Nota 1504 January 1984

Instituut voor Cultuurtechniek en Waterhuishouding

REUSE OF DRAINAGE WATER IV

Report of a mission to Egypt

period: Sept 24 - Oct 7, 1983

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ACKNOWLEDGEMENTS

The authors wish to express their gratitude to their collegues of the Drainage Research Institute for their hospitality and pleasant cooperation offered. Especially, dr. Mohammed Hassan Amer, director, dr. Samia El Guindy, head of the Reuse Division, dr. Mohamed Nasr Allam, advisor for the Reuse Division, Eng. Laila El Sissy, head of the Waterquality Division, Eng. Gamal Abdel Nasr and Eng. Samira Mahroos deserve to be mentioned. The discussions with the teamleaders of the other Dutch projects residing at the DRI (Ir. H.J. van der Zel, Advisory Panel for Land Drainage Project, Ir. H. Deelstra, Pilot Areas and Drainage Technology Project and Ir. H. van Leeuwem, Fayum Water and Salt Balance Project) have been very helpful.

1. INTRODUCTION

Within the context of the 'Reuse of Drainage Water Project', which is a joint activity of the 'Drainage Research Institute' (DRI) and the 'Institute for Land and Water Management Research'(ICW), supported by the Ministry of Irrigation of Egypt and the Ministry of Foreign Affairs of the Netherlands, the authors, dr. P.E. Rijtema and ir. C.W.J. Roest, visited the Drainage Research Institute in Cairo from September 24 till October 7, 1983.

The purpose of the visit was to discuss the workshop on Reuse of Drainage Water with the participants who will contribute to this workshop and to follow up the progress in the measurement programme of the reuse division. In annex 1 to this report the itenary of the visit is presented.

The absence of ir. D. Boels, Dutch teamleader of the project in Cairo, during the visit was regretted by the authors. Unfortunately dr. Rijtema could not postpone his presence in Egypt due to other commitments.

During the visit it was decided to purchase locally on short notice three air conditioners and one car from project funds. It was agreed that ICW will request DGIS for preparing the necessary arrangements.

In the next chapters the items that received attention during the visit will be reviewed shortly.

2. REUSE OF DRAINAGE WATER WORKSHOP

For the Reuse of Drainage Water Workshop, that will be held in Cairo during the second half of Febraury 1984, several institutes of the Ministry of Irrigation and the Ministry of Agriculture have been invited to contribute one or more papers. The invitations for participation have been sent by dr. Samia El Guindy immediately following the previous consultant mission of ICW (april 1983). During the present mission the Water Master Plan Project (Eng. Baiumy), the Groundwater Research Institute (dr. Kamal Hefny) and the Irrigation Research Institute (dr. Hassan Wahby) were visited. All three institutes reported that their contribution to the workshop were already under preparation.

Unfortunately the Alexandria University and the Soil and Water Research Institute could not be visited because the persons invited (prof. Balba and dr. Ibrahim Qantar respectively) were on mission abroad.

Very useful information on the operation procedures of the irrigation system were obtained during the visit to the Irrigation Research Institute. Also on farmer's bahaviour with respect to field irrigation interesting information was obtained. From farmers interview conducted by the Irrigation Research Institute in certain areas it appeared that roughly 50% of the farmers irrigated their land during the night for about 35% of the irrigation turns required. This means that a gross average of about 17.5% of the irrigation takes place during the night and 82.5% during the day time. Suprisingly only 50% of the farmers who practice night irrigation allege to do so because of a shortage of irrigation water during the day. About 70% of the farmers received adequate amounts if irrigation water and also the timing of delivery was satisfactory. About 15% have a continuous shortage of irrigation water and about the same percentage have a shortage during summer only.

During the discussions with the participants for the workshop it became clear that they did not have a good idea of the data requirements of the Reuse Project. It has therefore been decided to send all invited speakers a checklist of data required and subjects of importance for the project. This checklist is presented in annex 2 to this report.

3. MEASUREMENT PROGRAMME

The progress of the reuse division with respect to the routine measurement programme has been reviewed. It was noticed that, for several reasons, the frequency of field observations during 1983 has been decreased from forthnightly to monthly. Lack of reliable transport and shortage of engineers are the main reasons for this deficiency. During the visit it has been agreed to extend the waterquality sampling programme to cover also the irrigation water. It has been agreed that weekly watersamples will be collected from the Nile in Gizeh and that during the forthnightly field trips in the Nile Delta irrigation samples will be taken from 7 specified locations in the Eastern Delta, 11 in the Middle Delta and 7 in the Western Delta.

Considerable progress has been made with the data processing and data consistency analysis of the water quality data collected since 1979. For the data on discharge the progress in the 'office work' of the engineers has been considerably more modest. Unfortunately the duration of the consultants mission was too short for ir. Roest to pay much attention to these matters.

A field visit has been paid to the Bahr Hadus Outfall measurement point to survey the site-specific charateristics with respect to the instrumentation possibilities.

4. A WATER QUALITY SAMPLING EXPERIMENT

During the field trip to the Bahr Hadus Outfall on 6 locations water samples have been collected. On each location one standard DRI sample bottle of 1 l was filled completely and 2 small 100 ml bottles were filled and transported in a small refrigerator powered by the car's battery. The purpose of the experiment was to check the CO_2-production in water samples during transport to the DRI laboratory under normal conditions (non-cooled) and under improved conditions.

After analysis in the DRI laboratory of the cooled and the non-cooled water samples the non-cooled samples were left open for 24 hours in order to enable the CO_2, produced during transport, to escape and the samples were analysed again (Due to an electricity break down only pH, EC, CO_3^{2-} and HCO_3^- could be determined).

On the last day of the consultant mission small sub-samples of

Table 1. Chemical analysis of cooled, non-cooled and opened (for 24 hours) water samples

