# PERFORMANCE OF THE GEZIRA CANALS -REPORT BASED ON SECONDARY DATA (IIA)

BY
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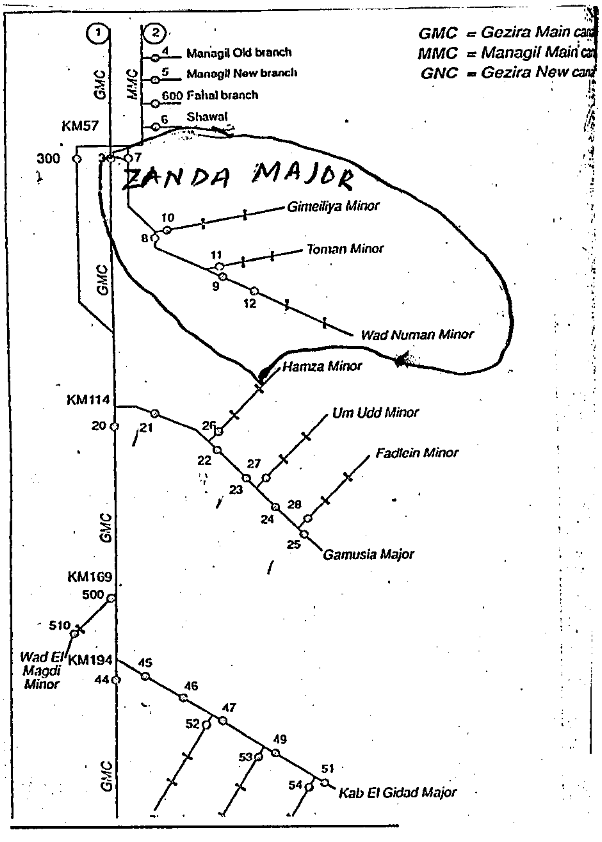
## *Majors (Sub-main Canals) of The Gezira Main Canal*

### *Brief Description about Selected Majors:*

*Figure 3 in the first part of this paper is reproduced here for quick reference. This is a schematic layout of Majors and Minors (secondary canals) selected along the main Gezira Canal for intensive monitoring over two irrigation seasons. The joint teams from the Hydraulic Research Station (HRS) and the Hydraulic Research, Wallingford collected data on collaborative basis during 1988-89 and 1989-90. The figure shows the measurements points for data collection.*




*The three Majors - (1) Zanda Major, (2) Gumasia Major, and (3) Kab El Gidad Major - have their supply points located at Kilo 57 (main pool), Kilo 114 and Kilo 194 respectively along the main canal. The analysis according to control points is based on either monitoring of required performance variables or information collected from different relevant sources of the Gezira scheme. The authors of the original report (TOR as defined in the first part) have proposed useful indices of performance. The data are tabulated in the above stated report. This paper uses this secondary data, both in terms of performance variables and indices, for additional analysis aimed at quantifying the performance of the system.*

### *1. Zanda Major ( Head Sub-main Canal)*

*Zanda Major does not draw it supplies from the main Gezira canal. Rather both the main canal and the major have common source, locally called as main pool, located at Kilo 57 from Sennar Dam. Because of its location, Zanda Major is taken as the head Major canal in the selected system.*

*Three selected control points are shown in Figure 3. The control point at head serves a total command area of 8520 ha (20285 feddans). The*

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command areas for the mid and tail control points are reported to be 5619 ha (13379 feddans) and 3634 ha (8652 feddans) respectively.

### a. Analysis According to Control Points (CP-analysis) & Discussion

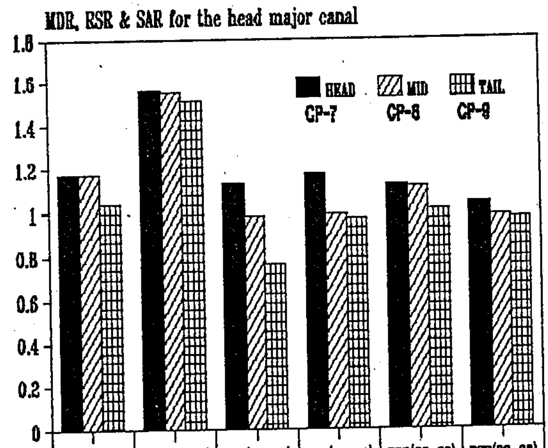
*In this analysis, the performance indices at head are average values for the entire command of the Major ( or any selected system). However, the performance indices associated with other control points along the subsystem represent only fractions of the total command downstream of each point.*

