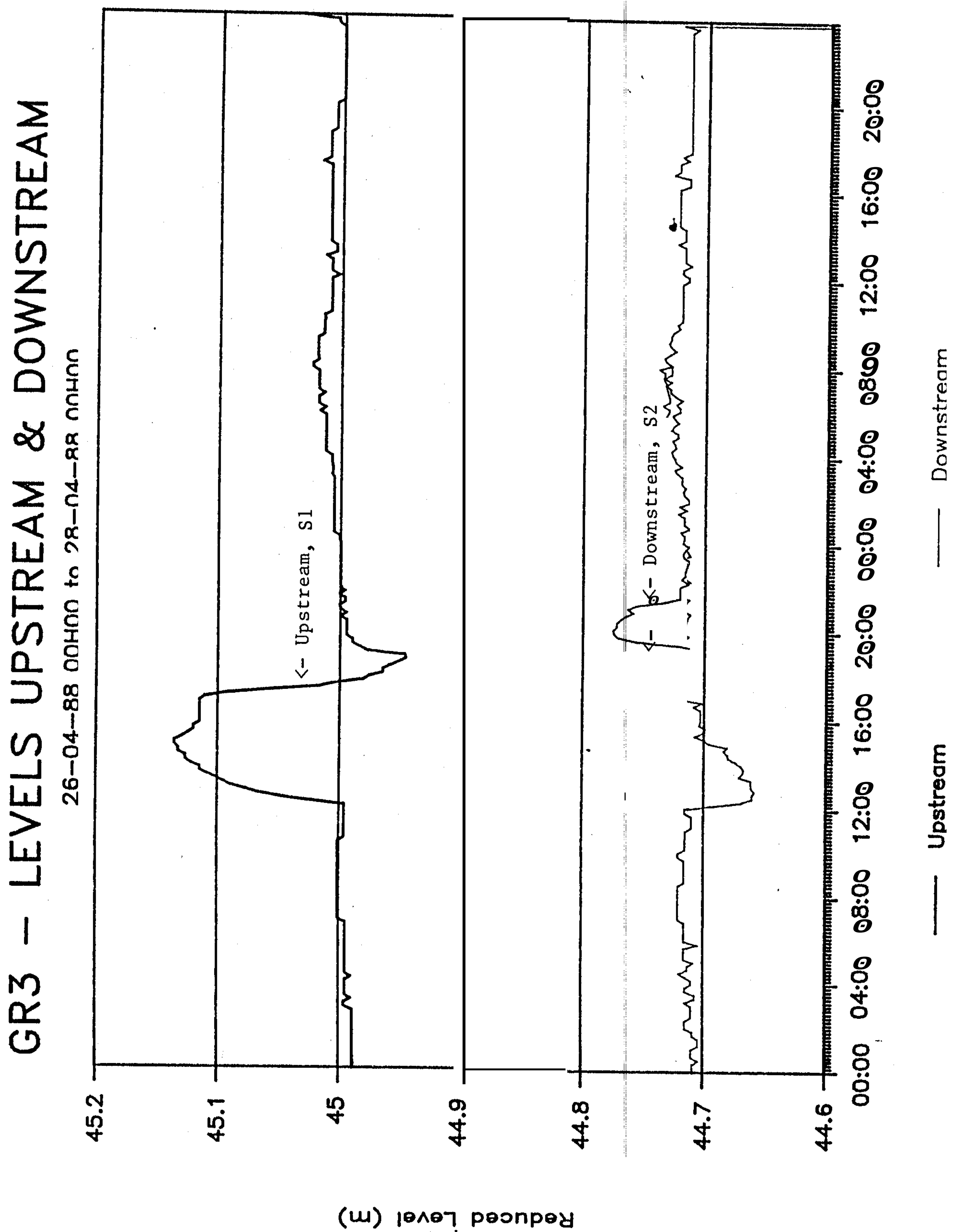



Figure 1


GR3 - LEVELS UPSTREAM & DOWNSTREAM
26-04-88 00H00 to 28-04-88 00H00
<- Upstream, S1
<- Downstream, S2
45.2
45.1
45
44.9
44.8
44.7
44.6
Reduced Level (m)
00:00 04:00 08:00 12:00 16:00 20:00 00:00 04:00 08:00 12:00 16:00 20:00
Upstream
Downstream

estimated by subtracting the flow over the side check walls and over any of the gates themselves (wherever applicable) from this value (Figures 3 and 4). The classic equation for free flow over a weir was used with a discharge coefficient of 0.36 to compute these overflows.