water sample description	pH	EC	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	$PCO_2/PCO_2(eq)$
Bahr Seghayar											
cooled	7.4	0.38	1.48	1.01	1.12	0.05	-	2.40	0.55	0.93	17.3
non-cooled	7.8	0.38	1.53	1.33	0.71	0.05	-	2.28	0.27	1.59	6.8
non-cooled,24 h open	8.5	0.38	nd	nd	nd	nd	0.32	1.76	nd	nd	1.1*
ICW	8.6	nd	1.39	1.63	1.35	nd	0.10	2.70	0.54	0.81	1.3
Serua Pump Station											
cooled	7.4	1.36	2.22	4.53	7.31	0.09	-	4.00	5.67	5.30	26.8
non-cooled	7.7	1.49	2.61	3.11	9.43	0.09	-	5.92	1.21	6.35	20.5
non-cooled, 24 h open	8.5	1.36	nd	nd	nd	nd	0.64	3.52	nd	nd	2.7*
ICW	8.4	nd	2.54	3.02	6.67	nd	0.11	4.60	1.88	6.20	3.3
Bahr Hadus Outfall											
cooled	7.5	2.17	6.14	4.16	12.07	0.11	-	4.40	5.67	11.13	22.8
non-cooled	7.6	2.36	6.89	3.12	13.59	0.09	-	5.20	6.56	11.64	21.5
non-cooled, 24 h open	8.5	2.36	nd	nd	nd	nd	0.80	3.84	nd	nd	2.8*
ICW	8.5	nd	4.28	2.90	11.83	nd	0.16	5.40	3.99	12.90	2.3
Matareya Pump Station											
cooled	7.8	5.58	6.20	15.81	34.55	0.72	-	5.60	9.88	41.87	13.2
non-cooled	7.2	6.20	7.65	12.37	45.20	0.76	-	5.44	13.64	44.44	47.6
non-cooled, 24 h open	8.4	6.20	nd	nd	nd	nd	0.56	4.16	nd	nd	3.0*
ICW	8.2	nd	5.40	13.42	39.90	nd	0.08	5.60	10.30	45.50	5.3
Sadi Pump station											
cooled	7.9	0.95	2.68	2.33	4.68	0.11	-	5.30	1.90	2.94	12.0
non-cooled	7.6	0.99	3.06	2.66	4.89	0.11	-	4.96	1.56	2.91	22.1
non-cooled, 24 h open	8.5	1.00	nd	nd	nd	nd	0.48	4.16	nd	nd	2.9*
ICW	8.3	nd	2.94	2.46	4.58	nd	0.09	5.00	2.10	2.80	4.6
Bahr Bagar Drain											
cooled	7.7	1.00	3.44	2.28	4.68	0.18	-	5.30	1.33	3.19	18.7
non-cooled	8.0	1.15	3.83	2.61	5.10	0.21	-	7.36	1.45	3.97	13.1
non-cooled, 24 h open	8.3	1.13	nd	nd	nd	nd	0.64	5.12	nd	nd	6.5*
ICW	8.1	nd	3.95	2.30	4.68	nd	0.08	6.70	1.89	3.20	9.6

nd = not determined

* = estimated from pH and HCO_3 concentration

100 ml were taken from the opened non-cooled water samples for analysis in the ICW laboratory.

The results are given in table 1. In this table also the CO_2 gas pressure divided by the equilibrium pressure (equilibrium with air), as calculated with the programme prepared by Eng. Abdel Khalik, is presented. It can be noticed from this results that no systematic difference in CO_2 pressure exists between the cooled and the non-cooled water samples. The reason for this absence of systematic difference is not clear without further investigation. Most probably the time required for the sample to cool to 4 °C is too long to prevent the oxidation of organic material present in the drainage water. An explanation for the fact that in some cases the CO_2 pressure in the cooled samples is even higher than the non-cooled ones (cf Bahr Seghayar, Serua pump station and Bahr Baqar drain) could be the degree of filling of the bottles. This point did not receive attention during this experiment.
The effect of opening the sample bottles for 24 hours on the pH and on the CO_2 pressure is remarkable. It is, however, not known whether the pH value measured after opening is indentical to that of the drainage water before sampling. Therefore it is recommended to do some experiments measuring the pH in the field, complete analysis in the laboratory with the samples collected and transported under normal conditions (non-cooled) and analysis after leaving the bottles opened for a period of 24 hours. From the analysis performed at the ICW laboratory (see table 1) it seems that the additional CO_2 production after taking the subsamples from the opened water bottles is only minimal. Comparing the analysis results of the cations (Ca, Mg and Na) of the DRI laboratory with those of the ICW laboratory it appears that the results at ICW are approximately 5 - 10% lower on the average. For the anion analyses (HCO_3, SO_4 and Cl) the difference is negligible. It seems worth while to check the cation analyses in both ICW and DRI laboratories in the near future and to find an explanation for the differences found.

All analyses discussed before (cooled, non-cooled, non-cooled after opening for 24 hours) have been duplicated, one with and one without filtering pre-treatment. The analysis without pre-treatment

Table 2. Comparison of the pretreated samples (filtration) and the duplicate without pre-treatment, expressed as the difference between both

Water sample description	pH	EC	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Σ cat	Σ an
Bahr Seghayar												
cooled	-0.1	+0.05	-	-	+0.26	-0.01	-	-	+0.13	-	+0.25	+0.12
non-cooled	-	+0.02	-	-	+0.05	-	-	-0.16	-	-	+0.05	-0.16
non-cooled, 24 h open	-	+0.01	nd	nd	nd	nd	-	-0.16	nd	nd	nd	nd
ICW	-0.1	nd	+0.08	-0.43	-	nd	-	+0.60	-0.26	-0.10	-0.35	+0.24
Serua Pump Station												
cooled	+0.3	+0.07	-	-0.36	+0.84	-	-	-0.40	+0.13	-	+0.48	-0.27
non-cooled	-	-	+0.45	-0.45	-0.09	-	-	-1.60	-	-	-0.09	-1.60
non-cooled, 24 h open	-	+0.06	nd	nd	nd	nd	-0.16	-0.16	nd	nd	nd	nd
ICW	-	nd	-	-0.04	+0.02	nd	-	-	-0.09	+0.30	-0.02	+0.21
Bahr Hadus Outfall												
cooled	+0.3	+0.06	-	-0.36	+0.58	-0.04	-	-0.40	-	-0.26	+0.18	-0.66
non-cooled	+0.2	-	-0.10	+0.16	-	-	-	-0.08	-	+0.79	+0.06	+0.71
non-cooled, 24 h open	-	-	nd	nd	nd	nd	-	-0.16	nd	nd	nd	nd
ICW	+0.1	nd	+0.06	-0.02	+0.28	nd	+0.04	-	+0.03	-0.10	+0.32	-0.03
Matareya Pump Station												
cooled	+0.2	-	+0.24	-0.10	-	-0.30	-	-0.40	+0.16	+0.54	+0.06	-0.30
non-cooled	+0.2	+0.37	+0.24	+0.05	-	-	-	+0.16	-	-2.12	+0.29	-1.96
non-cooled, 24 h open	-0.1	-	nd	nd	nd	nd	-0.08	-	nd	nd	nd	nd
ICW	+0.2	nd	-	+0.08	+0.70	nd	+0.05	-0.10	-	+1.90	+0.78	+1.85
Wadi Pump Station												
cooled	+0.2	+0.08	+0.65	-0.33	+0.52	-0.02	-	+0.30	-	+0.11	+0.82	+0.41
non-cooled	+0.4	+0.19	-		-0.21	-	-	-	-	+0.06	-0.21	+0.06
non-cooled, 24 h open	-0.1	-	nd	nd	nd	nd	-	-	nd	nd	nd	nd
ICW	-	nd	-	-0.30	-0.03	nd	-	-0.10	-0.12	-	-0.33	-0.22
Bahr Bagar Drain												
cooled	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
non-cooled	-	+0.15	+0.76	-1.12	-	-0.03	-	-	-	-0.27	-0.39	-0.27
non-cooled, 24 h open	-	+0.15	nd	nd	nd	nd	-	-	nd	nd	nd	nd
ICW	-0.1	-	-0.50	-0.06	-0.05	nd	-0.01	-0.10	+0.42	+0.10	-0.61	+0.41
AVERAGE	+0.07	+0.07	+0.12	-0.19	+0.18	-0.04	-0.01	-0.12	+0.02	+0.06	+0.06	-0.05

nd = not determined

have been reported in table 1. The filtering has been done in both laboratories using suction and filters with a grain size retention of 0.4 micron have been used. The expectation was that due to the suction the CO_2 pressure would be lowered and consequently the pH increased. Further, it was expected that the cation concentrations would be lowered due to the filtration of suspended matter (adsorption complex of suspended clay particles. In table 2 the result of the duplicate analysis with filtering pre-treatmentis presented after substraction from the duplicate without pre-treatment.