*Figure 6 displays different indices of performance such as MDR, SAR and RSR at selected control points. Each index presents performance over two irrigation seasons, 1988-89 and 1989-90.*

*The management delivery ratio (MDR) is defined as actual supply with respect to crop-water requirement. The referred figure shows that supply during the two seasons monitored was more than required. In 1988-89, the MDR was 1.17, 1.17 and 1.04 at head, middle and tail points respectively. Similarly the same index jumped to 1.56, 1.55 and 1.51 in 1989-90 for the same locations. This indicates that supply was always more than required for the Major.*

*The SAR in reality shows the extent to which actual supplies are matched with authorized releases. According to TOR, it is a measure of performance of a distribution system. But it should also include the performance of the individuals who are responsible for the matching process.*

*At the Major, the SAR value of 1.13 during the first season at the top control point indicates overall actual supplies were 13 percent more than authorized releases. This value reduces to 0.98 at the middle control point which is representative value for two-third command area of the Major. The SAR further dips at the tail control point, which serves about 43 percent of the command area, to 0.76. It clearly shows mismatch between actual and authorized releases at all control points. During the second monitoring season, there is good match at middle and tail control points; however, the section between head and middle control points absorbed 17 percent extra actual supply for the entire command of the Major.*




| | MDR(88-89) | MDR(89-90) | SAR(88-89) | SAR(89-90) | RSR(88-89) | RSR(89-90) |
|---|---|---|---|---|---|---|
| HEAD | 1.17 | 1.56 | 1.13 | 1.17 | 1.12 | 1.04 |
| MID | 1.17 | 1.55 | 0.98 | 0.99 | 1.11 | 0.98 |
| TAIL | 1.04 | 1.51 | 0.76 | 0.97 | 1.01 | 0.97 |

**Water Distribution along Zanda Canal**

**Fig. 6. Performance indices at selected control points**

*Comparison of SAR values of the Major with the main canal indicates a worsening trend in this context. It appears that more efforts are directed to operate main canal according to authorized releases as compared to the Major. Whether it is a general trend remains to be seen.*

*The RSR (relative water supply*

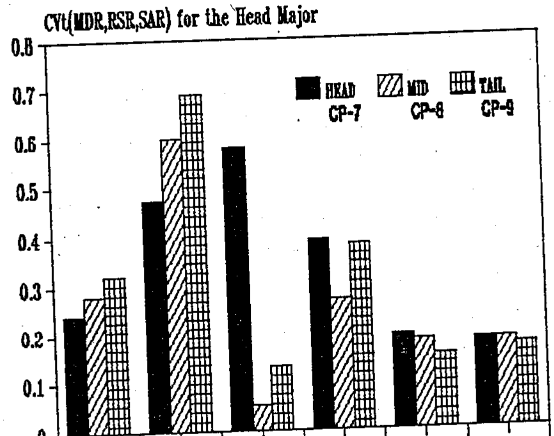
ratio) index is aimed to quantify the degree of water supply per unit command area at any lower level of a system corresponding to similar unit flow available for an entire selected system. Under the conditions where either cropping patterns are fixed or water is distributed on area basis and main concern is an equitable water supply, this index can be used to quantify the relative water supplies at different levels to the one available at the head of a selected system.

Figure 6 presents a comparison of the ratios according to head, middle and tail-positions over the two monitoring years (1988-90). The head Major, on an average basis, received 12 percent more available supply in the first year as compared to 4 percent in the following year. These figures show that the Major consumed more water than its due share based on area served.

Adequacy index, $P_A$, was calculated using Eqs. 1a to 1c as given in the Part I of the paper (reproduced in Appendix A for quick reference). The resulting values of the adequacy parameter, $P_A$, were found as 0.97, 0.96 & 0.90 for control points at head, middle and tail of the Major canal in the first monitoring year. In the second year these values were almost same i.e., 0.99, 0.96 and 0.96 respectively. This shows that an overall increase of MDR from 1.17 to 1.56 during the two seasons hardly made any contribution toward the values of $P_A$. The increase in MDR during the second year simply indicates a jump in over-supply from 21 percent to 57 percent. The over-supply ratio (OSR) is calculated as follows:

$$OSR = \left[\frac{MDR - P_A}{P_A}\right] \times 100 \quad ----(7)$$

In order to quantify the level of dependability for individual control points, Eq. 2 (reproduced in Appendix A) takes value of R (region or location) as 1. For each point, an average temporal coefficient of variation, $CV_T(Q_d/Q_r)$, is determined. Similarly, the same definition can be extended to other parameters such as SAR and RSR by replacing MDR $(Q_d/Q_r)$ with SAR $(Q_d/Q_{Auth.})$ and RSR$(q_{sub-system}/q_{system})$. Figure 7 presents such data.




