RAPID APPRAISAL OF IRRIGATION WATER DISTRIBUTION IN RAHAD

By
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Background:

The International Irrigation Management Institute (IIMI) initiated a research activity in the Rahad Irrigation Scheme in 1991. The research study entitled as "*Forces, Constraints and Interactions of Water Users, the Rahad Agricultural Corporation and the Ministry of irrigation in the operation and Maintenance of the Rahad Irrigation Scheme*" was aimed to achieve the following objectives:

(a) *To document the water indents, deliveries at Minor heads, and Abu Ashreens in the head, middle and tail sections of the Scheme.*

(b) *To document and understand the process by which water indents are determined by the Rahad Agricultural Corporation (RAC), and delivery responses to the indents by the Ministry of Irrigation (MOI).*

(c) *To evaluate the equity of water delivery among Abu Ashreens in the selected Minors.*

(d) *To document and understand water users response to water deliveries.*

The main principle of IIMI's strategy for its international field operations is based on securing maximum involvement of relevant local agencies. In doing so, the Institute seeks to strengthen the national capacity in the field of irrigation management. Under this setting, at IIMI we do acknowledge the important contributions of: (a) the Hydraulic Research Station (HRS) of MOI for taking leading role in the local calibration of irrigation control structures, and (b) the Department of the Rahad Irrigation Operations (RIO) & the Rahad Agricultural Corporation in extending full cooperation for undertaking the study.

The above stated objectives are simply building blocks of an overall objective:

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" to assist the relevant managing agencies and cultivators to field test practical tools for monitoring and assessing irrigation performance of the Rahad Irrigation System." It is the context in which IIMI-Sudan has undertaken two exercises for *Rapid Appraisal of Irrigation Water Distribution in Rahad."* In November 1992, first such exercise was conducted for the field managers of the Rahad Agricultural Corporation (RAC). One day was spent in explaining the use of a manual for flow measurements (Shafique, 1992). On the following day, the managers collected data and quick analysis of the flow data about main, Major, Minor and field canals was then done to compare the findings with indents placed by the field managers of RAC to MOI for the selected sub-system.

The second rapid appraisal exercise was designed for the MOI staff responsible for the irrigation operations in Rahad. Almost entire staff of the department, from director to section engineers, participated in this exercise held on 25 February 1993. The level of interest can be judged from the fact that the monitoring took place on a hot day during Ramadan and all the participants of the agency were fasting. On this day, the main canal (one control point only) and Major 5 (8 control points) were monitored.

This report is based on the data collected by the MOI staff on 25 February. The quick analysis was then discussed with the participants on 3 March 1993 at headquarters of "El Ain" Subdivision in Village 23 of the Rahad Scheme. The second-day gathering was aimed: (i) to share findings of the exercise with the officials, (ii) to interpret results, and (iii) draw conclusions jointly. Next step will be to repeat similar exercise for monitoring the performance of the Minor and field canals.

The third but very important party responsible for the management of the irrigated agriculture in the scheme is the farmers. They will also be invited to undertake such rapid appraisal of the system and then join with above mentioned managers of two agencies to analyze & interpret the existing irrigation performance. We hope that this joint effort should help to develop and field test a package of improvements. The main role of IIMI in this whole exercise will be to provide all the necessary support as an international neutral body to bring all the parties together, help to develop consensus about the problems and present potential management innovations to be tried.

Methodology:

The RIO staff of MOI, in cooperation with IIMI-Sudan, selected 9 control structures at the following points in the scheme: (i) Kilo 76 of the Main Rahad Canal, and (ii) Kilo 0.0, Kilo 1.5, Kilo 3.5, Kilo 12, Kilo 15, Kilo 18, Kilo 21, and Kilo 26 of Major 5. The main reason for selecting these structures for monitoring flows was that they were calibrated by a specialized agency of the Ministry of Irrigation: the

Hydraulic Research Station (HRS).