Although the results are not very conclusive they indicate that the pH is only slightly influenced by the filtration procedure. Remarkable is that the total amount of cations is not reduced, but increased instead. The reason for this could be that the suction exerted to the filtration receiver flask causes an increase in evaporation. This is consistent with the increase in EC that has been measured. in the DRI laboratory. The conclusion that can be preliminary drafted is that the filtration of water samples under Egyptian conditions (for the water types found) should not be recommended.

5. SOME NOTES ON THE SUSY SUBMODEL

The Susy submodel should describe the irrigation water distribution below the level that is under complete control of the Ministry of Irrigation (irrigation command areas). It has not yet been decided what type of approach for modelling the supply system will be used in the Reuse of Drainage Water model. It is important, however, to formulate pertinent relations concerning the water distribution and to check the sensitivity of certain parameters and assumptions. Some of the preliminary ideas generated during and after this consultant mission are reported below.

The standard unit area that will be used in the model is approximately 1000 feddans (2 km * 2 km). Within this unit area the water delivery and the cropping pattern will be considered diffuse. Nevertheless it will be necessary to describe the irrigation network and to formulate the irrigation efficiency with some detail. The irrigation network intensity can be schematically described with the following characteristic parameters:

- the area served by a command canal, A_c
- the length of the command canal, L_c
- the number of distributaries branching off from the command canal, n_d
- the number of meskaa's branching off from the distributary, n_m
- the number of sakkia's along the meskaa, n_s
- the number of fields irrigated by the sakkia, n_f

Using these parameters the following 'average' characteristics can be calculated:

- the average length of the distributaries in the canal command area, $\bar{L}_d$:

$$\bar{L}_d = A_c/2\ L_c \tag{1}$$

- the average area served by the distributaries, $\bar{A}_d$:

$$\bar{A}_d = A_c/n_d \tag{2}$$

- the average length of the meskaa's served by the distributaries, $\bar{L}_m$:

$$\bar{L}_m = \bar{A}_d\ /\ 2\ \bar{L}_d = 2\ L_c/n_d \tag{3}$$

- the average area served by the meskaa's, $\bar{A}_m$:

$$\bar{A}_m = \bar{A}_d/n_m = \frac{A_c}{n_d * n_m} \tag{4}$$

- the average length of the area irrigated by the sakkia, $\bar{L}_s$:

$$\bar{L}_s = \bar{A}_m/2\ \bar{L}_m = \frac{A_c}{2\ n_m L_c} \tag{5}$$

- the average area served by the sakkia, $\bar{A}_s$:

$$\bar{A}_s = \bar{A}_m/n_s = \frac{A_c}{n_d * n_m * n_s} \tag{6}$$

- the average length of the field plot, $\bar{L}_f$:

$$\bar{L}_f = \frac{\bar{A}_s}{2\ \bar{L}_s} = \frac{2\ L_c}{n_d * n_s} \tag{7}$$

- the average area of the field plot, A_f:

$$\bar{A}_f = \frac{\bar{A}_s}{n_f} = \frac{A_c}{n_d * n_m * n_s * n_f} \tag{8}$$

For the length/width ratio of the irrigation field plot it follows from (7) and (8):

$$R_f = \frac{4\ L_c^2\ \ n_m\ \ n_f}{n_d * n_s * A_c} \tag{9}$$

Per sakkia an area of 10 to 20 feddans is normally served. If it is assumed that the length/width ratio of an field plot is 2 : 1 and the size about 1 feddan (4200 m^2) it follows that the length of the field plot is 92 m and the width 46 m. Combination of eq.(9) and (7), assuming $n_f = 16$ gives for n_m, the number of meskaa's: $n_m = A_c/1472\ L_c$. With equation 6 the number of sakkia's per meskaa can be calculated: $N_s = A_c/6700\ n_d n_m$. If the key variables A_c, L_c and n_d are known all paramaters given by eqs (1) - (9) can be calculated.

For the calculation of the waterdistribution within the irrigation command area not only the watersupply has to be known, but also the demand for water has to be specified. The soil moisture deficit can be calculated on the basis of actual evapotranspiration rates of each crop in the crop rotation. The actual demand for water on field plot level will generally be greater than this soil moisture deficit. Due to the water distribution efficiency caused by different infiltration time for the upstream and the downstream part of the field plot the demand will be greater. Due to the capacity of the irrigation equipment (sakkia, diesel engine, etc.) a certain minimum water depth will be applied. If this minimum depth is greater than the soil moisture deficit corrected for the water distribution efficiency the actual demand for water at the meskaa level is determined by the capacity of the irrigation equipment.

When assuming a constant infiltration rate equal to the saturated hydraulic conductivity the advance of the water front is given with the equation:

$$v = \frac{dx}{dt} = \frac{q - kbx}{by_o} \tag{10}$$

where: v = advance rate of the water front in $m.s^{-1}$
x = location of the water front at time t in m
t = time in s
q = streamflow size in $m^3.s^{-1}$

k = saturated soil conductivity in $m.s^{-1}$

b = width of the irrigation field plot in m

y_o = average waterdepth for the distance x during the advance time

The average waterdepth on the field can be derived from the Manning equation:

$$y_o = \left(\frac{q\,n}{b\sqrt{S_o}}\right)^{3/5} \tag{11}$$

where: n = coefficient of Manning (= $1/K_m$)

S_o = ground surface slope in $m.m^{-1}$

Integration of equation (10) for the boundary conditions $t = 0$, $x = 0$ and $t = t_1$, $x = 1$ gives for the total advance time:

$$t_1 = y_o/k \ln \left(\frac{q}{q - kbl} \right) \quad \text{for } q > kbl \tag{12}$$

where: t_1 = time required for the water to reach the end of the field S

l = length of the field in m

For the location of the water front it follows:

$$x = \frac{q}{k\,b} \left(1 - e^{-kt/y_o} \right) \quad \text{for} \quad t \leqslant t_1 \tag{13}$$