The following equation was used for discharge through the cross-regulator gates:

$$Q = C_d . A . \sqrt{2g(S_1 - S_2)}$$

where
- $Q$ = Discharge through the regulator gates
- $C_d$ = Coefficient of discharge
- $A$ = Total area of flow through gates
- $S_1$ = Water level upstream of regulator
- $S_2$ = Water level downstream of regulator
- $g$ = Acceleration due to gravity

All quantities in the above equation are known (or measured) except for the coefficient of discharge $C_d$, which can thus be calculated.

The values of $C_d$ obtained at the end of each set of gate adjustments are as follows :

Test 1, $C_d$=0.659; Test 2, $C_d$=0.695; Test 3, $C_d$=0.648;
Test 4, $C_d$=0.620; Test 5, $C_d$=0.657.

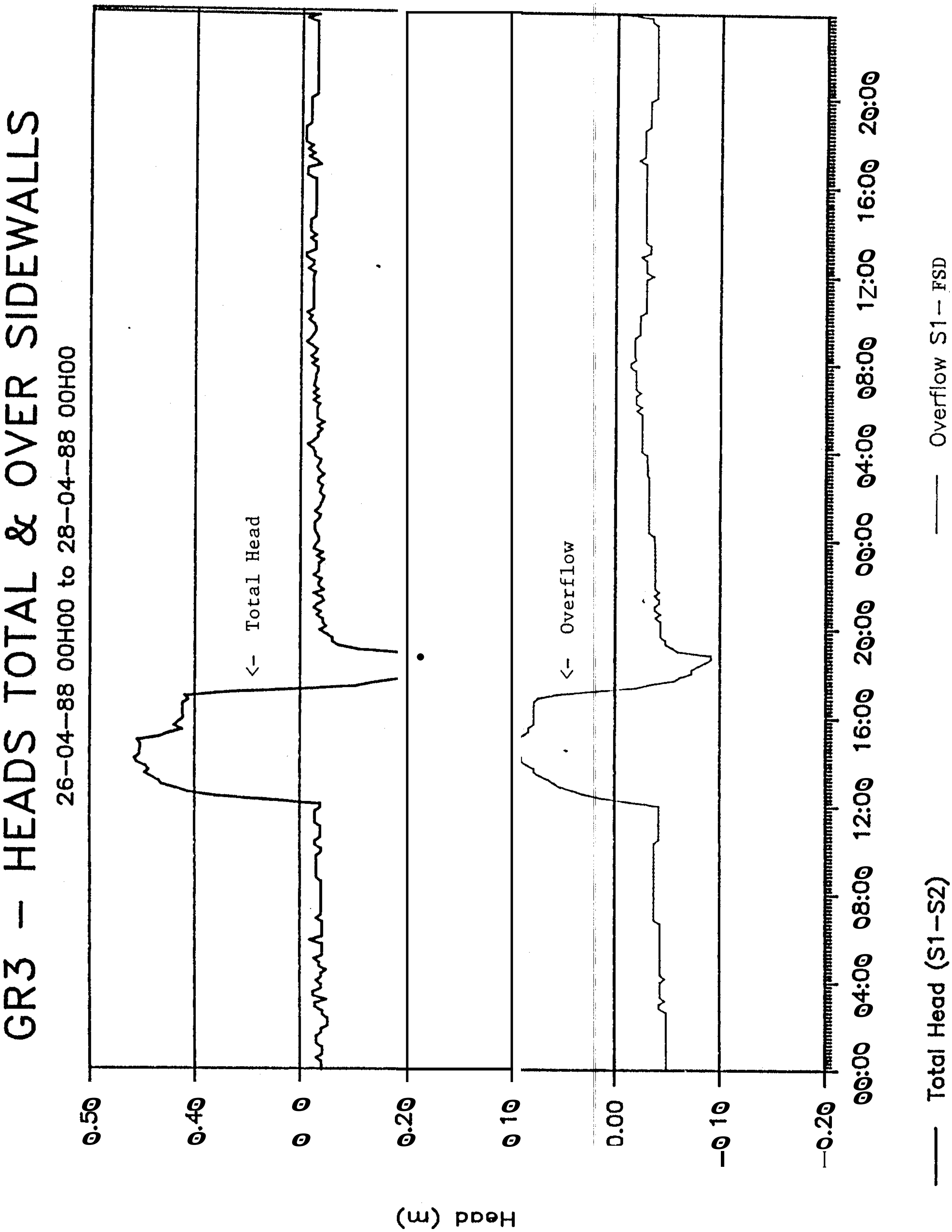
The range of different values obtained is perhaps due to the fact that fully stable conditions were not prevalent at the time of measurement. Figure 5 shows the different values of $C_d$ obtained for the whole record from 26 to 28 April. It would appear that the most persistent value of $C_d$ for this period is around 0.66.