At all the selected points, there were 8 sluice gates and one Butcher's Weir installed for controlling flows. They all are in good condition. After the referred calibration, these control structures are also being used by IIMI as flow measuring devices. In close cooperation with HRS, IIMI facilitated to paint gauges to read directly gate openings. Similarly, at the gated control points upstream and downstream gauges were installed to determined head across the structures. Such already existing arrangements did further facilitate the job of rapid appraisal of irrigation water distribution in the selected part of the Rahad System.

The data collection started from Kilo 76 of the main canal and ended at Kilo 26 of Major 5. At certain points where either the upstream and downstream gauges were stolen, a survey level was used to find out head across the sluice gates. As a matter of fact, the necessity to use the survey instrument also helped to correct certain bench mark errors which perhaps existed from the start of the scheme. As a side benefit of the exercise, the manager of the RIO immediately instructed the gauge readers to use new correct reference for recording hourly water levels at Kilo 76 of the main canal and the head of Major 5.

The irrigation staff were provided a manual for flow measurements based on field calibration conducted in 1991. This document helped the officials to know the status of irrigation water supplies along the Major 5 immediately. As the assistant divisional engineer of El Ain Subdivision was also a member of the team, information about indents was also readily available for comparison purposes. This paper, therefore, is only a documentation of the rapid analysis done by the MOI staff in the field.

As almost all the irrigation systems in Sudan are designed for an adequate and equitable water supplies, the main aim of the rapid appraisal was to evaluate if the design objectives were being realized. The data collection for rapid appraisal of irrigation water distribution was shaped by the above stated design considerations.

ANNOUNCEMENT

The International Irrigation Management Institute announces an award of 5000 sudanese pounds for selected research paper / papers on the following topic: " The Performance of Irrigated Agriculture is linked with Performance of its Managing Agencies."

IIMI will request a panel of national experts to help in the selection process. The last date for receiving such papers is April 30, 1993.

Data Collected:

Following table provides all the information collected during the exercise by the MOI staff of Rahad.

Observation Points	Gate openings (m)	Head (dh) (m)	Q_s (Supplies) Thousand m^3/day	Q_i (Indents) Thousand m^3/day
K 76	0.90	0.95	735	878
K 0.0	0.60	1.13	535	810
K 1.5	0.60	0.80	448	750
K 3.5	1.40	0.12	380	585
K 12	0.35	1.44	307	555
K 15	0.25	1.56	214	405
K 18	0.18	1.10	141	270
K 21	0.20	0.60	105	190
K 26		0.18	56	160

At a next step, this information was analyzed for participants' interpretations and recommendations. This strategy is aimed to support the findings with "inside" information and initiate a constructive debate about the status of water distribution in the scheme. This is expected to evolve a common understanding about the forces and constraints of the system.

Data Analysis:

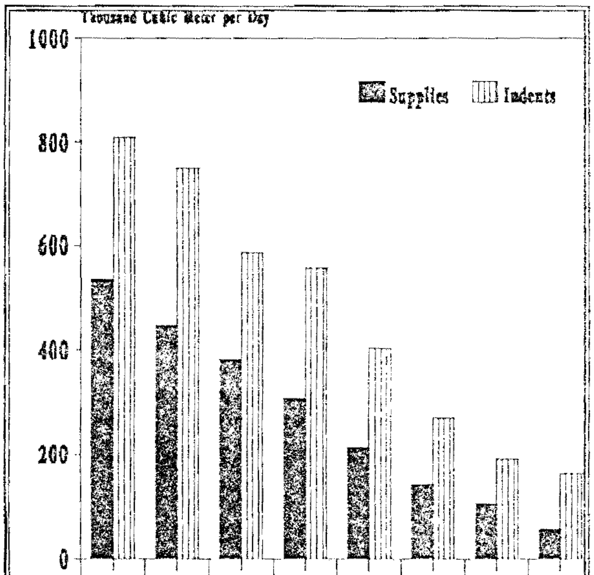
The analysis of the data collected is presented in Figures 1 through 8. This arrangement was to keep the classroom-discussion focussed on the selected aspects of irrigation performance.