The total amount of water infiltrated into the soil over the whole field during the irrigation advance time follows than

$$V_{t_1} = \int_0^{t_1} kb\,x\,dt = q\,t_1 - q\,y_o/k\,(1 - e^{-kt_1/y_o}) \tag{14}$$

where: V_{t_1} = volume of water infiltrated during the advance time in m^3

If t_a is the total application time it follows for the water distribution efficiency:

$$e_d = \frac{q\,t_a - V_{t_1}}{q\,t_a} \quad \text{for} \quad t_a \geqslant t_1 \tag{15}$$

where e_d = water distribution efficiency

t_a = application time in s

The net quantity of water applied to the rootzone can be calculated as:

$$y_n = y_o + \frac{q(t_a - t_1)}{b\ 1} \qquad (16)$$

where: y_n = net irrigation gift in m

If M_d is the soil moisture deficit in the rootzone the application efficiency can be defined:

$$\begin{aligned} e_a &= M_d/y_n \quad \text{for } M_d \leqslant y_n \\ e_a &= 1 \quad\quad\ \ \text{for } M_d > y_n \end{aligned} \qquad (17)$$

where Md = soil moisture dificit in m

e_a = application efficiency

So far surface drainage has not yet been considered. Assuming a maximim allowable infiltration time of t_m (avoiding plant stress caused by shortage of oxygen supply) the net quantity of water infiltrated in the rootzone can be calculated:

$$y_n' = k\ t_m \quad \text{for} \quad t_m < \frac{qt_a}{kb1} \qquad (16a)$$

where t_m = maximum period during which standing water is allowed on the field in s

y_n' = net quantity of water infiltrated into the rootzone in m

The infiltration efficiency can be defined as :

$$\begin{aligned} e_i &= y_n'/y_n \quad \text{for} \quad t_m < \frac{qt_a}{kb1} \\ e_i &= 1 \quad\quad\quad \text{for} \quad t_m > \frac{qt_a}{kb1} \end{aligned} \qquad (18)$$

where: e_i = infiltration efficiency

If q_c is the capacity of the sakkia or diesel engine used by the farmers to irrigate the fields the efficiency of the field canal is:

$$e_{fc} = q/q_c \qquad (19)$$

where: e_{fc} = conveyance efficiency field canal

q_c = water flow delivered by the sakkia in $m^3.s^{-1}$

The total field application efficiency can be calculated as:

$$e_{fa} = e_d * e_a * e_i * e_{fc} \tag{20}$$

where: e_{fa} = field application efficiency

With equations (10) to (20) the demand for water on sakkia level has been defined and the operation time required for a sakkia or diesel engine to apply a net irrigation gift of M_d is:

$$t_o = \frac{M_d \; A_s}{e_{fa} \; q_c} \tag{21}$$

where: t_o = time required for the sakkia/diesel engine to apply an average irrigation gift of M_d to the area served by the sakkia A_s in sec.

Normally the capacity of the sakkia/diesel engine expressed in mm.day^{-1} (for the area A_s) is greater than the capacity of the meskaa expressed in mm.day^{-1} (for the area A_m). This capacity factor will determine to a great extend the distribution of the irrigation water over the command area. Considering the extraction of irrigation water from the meskaa canal diffuse the discharge in the meskaa canal can be calculated with the Chezy formula:

$$Q = C \; A(RS_f)^{1/2} \tag{22}$$

where Q = discharge in m^3.s^{-1}

C = coefficient of Chezy in m$^{1/2}$.s^{-1}

A = wetted cross section in m^2

R = hydraulic radius in m

S_f = friction slope in m.m^{-1}

For the friction slope the following equation is valid:

$$S_f = S_o - \frac{dy}{dx} \left(1 - \frac{Q^2B}{gA^3}\right) + 2 \; i \; \frac{QB}{gA^2} \tag{23}$$

where: S_o = bottom slope of the canal in m.m^{-1}

y = waterdepth in m

x = distance in m

B = width of the canal in m

g = acceleration of gravity (= 9.81 m^2.s^{-1})

i = lateral outflow in m^3.s^{-1}.m^{-1}

Due to the differences in capacity for the sakkia and the meskaa, the operation time of the sakkia, t_o, will be less than the period during which water is supplied by the meskaa. As a consequence, farmers located at the beginning of the meskaa will withdraw water with an intensity higher than i $m^2.s^{-1}$ during the day (preference for day irrigation), hereby increasing the meskaa discharge (S_f increases cf eq 23, Q increases cf eq 22). During the night withdrawal of water will be very low for the upstream part of the meskaa, decreasing the meskaa discharge. This will have consequences for the downstream meskaa canals (less availability of water during the day and excess during the night).

The equations for field application efficiency eq.(15)- (20) have been programmed for the HP 97 calculator and the sensitivity of the irrigation efficiency for the acreage of the field plot, the infiltration velocity and the soil moisture deficit has been determined. In fig. 1 the efficiency is given as a function of the acreage A in relation to the discharge q and the soil moisture deficit M_d for a infiltration velocity of 0.02 $m.day^{-1}$.