| | CVt-MDR(1) | CVt-MDR(2) | CVt-SAR(1) | CVt-SAR(2) | CVt-RSR(1) | CVt-RSR(2) |
|---|---|---|---|---|---|---|
| HEAD | 0.24 | 0.47 | 0.58 | 0.39 | 0.19 | 0.18 |
| MID | 0.28 | 0.6 | 0.05 | 0.27 | 0.18 | 0.18 |
| TAIL | 0.32 | 0.69 | 0.13 | 0.38 | 0.15 | 0.17 |

Water Distribution along Zanda Canal

Fig. 7. Dependability index at selected control points

According to information given in Fig. 7, the index of dependability based on MDR, $P_D$(MDR), reveals an unsatisfactory levels over the both referred years. It also shows that the parameter doubles during the second year implying even worsening situation. But this may not be an alarming factor when average values of MDR at each point during the both periods are almost always more than 1. This index may reflect a serious situation under short supply scenario i.e., when MDR values are less than 1.

*Similar trend is observed in case of $CV_T$(SAR) which also indicates that efforts directed to match actual supplies with authorized releases are not dependable at this Major. During 1988-89, low values of the index at mid and tail of the canal are due to few data points.*

*According to a criteria set by Molden and Gates (1990), it is interesting to note that $CV_T$(RSR) can be classified in a fair range. This might have resulted due to the location factor too.*

*For individual points, the parameter of Equity, $P_E$, can not be calculated for individual locations. For determining the index, there should at least three data-locations. However, this parameter will be discussed at point of overall evaluation of the Major canal.*

*b. Analysis According to Sections (Section - analysis) & Discussion*

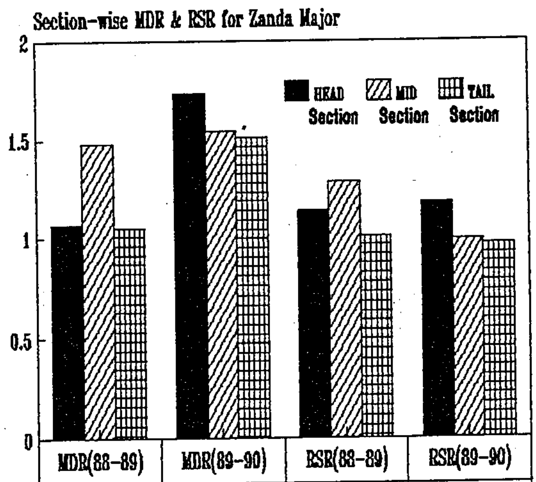
*In Part I of this paper, definitions of sections and reaches in the context of main canal are presented. Same understanding is extended to the next level i.e., sub-main canals of the system. As constrained by the availability of data, analysis on reach-basis could not be done.*

*As per definition of reaches / sections, it should be noted that tail reach / section will have the same values as the one determined by the data collected at tail control point. However, the same may not be true for the reaches, sections and control points on the upstream side.*

*In case of Zanda Major, the stretch between control points 7 and 8 is taken as head section. The middle section lies between control points 8 and 9. The segment of the Major below Control Point 9 is described as tail section. The corresponding command areas for these sections are as follows: (i) head section = 2901 ha (6906 feddans), (ii) middle section = 1985 ha (4727 feddans), and 3634 ha (8652 feddans).*

*Figure 8 provides information about water distribution according to the above selected sections of the Major. The figure only displays two performance parameters, MDR & RSR, for the monitoring seasons of 1988-89 and 1989-90.*