## 4.2 Unsteady Flow Calibration

The main purpose of this operation was to monitor the propagation along the RBMC of a wave generated by a sudden additional discharge at the head of the canal. The magnitude of this additional discharge was determined by trial runs of the simulation model (both steady and unsteady state) on the IBM-PC/AT micro-computer of the KOISP. A Strickler coefficient value of 25 was assumed throughout the length of the RBMC. The initial conditions for the unsteady flow simulations corresponded to the state of the system (water surface elevations, discharges etc.) obtained during; a steady flow simulation.

The choice of the magnitude and duration of the additional release to be made at the headworks was a compromise between (a) considerations of safety which required that the flow should not be so great that the RBMC would overflow its banks at some point, and (b) the need to generate a wave that would not attenuate too soon thereby making it difficult to monitor its arrival and progress especially towards the tail of the canal. It was finally decided that an extra release of about 1.5 $m^3/s$ over 3 hours would be suitable.

Figure 3


GR3 — HEADS TOTAL & OVER SIDEWALLS
26—04—88 00H00 to 28—04—88 00H00
<- Total Head
<- Overflow
Head (m)
0.50
0.40
0.20
0.10
0.00
-0.10
-0.20
00:00
04:00
08:00
12:00
16:00
20:00
00:00
04:00
08:00
12:00
16:00
20:00
Total Head (S1—S2)
Overflow S1— FSD