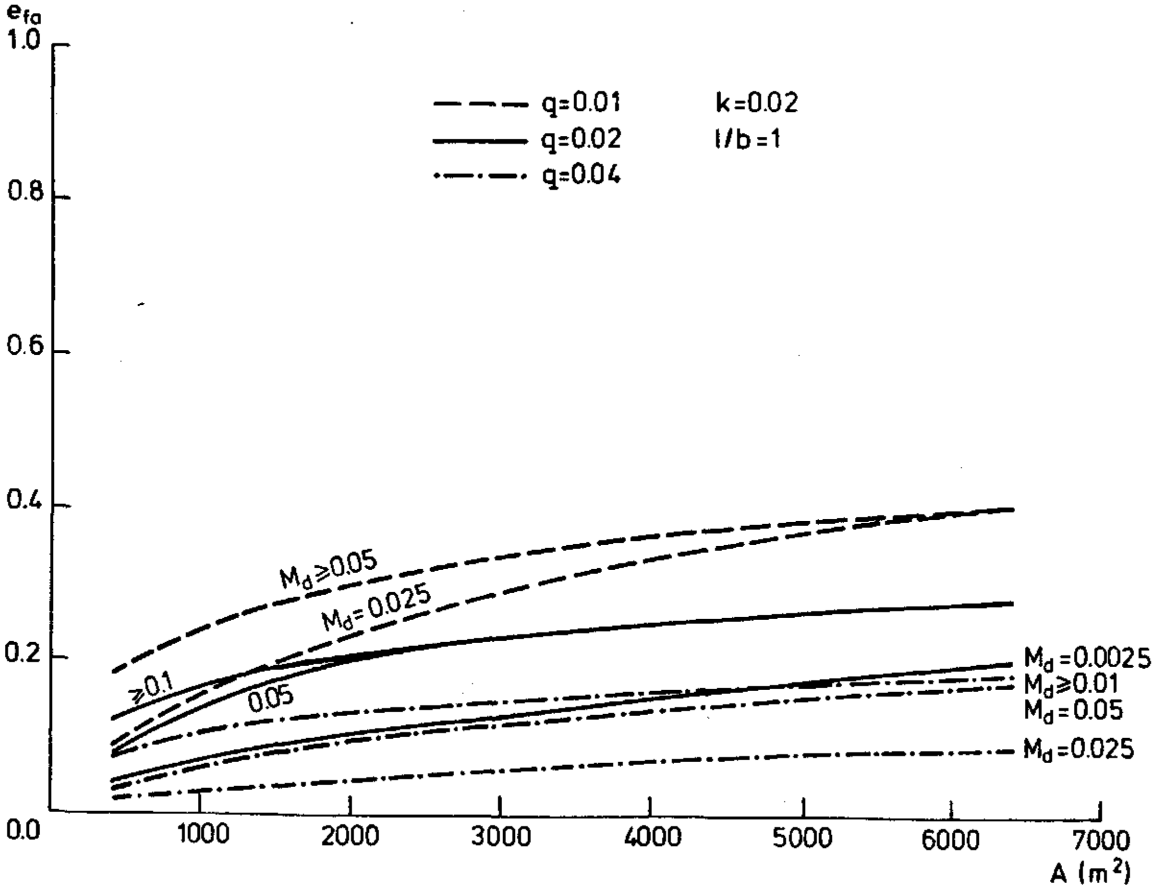

Fig.1. Field application efficiency in relation to field plot size for low soil permeability

Assumption that have been made for the efficiency calculations are the following:

- the fields are square ($l/b = 1$)
- the Manning coefficient of the soil surface $n = 0.33$ ($k_M = 3$)
- the maximum period water is allowed on the field is 12 hours
- the surface slope of the fields is 5 cm/100 m ($S_o = 5 * 10^{-4}$)

From fig. 1 it can be concluded that for soils with low permeability the relation between efficiency and size of the field is weak. Although higher efficiencies can be obtained with a lower discharge and with a higher soil moisture deficit, the efficiency is in all cases still very low.

In fig. 2 the same relation between efficiency and field plot acreage is given for a high permeability. For certain combinations of discharge and soil moisture deficit an optimum size of the field plot can now be observed. In general a smaller size of the field plot for lower discharge and smaller soil moisture deficit appears to be optimum. For greater field sizes higher discharges are appropiate.

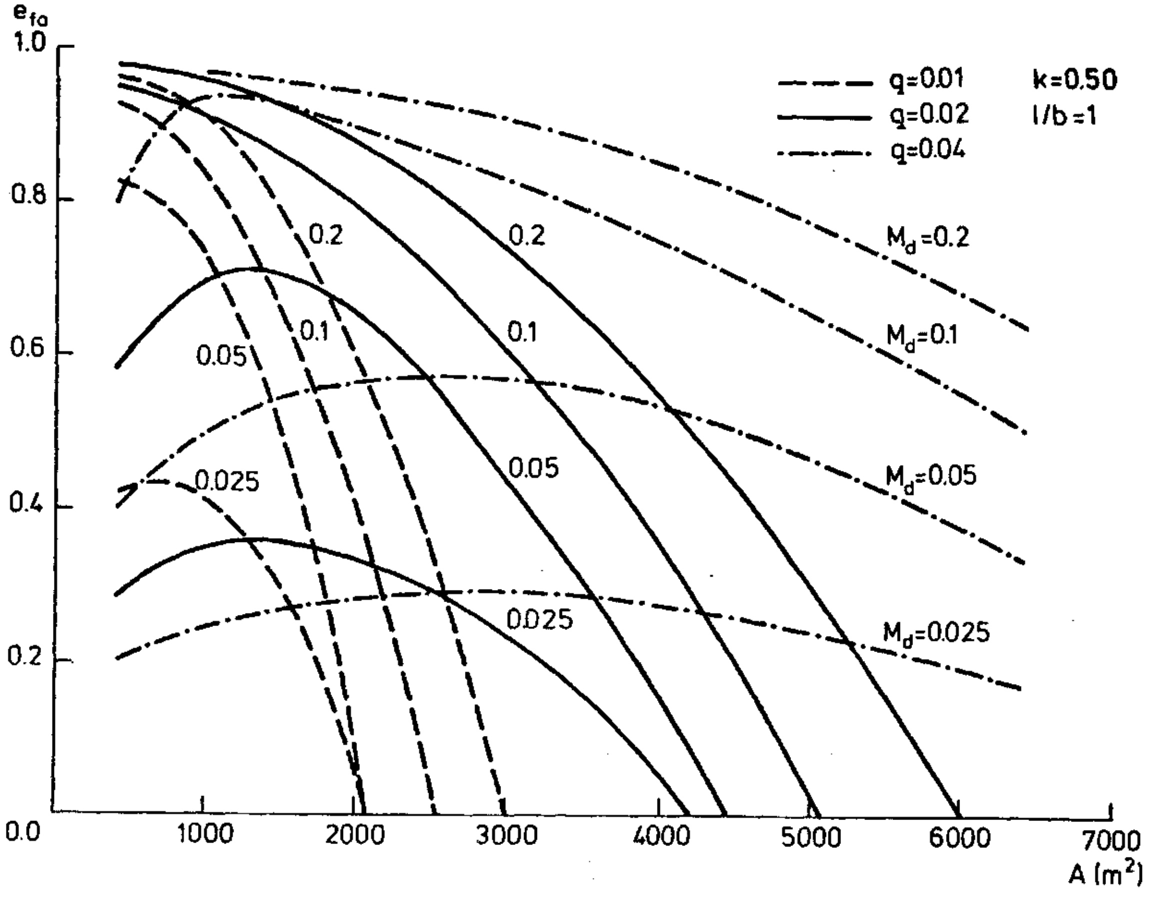

Fig. 2. Field application efficiency in relation to field plot size for high soil permeability

In fig. 3 the efficiency is given as a function of the soil permeability k in relation to the discharge q and the soil moisture deficit M_d for a field plot size A of 400 m^2. For low permeability there appears to be a strong relation with the efficiency untill a certain threshold value for the permeability is reached. For higher permeabilities the relation with the efficiency is weak.