Data Presentation:

Figure 1. shows a simple comparison of irrigation indents placed and supplies monitored along Major 5 on 25 February. This information is directly taken from the above given data Table.

For the purpose of interpretation and discussion, following questions were asked:

(1) *The indents placed by the Rahad Agricultural Corporation for Major 5 at each control point are*



	K 0.0	K 1.5	K 3.5	K 12	K 15	K 18	K 21	K 26
Supplies	535	448	380	307	214	141	105	56
Indents	810	750	585	555	405	270	190	160

Fig. 1. Supplies & Indents along Major 5

drastically more than delivery responses determined by the officials of MOI of Rahad. What are the factors which cause such mismatch?

(2) *In your opinion, what is the real use of placing or receiving indents on regular basis? Are there doubts about such requests to be irrelevant? How can such an existing institutional arrangement be utilized effectively?*

(3) *If the preparation of indents is practice with no practical use, should not it be better to eliminate it?*

(4) *What are conscious efforts (if any) made to bridge the wide difference between supply and demand?*

(5) *If there have been no efforts to bridge the gap, do you have suggestions to remedy the situation?*

(6) *Under the new extended role of MOI for delivering irrigation water to the level of field outlet pipe (FOP), how will it help to address concerns regarding water distribution in the scheme?*

The response from RIO staff is summarized below:

(1) *Drastic difference between demand and supply resulted partly an incorrect reduced level used to determine head difference across the first gated structure for Major Canal No. 5.*

(2) *The block inspectors of the scheme place indents which are more than required. According to the RIO staff, the RAC official think that MOI always deliver less than demanded and hence they try to indent maximum.*

(3) *The current procedure being used to determine indents needs to be revised. However, the practice is a useful institutional arrangement and it should not be eliminated.*

(4) *In order to overcome difficulties caused due to canal siltation and the dynamic nature of*

crop water requirements, indents should placed daily. If indented amount stays constant, the RIO will assume that supplies are sufficient. If the daily suggested requests change, then supplies can be adjusted accordingly.

(5) *The extension of RIO / MOI's role to FOP-level is expected to ensure supplies for intended Abu Ashreens only. This will also help to evaluate increases in demand with the design capacities of different channels.*

(6) *An interesting response about the adequate water supplies was based on the argument that planned and planted areas have not been abandoned.*

Perhaps the RAC officials may like to argue about some of the responses given above. However, the responses merit due consideration in the process of explaining the water distribution in the Rahad Irrigated Scheme. At the same time, there may more to be added.

In order to share and improve understanding about the water distribution along Major 5, the attention of the RIO officials was drawn to second graphic presentation i.e., Figure. 2. This figure displays the same above referred data transformed for each reach.

The concept reach is defined here as a section of canal between two control points. For Major 5, following are the reaches:

R - 1 = K 0.0 to K 1.5
R - 2 = K 1.5 to K 3.5
R - 3 = K 3.5 to K 12
R - 4 = K 12 to K 15
R - 4 = K 15 to K 18
R - 6 = K 18 to K 21
R - 7 = K 21 to K 26
R - 8 = K 26 to K 38

Using the collected information the supplies and indents for each reach were determined by deducting cumulative supplies / indents of downstream reach from the cumulative supplies at the head of upstream reach.