# GR3 - FLOWS

26-04-88 00H00 to 26-04-88 00H00

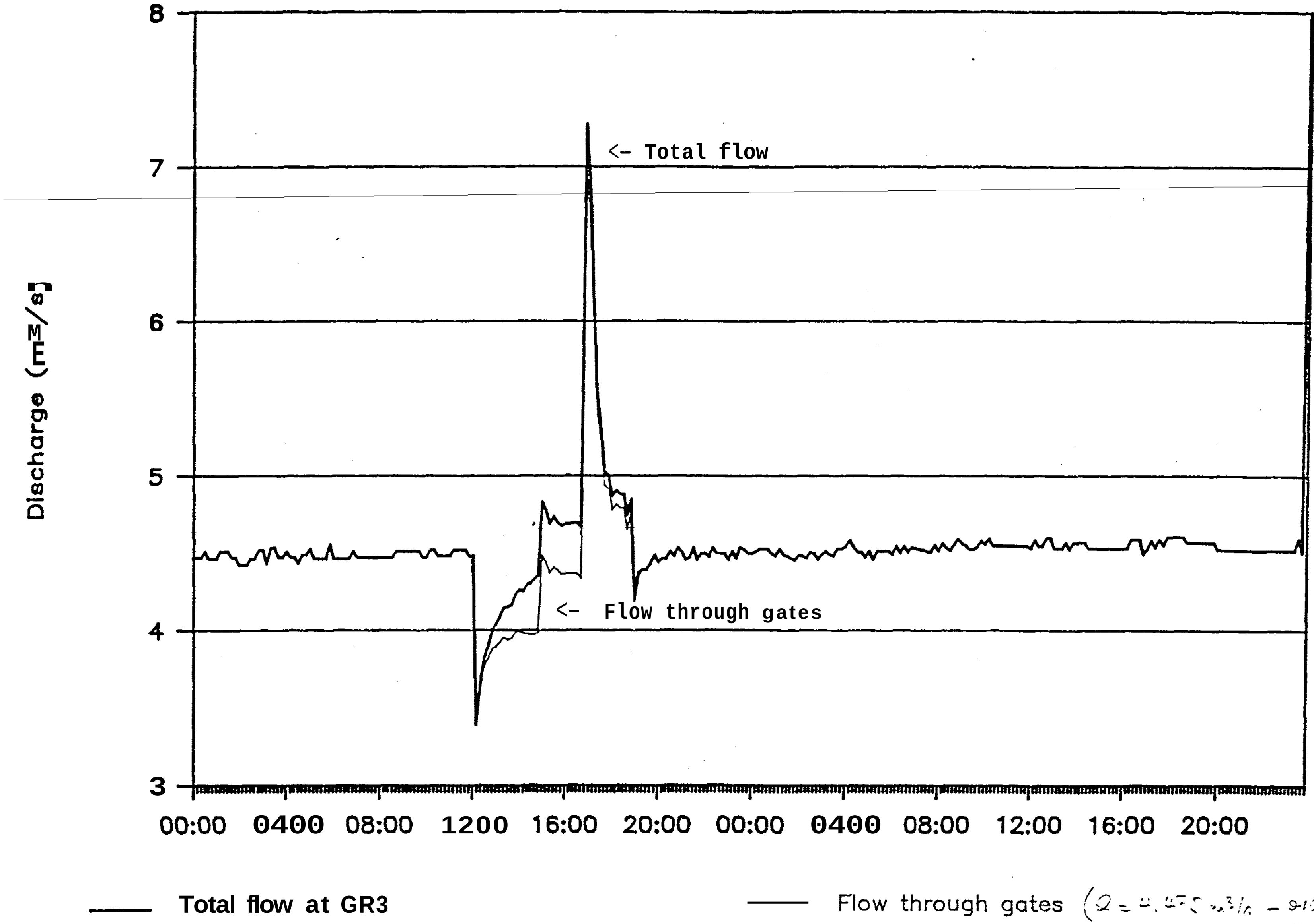
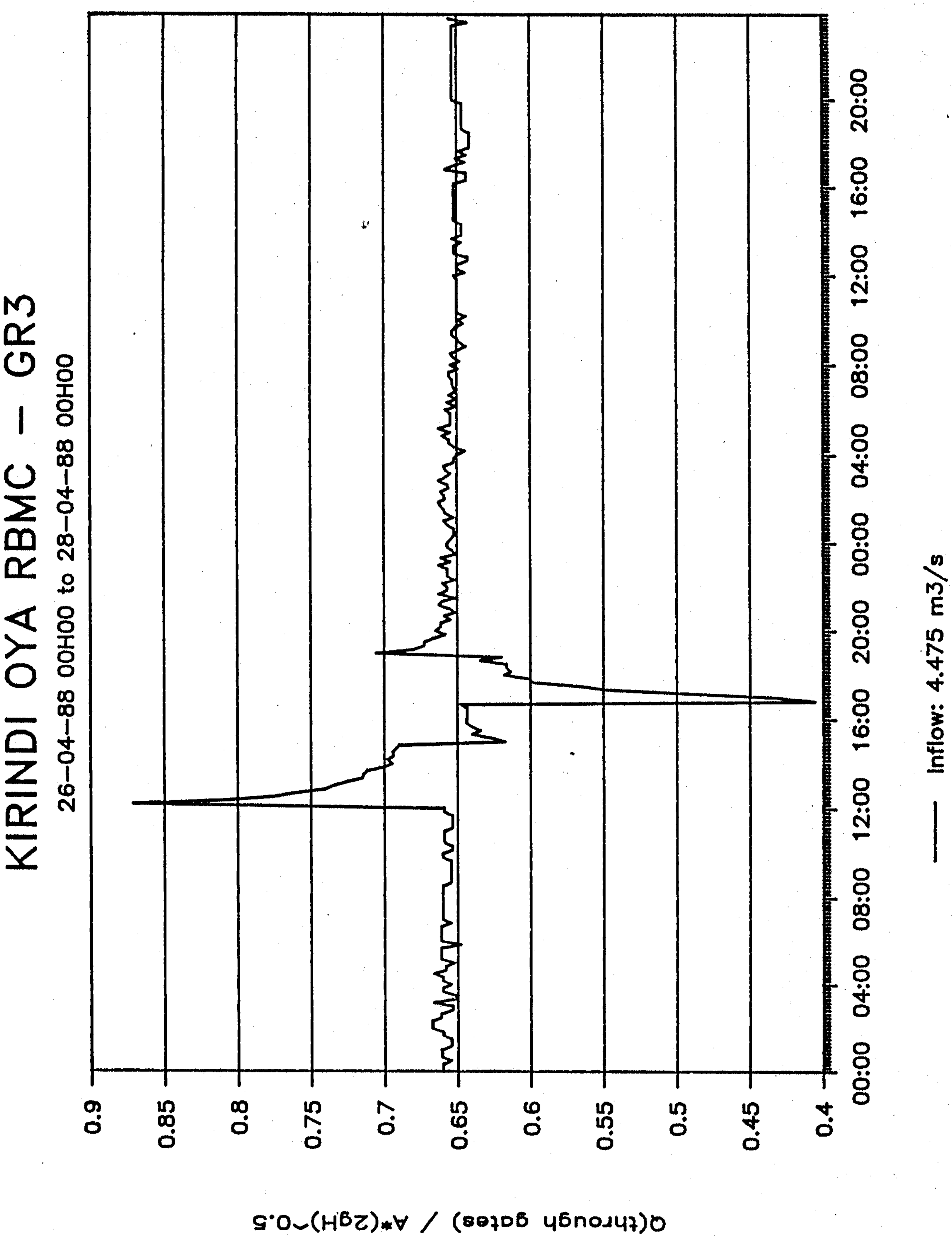