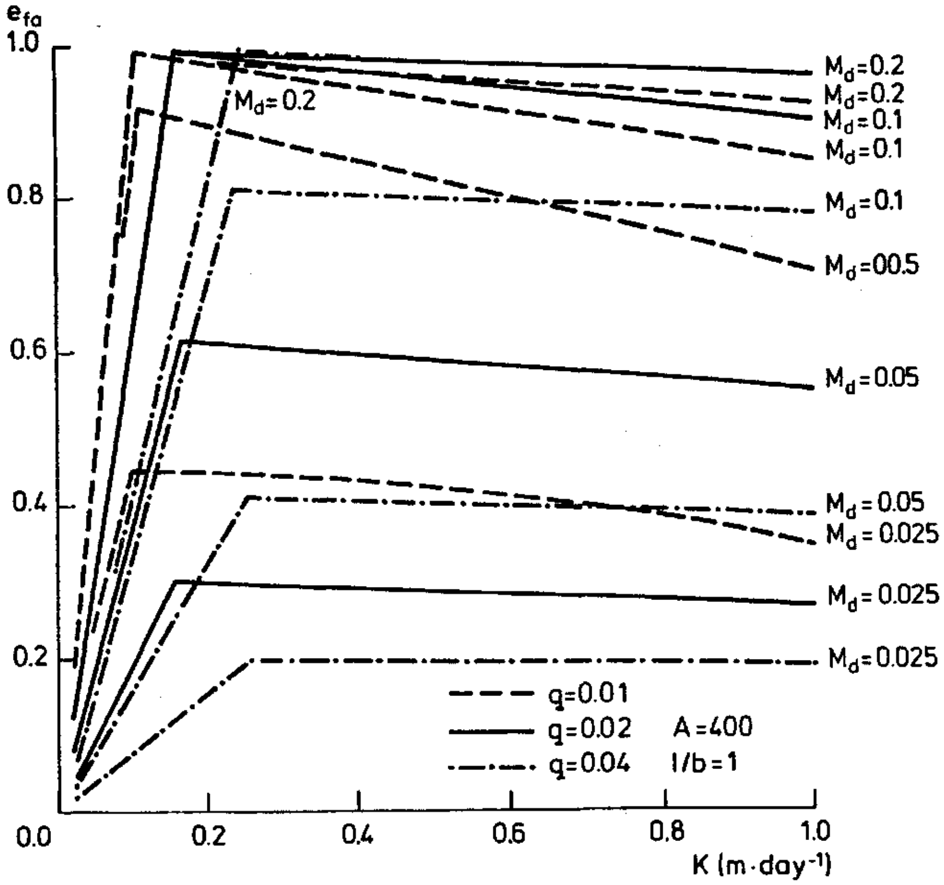

Fig. 3. Field application efficiency in relation to soil permeability for a small field size

At low permeability rates the lower discharges result in higher efficiencies. For higher soil moisture deficit and for higher permeabilities the influence of discharge and permeability becomes very low.

In fig. 4 the same relation is given for a large field plot size (A = 3200 m^2). For larger fields in all cases the relation between permeability and efficiency is strong.

The threshold value for permeability observed for a small field is an obvious optimum in this case. For low permeability a low discharge is required, for higher permeabilities a high discharge gives better results.

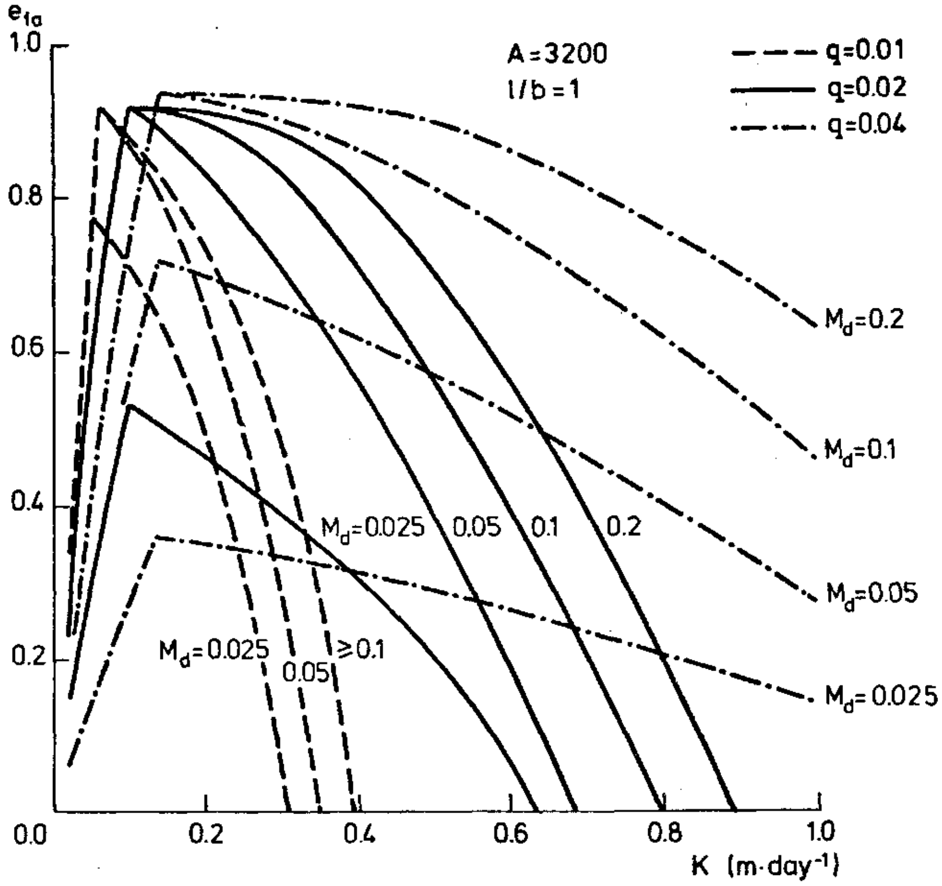

Fig. 4. Field application efficiency in relation to soil permeability for a great field size

Always a higher soil moisture deficit is more favourable than a low deficit.

In fig. 5 the efficiency is given as a function of the soil moisture deficit M_d in relation to the field plot size A and the soil permeability k for a low discharge q of 0.01 $m^3.s^{-1}$. For low permeabilities the largest field gives the highest efficiency. For the intermediate permeability (k = 0.1) an intermiate field size is optimum and for a large permeability the smallest field gives the best results. For the lower permeabilities the efficiency is strongly dependent on the soil moisture deficit untill a certain threshold value. Above this threshold value the efficiency is indepent of M_d. For larger permeabilities and field sizes the efficiency is related to M_d for the complete range.