*According to MDR values calculated pertaining to the first monitoring season show that the head and tail sections received supplies on an average basis almost equal to estimated crop water requirements. However, middle section gained 48 percent more supplies as compared to its crop water requirements. When the values of the management delivery ratios calculated for 1989-90 are compared with those of 1988-89, there is an increase of 62.6, 4.1, and 43.8*




| | MDR(88-89) | MDR(89-90) | RSR(88-89) | RSR(89-90) |
|---|---|---|---|---|
| HEAD | 1.07 | 1.74 | 1.13 | 1.17 |
| MID | 1.48 | 1.54 | 1.28 | 0.99 |
| TAIL | 1.05 | 1.51 | 1.01 | 0.97 |

Water Distribution along Zanda Major

Fig. 8. Performance indices for selected sections

*percent at head, middle and tail sections of the canal. It should also be noted that during the second referred season, average supplies were atleast 50 percent more than crop water requirement for all three sections.*

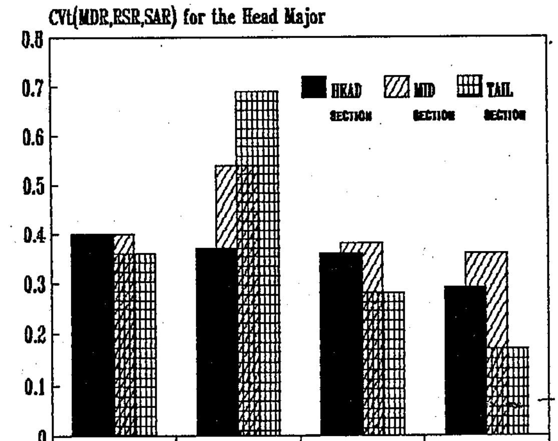
*The above situation at the head Major should be evaluated by comparing these excessive supplies with the ones available for the entire command area of the Gezira main canal being 13 percent less than required. However, in addition to water distribution problems the increase in MDRs was also resulted due a net effect of decrease in cropping intensity ( 68 % to 65%), proportional areas under cotton, groundnut / sorghum and increase in the proportional area under wheat over the first year. This caused requirements to drop about 27.3, 8.8 and 13.1 percent for the head, middle and tail sections respectively. As the total supply to the Major did not decrease accordingly, rather increased slightly (0.04 %), the MDR values jumped up. However, the relative situation at the Major and main canal does not change with the given explanation.*

*Figure 8 shows that the relative supply ratios (RSR) for the Major were either close to 1 or more than 1. According to the information presented, supplies at Zanda Major were found to be 13, 28 and 1 percent more at head, middle and tail sections during 1988-89 as compared to an average amount available at the Gezira main canal level. During 1989-90, only the head section received 17 percent more than the average supply calculated at the head of main canal and the RSRs for other two sections were slightly less than 1. However, this change might have resulted due to a 5.2 percent increase at main canal over the previous year and almost no corresponding increase at the Major level.*

*The values of adequacy index, $P_A$, are calculated using Eqs. 1a, 1b & 1c. For the head, middle and tail sections the indices are estimated as 0.89, 0.96 and 0.90 during 1988-89 and 0.98, 0.92 and 0.96 during 1989-90 respectively. From adequacy point of view, the results show a good performance. However, to achieve such goal the over-supply ratios are in the range of 17 to 54 percent in the first year and 57 to 78 percent in the second year. It can be noticed that with a very little improvement in the values of $P_A$ (3 percent), there was substantial increase in OSR (almost doubled). So, when the good levels of adequacy achieved are evaluated with the resulting OSRs, the price seems to be fairly high.*

*Next step is to look at the level of dependability of supplies according to each section. To quantify this occurrence, an index termed as $P_D$ is already defined by Eq. 2 in the first part of this paper. However, for individual points it will reduce to $CV_T$(MDR or RSR). Figure 9 presents the values of $CV_T$(MDR) and $CV_T$(RSR) for the period of two years under consideration.*

*In the context of dependability, farmers and managers have to be concerned with the availability of supplies in response to crop water requirements during a specific period of time. So, for the individual points $CV_T$(MDR) is a relevant index. When the values of the index in the above figure are compared with the criteria stated by Molden and Gate (1990), the performance parameter falls in a category termed as unsatisfactory level. As a matter of fact, it gets bad to worse as the monitoring study advances from Year 1 to Year 2. However, one may have to evaluate the*




| | CVt-MDR(1) | CVt-MDR(2) | CVt-RSR(1) | CVt-RSR(2) |
|---|---|---|---|---|
| HEAD | 0.4 | 0.37 | 0.36 | 0.29 |
| MID | 0.4 | 0.54 | 0.38 | 0.36 |
| TAIL | 0.36 | 0.69 | 0.28 | 0.17 |