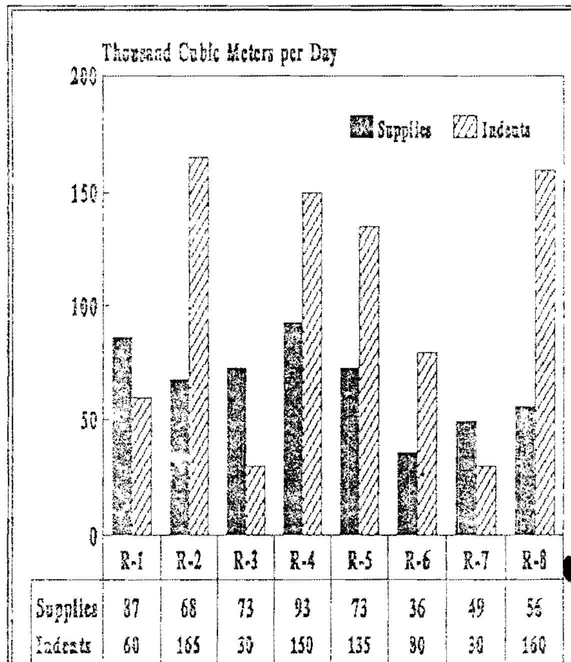


Fig. 2. Reach-wise Supplies and Indents

Looking at Fig. 2, following point questions aimed at seeking responses:

(1) *Fig. 1 shows a drastic difference between indents placed and supplies provided along each control point of Major 5 i.e.; more*

quantities requested and low delivery responses. However, the reach-wise data presentation in Fig. 2 provides some interesting contrast. Reach Nos. 1, 3, & 7 are receiving more than amount indented. On the other hand, situation for the rest of the reaches is quite opposite. Why is it so?

(2) *Are we aware of the phenomenon of under and over supplies on reach basis as compared to under supply at each control point of Major 5?*

(3) *Do we need to look at each individual reach? There are certain reaches which have more direct Double Abu Ashreens (D.A.XXs), Abu Ashreens (A.XXs) as compared to the ones which have more Minor canals for D.A.XXs an A.XXs. It would also be important to discuss head-tail syndrome in this context.*

In response to the above inquiries, the officials were little bit surprised and taken aback. They did acknowledge the points raised. However, additional reasons for the depicted inequitable water distribution were as follows:

(1) *Guards (Gaffirs) of control structures do contribute to this problem of inequitable water distribution. However, they do it in response to complains from tails sections of different Minor canals.*

(2) *Changes in the water levels of main canal is an added factor.*

(3) *Double gated Minor canals also have a potential to receive more water.*

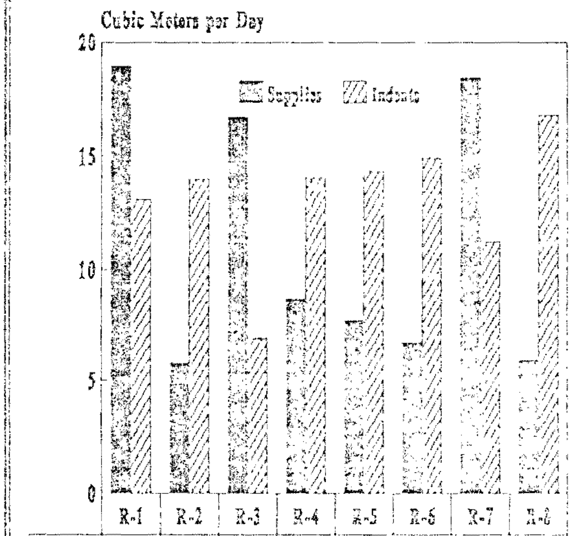
The above factors may contributes some inequity but they definitely do not tell the whole story. Fact remains that the system needs to be monitored regularly for making and implementing appropriate decisions to deliver adequate and equitable water supplies.

Further to elaborate on the distorted water distributions, Fig. 3 is presented here to show the differences in indents and supplies per feddan of reach-command areas. The referred reach-wise command areas are:

R - 1 = 4599 feddans
R - 2 = 11809 "
R - 3 = 4361 "
R - 4 = 10695 "
R - 5 = 9418 "
R - 6 = 5362 "
R - 7 = 2664 "
R - 8 = 9501 "

The reach-wise indents and supplies calculated earlier were divided by the command areas of reaches as given above. The resulting information is tabulated in Fig. 3.