Figure 4


KIRINDI OYA RBMC — GR3
26-04-88 00H00 to 28-04-88 00H00
Q(through gates) / A*(2gH)^0.5
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
00:00
04:00
08:00
12:00
16:00
20:00
00:00
04:00
08:00
12:00
16:00
20:00
Inflow: 4.475 m3/s

At **0630** on **2** May 1988 this additional release was made at the Lunugamvehera reservoir headworks. Water level variations were recorded every 10 minutes upstream and downstream of the side check-wall of every cross-regulator. These tasks were performed by **15** students from a local school each of whom was equipped with a watch, ruler and record-book.

The variation in water levels recorded by the data-logger at the GR3 location (upstream and downstream of the cross-regulator) in response to this additional release is illustrated in Figure **6**. This plot indicates that the wave first arrived at this point about half an hour after it was released at the headworks, and that the peak arrived about 3 hours after the release.

At the same time the RBMC discharge was gauged from time to time at the Br 1 location. The gauging results were as follows :

Table **7**

| Time | Discharge (l/s) |
|---|---|
| Initial Value | 4607 (Steady flow value) |
| **0723** | 5831 |
| **0745** | 5765 |
| **0915** | 6159 (New steady flow regime) |

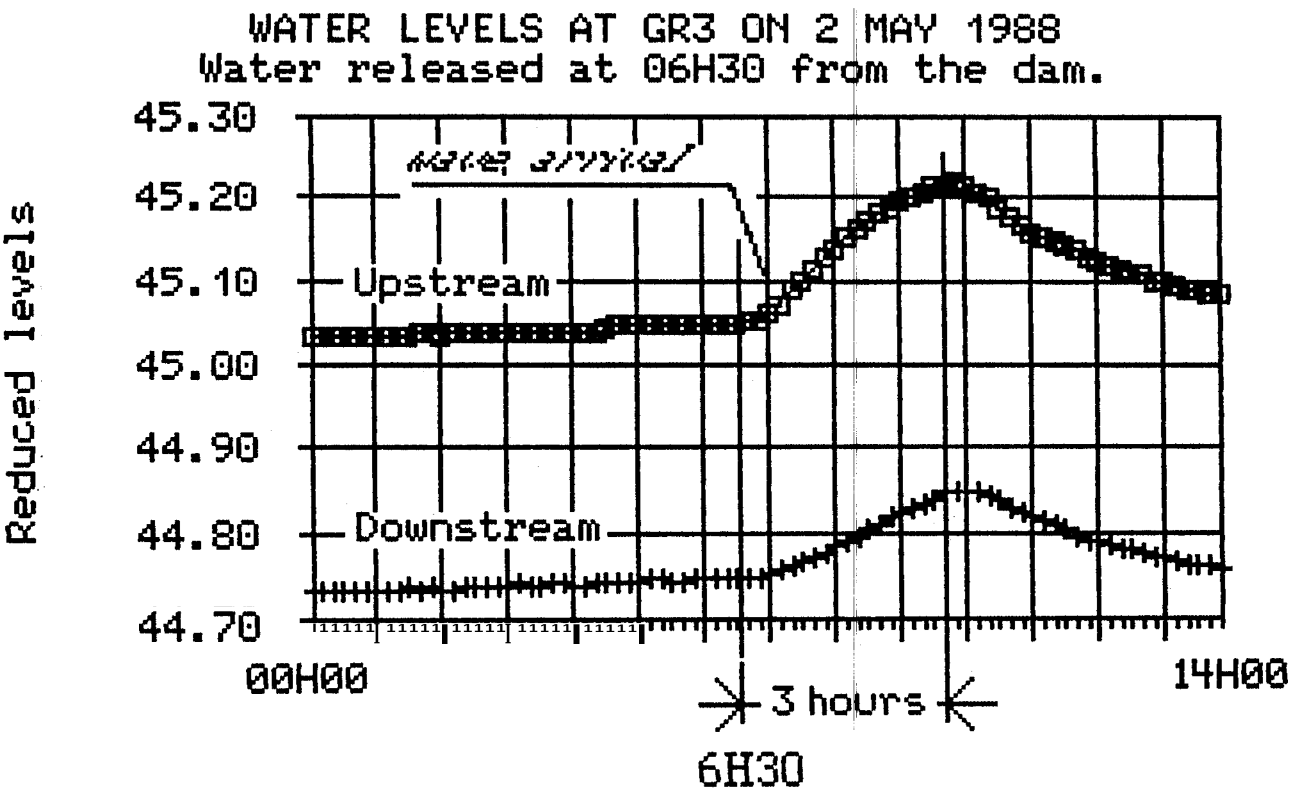
The main sluice was returned to its original position at **0940**. The supplementary discharge measured was **1.552** m$^3$/s.

The water level observations at the cross-regulators continued until the new steady flow regime was established at each location. This occurred progressively at each regulator from upstream to downstream.

Interpretation of the observations was however rendered difficult by the cleaning of the protective grill at the upstream end of the siphon located at a distance of approximately **7** km. Weeds and other debris had been deposited against this grill overnight, causing an accumulation of water in the canal reaches upstream of this location. Their removal (which took place between **0730** and **0830**) provoked a sudden release of this stored water resulting in the propagation of another positive wave downstream of the siphon (and possibly a negative wave upstream of it).

The estimated times of arrival of the wave and its peak are Riven in Table **8**. The average velocity of wave propagation was around **3** km/h (**1.9** mile/h), whereas the peak of the wave was propagated at a velocity of **1.8** km/h (**1.1** mile/h). Such values are useful for design purposes and for estimation of response times.