Water Distribution along Zanda Canal

Fig. 9. Dependability index for selected sections

*impact of this index differently under two supply settings: (i) adequate / over-supply, and (ii) short-supply. One more question can be raised about the usage of this index when a system or components of a system have management delivery ratios either close to one or more than one over a selected period considered for evaluation.*

*The other $CV_T(RSR)$ index indicates variations in the distribution of supply received by the Major relative to an average water supply available, adequate or not, at the main canal level. These values are not very good either, however, they are better than those determined by $CV_T(MDR)$. This is particularly right when the result of second year are compared. Corresponding to similar values of $CV_T(RSR)$ at the main canal, the Major shows a worsening trend.*

*c. Comparative Analysis*

*It will be useful to compare results for the two different types of analyses applied: (i) according to control points (CP-analysis), and (ii) according to sections (Section-analysis) of the Major. This comparison is intended to better understanding about water distribution at the Major level as the two methods complement each other in this context.*

*Analysis based on data collected at different control points presents performance of an entire stretch of canal on the downstream side of a location under consideration. The analysis according to sections helps to look at segmental performance of a selected system. This segment may contain one or more reaches as defined before. Accordingly, results are displayed in Figs. 6 & 8.*

*As per explanation given earlier in this paper, the resulting indices for the tail control point and tail section have to be same; however, the performance parameters for the other points / sections do differ significantly. Figure 6 shows values of MDR very uniform ( 1.17, 117 & 1.04 in 1988-89 or 1.56, 1.55 & 1.51 in 1989-90) during a period of two years. However, Fig. 8 indicates that water distribution is not as uniform as displayed by CP-analysis (1.07, 1.48 & 1.04 in 1988-89 or 1.74, 1.54 & 1.05 in 1989-90).*

*From Fig. 6, average relative supply ratios (RSR) show that the entire Major received more than its due share by 12 and 4 percent during 19988-89 and 1989-90 respectively. The way this surplus supply is distributed is evident from Fig. 8. The extra supply of 12 percent during the first year gives distribution according to sections 13, 28 and 1 percent at head, middle and tail* respectively. For the following year, the figure of 4 percent results into 17 percent increase for the head section only. There is very little change in the values of RSR for the remaining two sections during 1989-90.

It is also interesting to note that the average values of adequacy parameter, $P_A$, are 0.97 and 0.99 based on CP-analysis for the two year period. Whereas section-analysis shows that these values for the head, middle and tail sections are 0.89, 0.96 & 0.90 in the first year and 0.98, 0.92 & 0.96 in the second year respectively. Averages of these figures are going to be less than overall $P_A$s determined at the head control point. This difference can be attributed to an inequitable water distribution which caused drop in adequacy levels within a system.

d. <u>Overall Performance of Zanda Major</u>

Overall performance of the Major canal will be subjected to its design objectives: (i) adequate, (ii) dependable, and (iii) equitable water supplies within the command area. Corresponding performance parameters were defined in the first part of this paper by Eqs. 1 to 3 (also given in Appendix A).

As the resulting performance parameters with respect to different control points or sections may contribute differently toward overall performance, use of some kind of weighting factors seems appropriate. In Part 1 of this paper while describing an overall performance of the main canal, respective command areas were considered as weighting factors. Same technique is tried for the sub-main canals (Majors). Equations 4 to 6 are reproduced in Appendix B for quick reference.

Based on Eqs. 1 to 3, Table 5 presents unadjusted values of $P_A$, $P_D$ and $P_E$ being parameters of performance in terms of adequacy, dependability and equity of water distribution. Averaging scheme of the parameters at three control points is debatable due to the fact that the first control point provides an average value for the entire command. As the adequacy can be effected due to actual inequitable distribution at different locations, a simple average of each parameter at three control points was assumed to present relatively accurate status.