From the information presented, it can be noticed that maximum supplies per unit command area were found in case of Reach Nos. 1, 3, and 7. However, respective supplies for rest of the reaches ranged half to one third of the above



	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
Supplies	18.92	5.76	16.74	8.7	7.75	6.71	18.39	5.89
Indents	13.05	13.97	6.88	14.03	14.35	14.97	11.26	16.84

Fig. 3. Reach-wise Qs & Qi per Feddan

stated "lucky" reaches. Similarly when we look at the indents per unit command area of each reach, except Reach No.3 the indents per feddan are within an acceptable range. Some difference might have resulted because of some difference in the ratios of cropped areas to the commanded areas of different reaches.

For discussion, following questions were asked:

(1) *Why the supplies/feddan of Reach Nos. 1, 3, and 7 are two or three times as compared to the rest.*

(2) *Why the indent per unit command area is very low in case of Reach No. 3 ?*

In response, it was recognized that drastic discrepancy existed among reaches. The most significant outcome of the exercise was the fact the RIO staff showed courage to confront by accepting its very existence. In addition to the obvious opportunities for improving the operational practices, following other contributing factors were also mentioned:

(1) *In case of Reach 1, its location at the head-end was considered to be an important factor. Also, the head Minor is the only Minor of Major 5 with two gates. Excess supplies can also result due the operation of such unique structure.*

(2) *Reach 3 has a unique feature: it has more direct double Abu Ashreens from Major 5. As the operations of such canals at this time are not strictly controlled, farmers are getting more share of water supplies as compared to the rest. Additional factor in such commands is the presence of influential farmers with a flexible cropping pattern. As the RAC is not responsible for the operations of such direct field canals, the indents placed are generally low - call it a " futile step treatment."*

(3) *Reach 7 has also more direct Abu Ashreens and Double Abu Ashreens and shares the same fortunate features as described for Reach 3.*

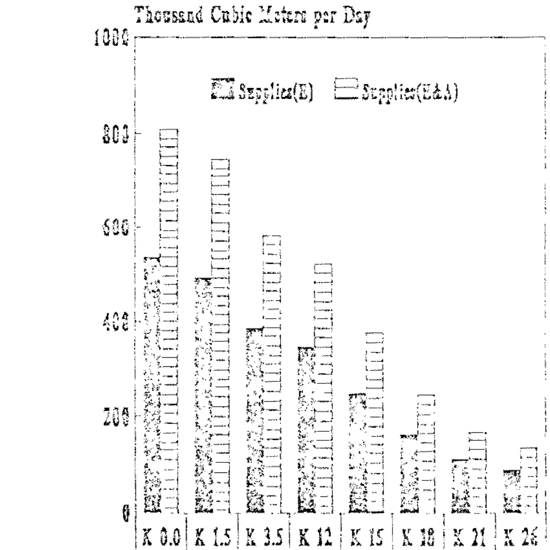
Ideas for Operating System for an Equitable and Adequate Water Distribution:

Like many other irrigation systems in Sudan, the Rahad System is also designed for adequate and equitable water distribution (irrespective of time and location). Even if the supplies are not adequate as compared to the ones requested / indented, for example on 25 February 1993, one can still operate the system such a way to achieve an equitable water distribution based on an agreed criterion. If we agree to an equitable water distribution on command area basis, the supply received head of a canal be divided by its total command area and then calculations can be made for respective supplies at each control point down the line as shown in Fig. 4. Similar exercise can also be repeated for adequate and equitable water supplies. If we assume that indents indicate the irrigation water requirements, then projected adequate and equitable quantities of water supplies in case of Major 5 will result as shown in Fig. 4.

In the context of Fig. 4. following questions are for discussion:

(1) In order to distribute the projected supplies, how should we proceed?

(2) What kind of facilities are needed for implementing the potential options for equitable or equitable and adequate water distribution?