Figure 6


WATER LEVELS AT GR3 ON 2 MAY 1988
Water released at 06H30 from the dam.
Reduced levels
45.30
45.20
45.10
45.00
44.90
44.80
44.70
Upstream
Downstream
00H00
14H00
3 hours
6H30

Time of arrival of the wave :

Figures in brackets are doubtful data

| distance | arrival of wave (HH:MM) | mean velocity (km/h) | arrival maxi (HH:MM) | mean velocity (km/h) | device |
|---|---|---|---|---|---|
| *1493* | | | | | |
| 2410 | 0:20 | 7.3 | 3:10 | 0.7 | GR 2 |
| 4010 | 0:30 | 8.2 | 3:30 | 1.2 | GR 3 |
| *5044* | | | | | |
| 7007 | 2:00 | 3.5 | 4:30 | 1.5 | GR 4 |
| 7367 | 2:00 | 3.7 | 4:40 | 1.6 | Syphon |
| 8550 | 2:20 | 3.7 | 5:00 | 1.7 | GR 5 |
| *8806* | | | | | |
| 10532 | 3:30 | 3.0 | 5::30 | 1.9 | CR 6 |
| 12020 | 3:40 | 3.3 | 6:40 | 1.0 | GR 7 |
| *12092* | | | | | |
| 13732 | (5:10) | (2.6) | 7:10 | 1.9 | CR 8 |
| *14785* | | | | | |
| 15137 | ? | | 8:00 | 1.9 | GR 9 |
| 16166 | ? | | 9:00 | 1.a | GR 10 |
| *17844* | | | | | |
| 18112 | (6:50) | (2.7) | 9:30 | 1.9 | GR 11 |
| *19802* | | | | | |
| 19860 | (6:50) | (2.9) | (11:00) | (1.8) | GR 12 |
| *21678* | | | | | |
| 22110 | (7:40) | (2.9) | (12:00) | (1.8) | GR 13 |
| 23342 | (8:00) | (2.9) | after 12.00 | | GR 14 |
| *24220* Br 9 | | | | | |
| | (10:40) | 2.3 | alter 12:00 | | GR 15 |
| *24530* Cof.dam | | | | | |
| averages | | 3 km/h | | 1.8 km/h | |
| or | | 1.9 mile/h | | 1.1 mile/h | |

## V CONCLUSIONS AND FUTURE DEVELOPMENTS

The field measurement campaign was an essential step in the development and exploitation of the Kirindi Oya RBMC mathematical, flow simulation model. In order that it yield reliable and useful results the model should accurately reflect the physical and hydraulic features of the canal. The field measurements contribute to matching the model behavior to actually observed situations. The staff of the irrigation agency would then be able to recognize the model as truly representing "their" canal.

The cooperation and active participation of ID project staff in different phases of the field measurements largely contributed to the success of this campaign. They were particularly interested in using the model to estimate maximum conveyance capacities and identify potential bottlenecks to the smooth operation of the RBMC (e.g. the siphon grill, points of insufficient freeboard), Though not yet fully calibrated, the model did yield some indicative results in this direction.

Once fully calibrated IIMI intends using the model as a research tool to further its objectives in the field of design and management interactions. The Kirindi Oya RBMC model will be used as a test case to demonstrate the potential of the mathematical simulation model in investigating innovative main canal design and management practices. Different canal regulation technologies and design concepts can be evaluated without having to incur expenditure on actual field installation or testing. It is hoped that the dissemination of the results of this case study will generate sufficient interest amongst other agencies to employ similar methodologies in their own work.

The model also offers a training tool for system managers to familiarize themselves with the behavior of the main canal in response to a variety of design and management scenarios. This is especially useful if the canal has been recently commissioned, or in the event of a change in system operators.

IIMI, in collaboration with ID, can use the model to identify and practical procedures for improved manual operation of the main canal. The development of user-friendly input and output interfaces, now underway, will facilitate model use and interpretation of results. This collaborative relationship could be extended to the implementation and monitoring of such operational procedures.