**Table 5. Unadjusted performance parameters ( $P_A$, $P_D$ & $P_E$)**

| INDEX | VALUE | ANALYSIS TYPE |
|---|---|---|
| $P_A$ 1988-89 | 0.94 | CP |
| | 0.92 | SECTION |
| $P_A$ 1989-90 | 0.97 | CP |
| | 0.95 | SECTION |
| $P_D$ 1988-89 | 0.28 | CP |
| | 0.46 | SECTION |
| $P_D$ 1989-90 | 0.59 | CP |
| | 0.53 | SECTION |
| $P_E$ 1988-89 | 0.09 | CP |
| | 0.25 | SECTION |
| $P_E$ 1989-90 | 0.10 | CP |
| | 0.25 | SECTION |

The above table shows that the adequacy parameter, $P_A$, is very high during the monitoring period of two

Table 6. Adjusted performance parameters ( $P_A$, $P_D$ & $P_E$)

| INDEX | VALUE | ANALYSIS TYPE |
|---|---|---|
| $P_A$ 1988-89 | 0.95 | CP |
| | 0.91 | SECTION |
| $P_A$ 1989-90 | 0.97 | CP |
| | 0.96 | SECTION |
| $P_D$ 1988-89 | 0.27 | CP |
| | 0.44 | SECTION |
| $P_D$ 1989-90 | 0.56 | CP |
| | 0.55 | SECTION |
| $P_E$ 1988-89 | 0.09 | CP |
| | 0.26 | SECTION |
| $P_E$ 1989-90 | 0.10 | CP |
| | 0.25 | SECTION |

1. Adequacy of water supply falls in a range classified as "good."

2. The dependability of water distribution is found unsatisfactory. However, as the values of MDR are almost always More than 1, the deterioration may not be very serious.

3. The index of equity also shows water distribution unsatisfactory. However, with some efforts it could brought within a fair range.

## References


(1) HR Wallingfrd & HRS. 1991. Research for Rehabilitation: Study of Reliability of Water Supply to Minor Canals (TOR). Volume 1 & 2.

(2) Molden, David J. and Timothy K. Gate. 1990. Measures of Evaluation of Irrigation Water Delivery Systems. In: Journal of Irrigation and Drainage Engineering, Volume 116,No. 6, ASCE.

years. Whether these values are determined by Cp-analysis or section analysis, adequacy index is higher than o.90. According Molden and Gate (1990), the performance in terms of adequacy will be classified as good. When these values are compared with those of the main canal, adequacy level at the Major comes better. Main reason for such improvement seems to the location of the Major. The "pool" located at Kilo 57 serves joint source for the main canal and Zanda Major. Relatively much less command and length of the Major also helps to achieve the difference. The values of the performance parameter based on section-analysis are slightly less than those determined by CP-analysis. We can hypothesize that had we extended our analysis to include reaches, the values of the index might drop further.

Table 5 also presents information about the parameter of dependability, $P_D$, at the Major level. Following observations are quite obvious:

(1) Values of $P_D$s over the period show that the performance in terms of dependability is not within desirable levels (i.e., it is un-satisfactory).

(2) When compared with the main canal, the Major indicates a worsening trend in the parameter.

(3) There is a dramatic difference between the values of $P_D$s determined by two methods: Cp-analysis and the section-analysis during 1988-89. However, the difference in following year is not very striking.

The parameter chosen to show status of water distribution in terms of equity, $P_E$, quantifies the respective performance as displayed in Table 5. Based on the information presented in the table, following comments can be made:

(1) When compared with the main canal, the values of $P_E$ derived by CP-analysis show a marked improvement in the performance at the Major level. However, Section-analysis does not show any change in the parameter from main canal to the head Major.

(2) It is important to note that the values determined by Section-analysis are about two and half time higher than the ones obtained by Cp-analysis. This trend shows the when a system is broken into smaller segments, the overall performance parameters show a noticeable change. As the reaches of a conveyance system are natural basic units for water distribution, results based on reach-analysis might be more realistic and different from the other two methods discussed in this paper.

(3) Water distribution according to Cp-analysis can be termed as good. However, the Section-analysis indicates $P_E$ in the unsatisfactory range. Based on the trend, it is hypothesized that $P_E$ would have further deteriorated had it been derived based on reach-wise data.

Table 6 presents adjusted values of $P_A$, $P_D$ and $P_E$. It is interesting to notice that adjusted values of different parameters given in the table are not very different from the unadjusted values of Table 5. This may be because of the differences in the respective command areas were not as big as in case of the main canal.