	K 0.0	K 1.5	K 3.5	K 12	K 15	K 18	K 21	K 26
Supplies(E)	535	493	385	345	247	161	111	87
Supplies(E&A)	810	746	582	522	374	243	169	132

Fig. 4. Projected Water Supplies

The response to these questions resulted into a brainstorming exercise. A summary of views expressed is given below:

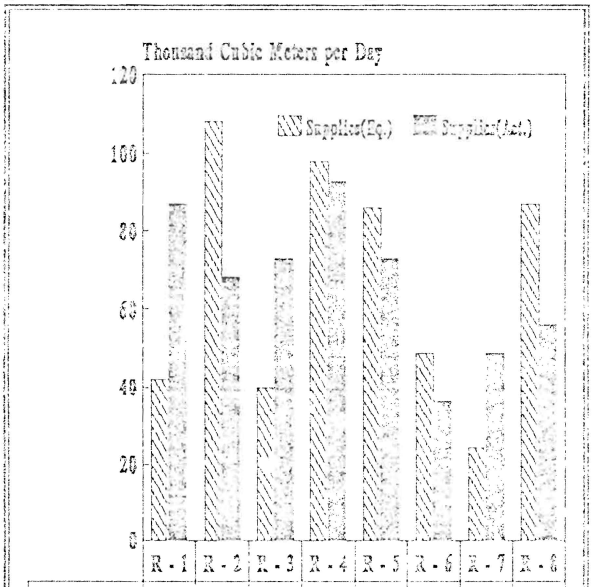
(1) Using the "Decision Support Manual for Flow Measurements (Shafique, 1992), the weirs and gates can be set or adjusted to match the projected supplies. In case of gate-structures, gate openings may have to be readjusted when water levels on upstream and downstream stabilize. However, gate setting will have dominating effect as compared to change in the operating head across a structure.

However, to deliver pre-determined supplies at different control points along Major 5, close *monitoring and adjustments of Minors and other direct canals have to be ensured. Such a simple methodology is recommended to be tested during the next irrigation season.*

(2) *For pilot testing the suggested operational scheme, improved communication system such as "walky-Talky hardware" will be of immense use.*

Comparison of Actual versus Projected Supplies:

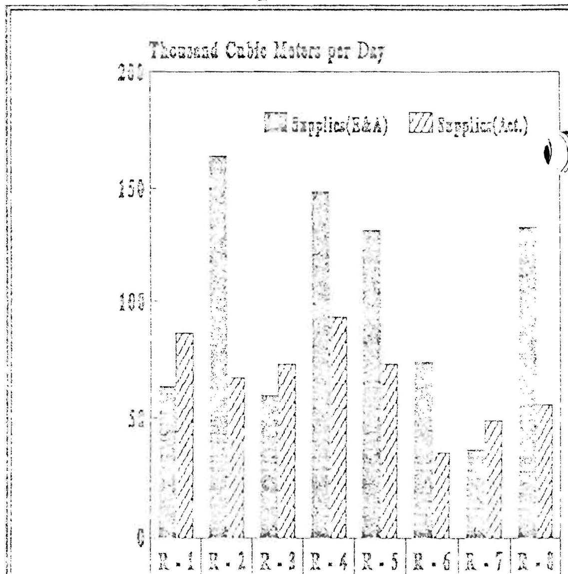
Fig. 5 presents almost similar information as shown in case of Fig. 4. However, the latter is intended to show differences in actual supplies as compared to the ones projected for an equitable



	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
Supplies(Eq.)	42	108	40	98	86	49	24	87
Supplies(Act.)	87	68	73	93	73	36	49	56

Fig. 5. Projected (E) & Actual Supplies

water supplies of different reaches of the Major 5. Similarly, Fig. 6. presents a comparison between actual and equitable & adequate water supplies for different reaches. One has to note that in either case, actual supplies in case of Reach Nos. 1, 3, and 7 are still higher than projected supplies. Naturally such phenomenon should effect others reaches adversely under short supply situation as monitored on 25 February 1993.



	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
Supplies(E&A)	64	164	60	148	131	74	37	132
Supplies(Act.)	87	68	73	93	73	36	49	56

Fig. 6. Projected (E&A) & Act. Supplies

In this context, the discussion was focussed around following questions:

(1) *What makes the Reach Nos. 1, 3, and 7 so lucky ? Is it only a chance or are there some other factors which favor this situation?*

(2) *How can appropriate management decisions help to distribute this abundance of luck to relatively unlucky*

reaches of the same system?