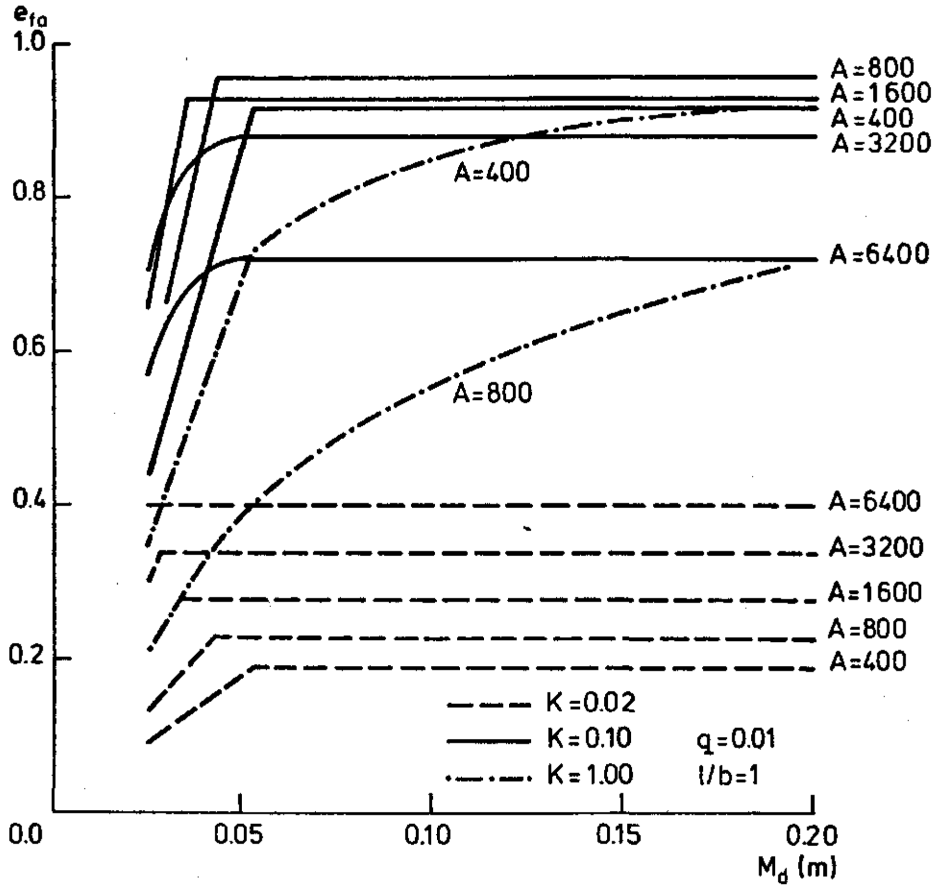

Fig. 5. Field application efficiency in relation to soil moisture deficit for low discharge

In fig. 6 the same relation is given for a high discharge. In general the same impression of the relation between efficiency and soil moisture deficit is displayed. The threshold value for M_d is much higher in this case, however, and for the lower permeabilities the efficiency is lower and for the higher permeabilities the efficiency is higher.

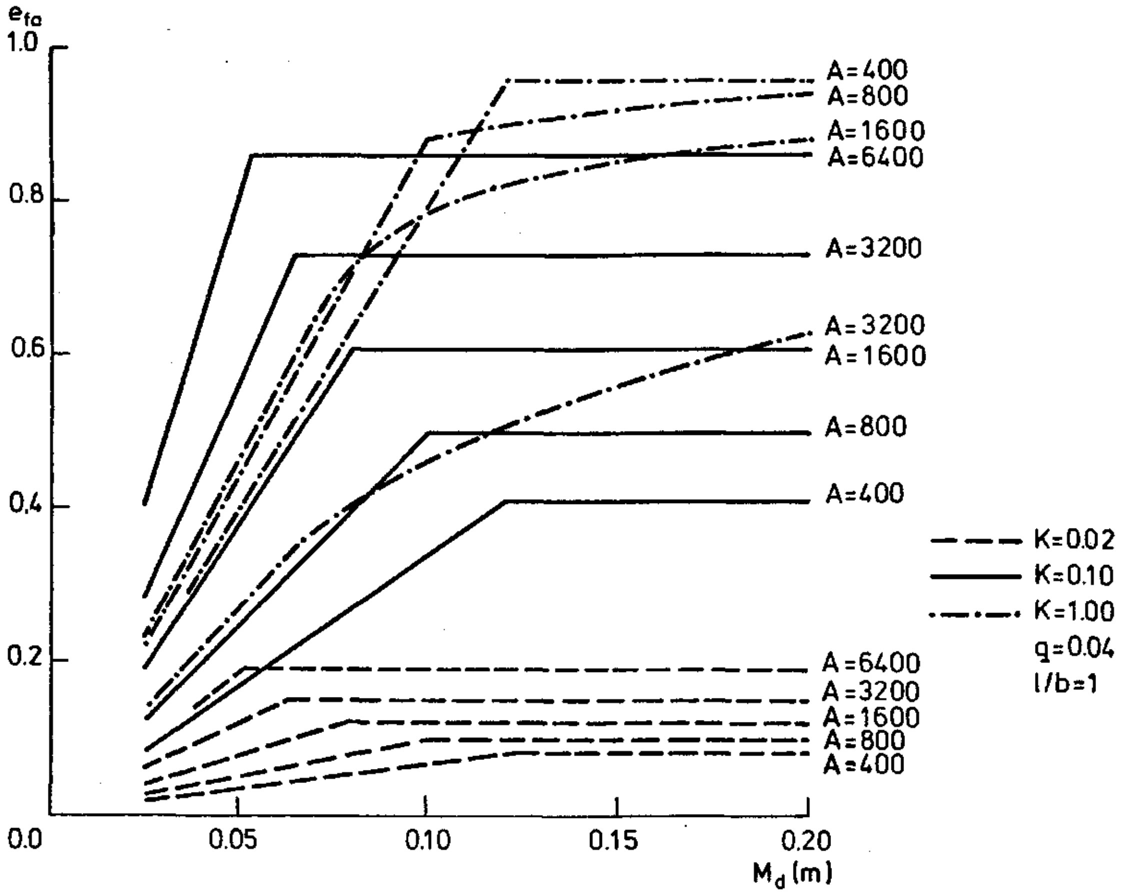

Fig. 6. Field application efficiency in relation to soil moisture deficit for high discharge

ANNEX 1: Itinerary

24- 9	Departure to Cairo
25- 9	Work at DRI. Discussions with dr. Amer, dr. Nasr and ir. v.d. Zel
26- 9	Work at DRI. Discussions with Eng Adel Abdel Rashid and engs Mohamed Saad Abbas
27- 9	Work at DRI. Visit to dr. Kanral Hefny, director of the Groundwater Research Institute. Discussions with Eng Mohamed Ezzet
28- 9	Work at DRI. Visit to dr. Hassan Wahby, director of the Irrigation Research Institute. Renting a house for ir. Boels
29- 9	Field visit to the Bahr Hadus Outfall with dr. Nasr, Eng Hussein El Atfy, Eng Mohamed Ezzet and Murad
30- 9	Official holiday. Discussions at the Dutch Embassy with mr. M. Rutgers. Lunch with eng. Gamal Abdel Nasr. Sailing at the Nile with the Dutch resident teams working with DRI on invitation of ir. V.d. Zel.
1-10	Work at DRI. Discussions with dr. Amer on logistic matters. Discussions with eng Omayma. Lunch at eng Laila El Sissy's residence.
2-10	Work at DRI. Discussions with the junior engineers on the Reuse Test Areas
3-10	Work at DRI. Visit to Khan El Khalily and lunch with dr. Samia El Guindy
4-10	Field visit to the Fayam oasis with dr. Amer, eng Eissa and ir. Van Leeuwen. Discussions with the director of the Regional Irrigation Department, eng El Atfy and with eng Hamdi Kutub
5-10	Work at DRI. Discussions with prof. El Gabaly, dr. Amer and ir. Van Leeuwen on the plan of operations for the Fayoum project. Discussions with dr. Amer and dr. Samia on the workprogramma for the reuse division
6-10	Official holiday. Visit to the museum and lunch with eng Gamal Abdel Nasr
7-10	Departure to Amsterdam

ANNEX 2. Checklist of data requirements for the Reuse model

Reuse of Drainage Water Project

The 'Reuse of Drainage Water Project' is a joint activity of the technical agencies:

Drainage Research Institute (DRI), Giza/Cairo-Egypt

and

Institute for Land and Water Management Research (ICW), Wageningen, The Netherlands.