Based on section-analysis, which is considered to be the next option as compared to a reach-analysis, final comments about the head Major can be presented. According to the analysis, the performance in terms of water distribution for the head Major at head is summarized as follows:

## *APPENDIX A*

### *Performance Indices*

***Adequacy:*** A fundamental objective of irrigation systems in Sudan is to deliver the amount of water required to crops. To quantify the adequacy achieved, the authors have defined $P_A$ as

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

$$P_a = \frac{Q_d}{Q_r} \quad If \quad Q_d \le Q_r \text{------}(1B)$$

and

$$P_a = 1 \quad otherwise\text{--------}(1c)$$

Where $P_a = Q_d/Q_r$ is the ratio of water delivered over water required. In the context of Sudan, the water demand can be either crop water requirements or indents placed. The Equation 1 implies that $Q_d$ and $Q_r$ are defined for discrete locations where water is conveyed in a region R at finite time intervals within a period T.

Molden and Gates (1990) also proposed that $P_a$ value more than 0.9 is assumed to be good, between 0.8 to 0.9 fair, and below 0.8 poor (unsatisfactory as used in this paper).

**Dependability:** The performance measure indicates the uniformity of $Q_d/Q_r$ over time. system which achieves almost steady state is considered to be dependable. The dependability parameter is defined as follows:

$$P_D = \frac{1}{R}\sum_{R} CV_T\left(\frac{Q_d}{Q_r}\right)\text{-----}(2)$$

In this case $CV_T$ $(Q_d/Q_r)$ is the temporal coefficient (standard deviation / mean) of variation of the ratio $Q_d/Q_r$ over discrete locations in a region R, in a time span T.

Molden and Gate (1990) presented performance standard for $P_D$ as given below:

$P_D$ 0.0 to o.1 -- good,
$P_D$ 0.11 to 0.2 -- fair, and
$P_D$ over o.2 -- unsatisfactory.

( The authors have used term "poor" instead of unsatisfactory).

**Equity:** As defined by Mohamed (1987), it indicates the ability of a system to uniformly deliver water. Molden and gate (1990), Kuper and Kijne (1992) have suggested the following performance indicator for equity:

$$P_E = \frac{1}{T}\sum_{T} CV_R\left(\frac{Q_d}{Q_r}\right) \text{----}(3)$$

where $CV_R(Q_d/Q_r)$ is the spatial coefficient (standard deviation / mean) of variation of the ratio of delivered water to the required amount $(Q_d/Q_r)$. This coefficient of variation is defined for a specific time over a region R.

In this case also Molden and gate (1990) have proposed that the performance should be taken good if the equity parameter is between 0.0 to 0.1, fair if it falls between 0.1 and 0.2 ( and unsatisfactory if it exceeds 0.2).

# APPENDIX B

## Adjusted indices of Performance

In view of design objectives of the Gezira canals, following performance parameters are selected: (1) adequacy, (2) dependability, and (3) equity. These parameters are defined by Eqs. 1 to 3 given in Appendix A. However, it is proposed that for an overall performance values the referred equations have to modified. As the resulting parameters for different control points and sections will contribute toward an overall value differently, use of some kind of weighting factors seems appropriate. One such weighting factor could be an areas ($A_i$s) served by a reach, section or canal command below a control point. If the suggested weighting factor is used, the Eqs. 1 to 3 of Appendix A can be rewritten as follows:

$$P_A = \frac{1}{T} \sum_T \left[ \frac{\sum_R (P_a)_i \times A_i}{\sum_R A_i} \right] \quad \text{----(4)}$$

However, Eqs. 1b and 1c will define $(P_a)_i$ as before.

The performance parameter for dependability ($P_D$) can be redefined as

$$P_D = \frac{\sum_R \left[ CV_T \left( \frac{Q_d}{Q_r} \right) \right]_i \times A_i}{\sum_R A_i} \quad \text{-----(5)}$$

In this case also, $A_i$ are areas of ith reach, section or canal command below a control point. Rest of the variables are already defined.

While deriving the equity parameter, $P_E$), Eq. 3 will be used as it is. However, only one slight change is proposed to calculate mean value $(Q_d/Q_r)$ over entire region R at time period T by the following relationship:

$$Mean\left(\frac{Q_d}{Q_r}\right) = \frac{\sum_R \left[ \left( \frac{Q_d}{Q_r} \right)_{i times} A_i \right]}{\sum_R A_i} \quad \text{-(6)}$$

Rest of the procedure to calculate $CV_R$ will not change.