In response to the above question, similar factors were narrated as before. It was hoped that pilot testing of new methodology for operation should minimize difference between the referred reaches.

Status of Irrigation Performance:

Irrigation performance has been evaluated in relation with the two design criteria stated earlier: adequacy and equity. Following Molden and Gates (1990) and Kuper and Kijne (1992), two performance indicators for Major 5 were calculated as described in the next section.

Adequacy

The concept of adequacy is to deliver the required amount of water over the command area of a system such as Major 5. In the local setting of Sudan, indents are perceived to be required amounts. If it is accepted that the indents do represent irrigation requirements, the adequacy index can be defined as supply-indent ratio or SIR. With this elaboration, a measure of performance in the context of adequacy can be given as

$$P_A = \frac{1}{T}\sum_{T}\left(\frac{1}{R}\sum_{R} P_a\right) \text{--(1a)}$$

$$P_a = \frac{Q_S}{Q_I} \text{ if } Q_S \leq Q_I \text{--(1b)}$$

$$P_a = 1 \text{ if } Q_S \geq Q_I \text{---(1c)}$$

Where

In the above equations, Q_s / Q_I (SIR) is ratio of water supplied in response to water indented. Here Q_s and Q_I are defined for discrete location n within a region R and for finite times t, over T. Overall measure is denoted by P_A and individual measures as P_a.

Figs. 7 & 8 provide information about supply-indent ratios (SIRs) about Major 5. Fig. 7. presents these ratios from head-end to tail-end. It is interesting to note that the range of SIRs was 0.35 to 0.66. (It is also interesting to note that SIR value for Major 5 is 0.66 as compared to 0.84 for the tail reach of the Rahad main canal below Kilo 76. Was it special one-day favor from one middle subdivision to the tail subdivision? Hard to tell at this point.) This implies that supplies were all the way less than what was indented at each control point along the system. In this case using Eqs. 1a, 1b, and 1c, P_A is found as 0.55. This should be evaluated with tentatively suggested standard of performance by Molden and Gates (1990). The authors describe that P_A value of more than 0.9 is assumed to be good, between .9 and .8 fair, and below .8 poor.

However, the Fig. No. 8. demonstrates that even under short-supply situation, the command areas of some reaches get supplies more than what was indented. In this case, reach-wise SIRs range 0.35 to 2.43. Here again it can be observed that "lucky" reaches are doing much better than other perhaps at the expense of others. P_A for reach-wise case comes to *reaches of the same system?*

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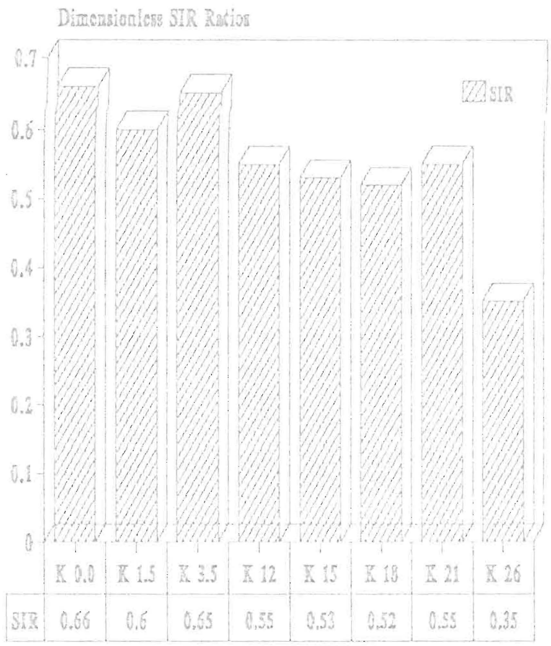