The project is funded by the Ministry of Irrigation of Egypt and the Ministry of Foreign Affairs of the Netherlands in the framework of the joint programme of Technical Cooperation between Egypt and the Netherlands.

The Advisory Panel for Land and Drainage in Egypt acts as steering committee.

The objective of the project is to supply the Government of Egypt (Ministry of Irrigation, Minstry of Land Reclamation and Ministry of Agriculture) with the information on location, quantity, suitability and expected future changes of the drainage water resources in the Nile Delta required for the utilization of these recources in such a way that the envisaged land reclamation programmes can be implemented to the maximum feasible degree, with the minimal possible negative effect on the productivity of the new and old agricultural lands.

The immediate objectives of the project are to collect data on drainage water quantities and qualities, in order to forecast future changes thereof and to train the Egyptian staff involved.

For the formulation of a mathematical model, describing the relation between irrigation, soil moisture, soil salinity, crop production and drainage, information on available input data is required. For this reason the following questionnaire has been prepared.

I. Irrigation distribution system.

1. Is the capacity at the inlet point of the distributary dependent
   on: - the level in the main canal
       - water level in the distributary.

   If yes, detailed information of this dependency is required.

2. What are the design norms of the distributary canals? Can the design norms of the distributary be used in this study? If not, quantitative data on reduction of capacity due to poor maintenance are required.
3. What is the operational system during the inlet period? Is the opening of the inlet gate constant during this period? If not, detailed information on the operational procedures is required.
4. What is the capacity of the inlet system in relation to the area served? Detailed information and possible zonal variation (per Governorate or per irrigation district) is required.
5. What is the maximum allowed level in the distributary canal before the overflow starts to work. What type of overflow is present at the tail end of the distributary and what are its hydraulic characteristics.
6. What are normally the distances between misqaa's? 500m ? 800 m ? 1000 m ? more ?
7. What are the lengthes of the misqaa's? What are the area's served and at which level start the overflow (tail escape) to work?
8. What is the capacity of the misqaa's in relation to area's served? Should the design norms be reduced due to poor maintenance? Detailed information is required, with zonal distribution (per governorate, irrigation district).
9. What are capacities of sakkia's, magma's and diesel pumps in relation to area served? Detailed information on the occurrence of the different irrigation means is required with emphasis on their zonal distribution.
10. What are the water levels in the distributary or misqaa's before sakkia's, amgma's and motor pumps can start to operate?
11. How are the crop water requirements (frequency and quantity) translated into actual quantities supplied to the main canals and how are the distributary inlets operated?

12. What are the farmers priorities when irrigating his crops? Suppose all summer crops (cotton, rice and maize) need water, which crop will be irrigated first, second, last?
Suppose both winter crops need water which crop will be irrigated first? Berseem or wheat?

13. How much is an adequate irrigation application? Which allowance should be made for leaching?
How much is the normal field application of irrigation water when the farmer uses the sakkia for irrigation? 50 mm? 100 mm? 150 mm? more? How much when they use a diesel engine for irrigation?

14. If farmers have enough irrigation water they tend to over irrigate. How much will this overirrigation be? 25%, 50%, more?
Which percentage of the area will be overirrigated? Which percentage underirrigated?

15. How should the 20% conveyance losses be interpret? Are these the losses occuring after release of the water from the Asswan dam until the inlet of the main irrigation canals? Or are these the assumed operational losses in the main irrigation canal distribution canal system including the spill of water at the tail escapes?
If so, should one assume that of the 3 mm/day total drainage to the sea about 1,5 mm is irrigation water spilled directly to drains and about 1,5 mm is leachate?

II. Model input data

16. What is the quality of the irrigation water? Detailed information on seasonal and zonal variations in water quality are required.

17. What are the actual quantities supplied to the distributaries? Detailed information on seasonal and zonal variation is required.

18. Data on horizontal and vertical permeability of the top soil and spational variation (maps).

19. Data on horizontal and vertical permeability of the sub soil and spational variation (maps).

20. Data on infiltration into and seepage from the sand aquifer and zonal distribution (maps).

21. Piezometric heads of the shallow and deep groundwater (maps).

22. Data on soil moisture characteristics and capillary conductivity for the main soil groups.

23. Distribution of soil salinity, as well spational (zonal) variation (maps), as vertical distribution.

24. Salinity of shallow and deep groundwater and spational variation (maps).

25. Effects of leaching and drainage on soil properties. Detailed quantitative information is required.

26. What percentage of the gross area is in non-agricultural use (villages, roads, railroads, etc)? Detailed information on zonal distribution (per Governorate, per district) is required.

27. What are the drain depth and drain distances of the sub-surface drains for the different soil types? What is the zonal distribution of these characteristics (maps)?

28. Which areas have been provided already with tile drainage? When was the system constructed in which area? (maps). What is the future plan with respect to tile drainage (maps)?

29. What are the drain depths and drain distances of the open field drains in areas not yet provided with tile drainage? Detailed information on zonal variation (maps) is required.

30. What is the density of the main open drainage system? What is the zonal variation (to be used for estimation of unofficial reuse of drainage water)?

31. What is the quality of the water in the main open drainage system with both zonal distribution and seasonal variation? Also historical data are required.

32. What are the quantities of drainage water in the main open drains with both zonal distrivution and seasonal variations?

III. Crop data

33. What is the cropping pattern in summer and winter season in the

different agricultural zones (per Governorate, per district)?

Data required per crop (per agricultural zone):

- area occupancy (percent)
- planting date
- harvesting data
- soil cover (percent) and crop height during growing period
- flowering data (if applicable)

What is the irrigation schedule of the major crops in the Nile Delta:

Cotton
Rice
Maize
Berseem (Long)
Berseem (Short)
Wheat

Detailed information on frequency and quantity of water application per crop (including pre-planting irrigation) is required.

34. Data on crop production in relation to water use and soil salinity.

35. What is the expected future cropping pattern and its zonal distribution?

IV. Model test area's

36. For model test areas all the afore mentioned questions have to be answered, be it with more detail.

37. Which are areas suitable for the study? Preferably areas with existing detailed information should be selected in order to obtain a speedy confirmation of the model.