Fig. 7. SIRs at Control Points

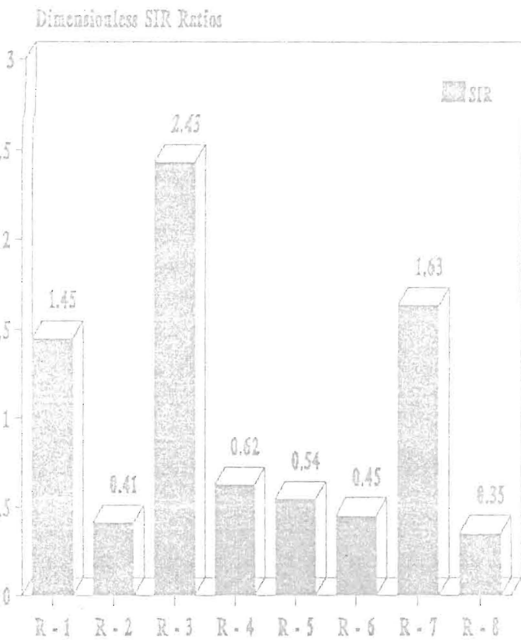

Fig. 8. Actual Reach-wise SIRs for Major

0.67. Either case, the chosen index shows performance below 0.8. It also indicates that the system which was designed for an adequate water supplies was not performing well on the day it was monitored.

Equity

The equity water distribution is defined as the ability of a system to uniformly deliver water over the system (Mohammed, 1987). Following Molden and Gates (1990), the equity parameter is defined as

$$P_E = \frac{1}{T}\sum_T CV_R\left(\frac{Q_S}{Q_I}\right) \text{---}(2)$$

In the above equation, $CV_R(Q_s/Q_I)$ or $CV_R(SIR)$ is the spatial coefficient of variance

(standard deviation / mean) for specific period T over the Region R. As the monitoring exercise was only for one day, time T is taken one. This parameter describes the degree of variability in relative water supply from location to location in region R. According to Kuper and Kijne (1992), the closer the value of parameter P_E is to zero, the greater the degree of equity (spatial uniformity) in supply. Molden and Gates (1990) propose good, fair and poor performance with values of P_E <.1,.1 to <.2 and > .2 respectively.

The P_E for data reported in Fig. 7 is .18 which is an index of fair performance. On the other hand, the P_E value based on reach-wise SIRs comes to 0.77. This implies a very poor performance of the system in meeting the objective of equitable water distribution.

It interesting to compare

P_A and P_E values derived from the data given in Figs. 7 & 8. The value of P_A is found to be 0.55 and 0.67 respectively. The difference is due to SIRs which are determined differently: cumulative basis for downstream reaches at each control point and individual basis for reach-wise supplies. It is better to use former data set for deriving P_A or adequacy measure. If no weighting factors are applied for reach-wise data (Fig. 8), the resulting P_A value may deviate from its actual average value.

However, in case of P_E, the data given in Fig. 7 hides lot of variability. It happens due to an averaging effect which occurs as indents and supplies of downstream reaches are combined at each control point. In this case, it recommended to use data as presented in Fig. 8 i.e., data organized on reach basis. The latter case is more appropriate for determining the actual spatial variability of relative water supply. This difference is quite obvious from P_E values of 0.18 and 0.77 based on information provided in Figs. 7 and 8 respectively.

Conclusions

A part of Rahad Irrigation System was assessed to see if it was meeting its design objectives i.e., an adequate and equitable water distribution. Based on above selected criteria, It was concluded that the distribution was neither adequate (P_A=0.55) nor equitable (P_E =0.77). In both cases, the performance on 25 Feb. 1993 shows vast room for improving canal operations.

Recommendations

(1) *At least one irrigation system should be monitored on regular basis for evaluating its performance.*

(2) *On pilot level (for example Major 5), the generated information from the above proposed should be used for proper gate setting for adequate &/ equitable water distribution.*

(3) *For improving the operations of a selected system, the relevant agency staff should be equipped with better communication facilities.*

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