ASPECTS OF WATER RESOURCES PLANNING USING LOW QUALITY WATER IN NEW RECLAIMED AREAS

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ABSTRACT

In 1980 Egypt started to face water problems as a result of the rapidly growing population and the intensified industrial and agricultural development projects. The limited freshwater supply and the future increased demands forced Egypt to develop an integrated water management policy to fill the existing gaps between the future demands and the limited available water supplies in an environmentally safe manner. The Government of Egypt implemented an agricultural development project in the Northern Marshland of the Eastern Delta using a mix of low quality drainage water and Nile water for irrigation. The evaluation of the proposed plan indicated that there could be a long term water shortage problem during the months of June and July when the project is fully operational. To solve this problem, an alternative plan is proposed where an additional drain and more water from the Nile River can be added. Environmental, social and economical data were collected from three pilot areas within the project area. The data analysis revealed that the plots owned by the uneducated farmers and the big investors are more developed compared to those owned by the educated farmers. The provision of public services, the selection of the target group and awareness campaigns should be considered in the water resources planning process.

Key Words: Drainage water reuse, Planning, Socio-Economic, El-Salam Canal, Nile River, water resources planning

1. INTRODUCTION

Since ancient Egypt till the present, the main objective of water resources planning in Egypt has been two fold: first, to manage the water supply by controlling the highly fluctuating Nile flow; secondly, to satisfy the water demands through a better utilization and efficient use of the available resources. Recorded history has shown that Egypt suffered from either too little water or too much water according to the flood wave received by the Nile River. Accordingly, Egypt experienced different scenarios for managing both water supply and demands. In spite of the limited water resources available in Egypt associated with the annual gradual population increase, the intensified agricultural development, urbanization and industrial development, Egypt has been so far successful in managing its available water resources without too much adverse impact on the population. However, this type of management will not last for long if the available water is not properly managed. The water demand will exceed the water supply.

Egypt has a history of nearly 7000 years when it comes to practicing irrigation and utilizing water resources. Since the mid 18th century, new practices and technologies have gradually been implemented on a wide scale. As the final attempt to harness the Nile River, the High Aswan Dam was completed in 1970. The HAD ensures Egypt an annual quota of 55.5 billion cubic meters for irrigation and other purposes. This volume of water has provided agriculture with a steady, year-round and plentiful source of irrigation water. As shown in Figure (1), with the population of approximately 68.8 million in 2001, the annual water share from the Nile River per capita is 810 m^3 compared to 1600 m^3 in 1970. By 2017, Egypt's population is expected to increase to 87 million (MWRI, 2001), therefore, reducing the annual water share per capita to 640 m^3. This low figure indicates clearly that Egypt will be suffering from a water deficit. Therefore, other conventional (water harvesting, shallow and deep groundwater) and non-conventional (drainage water, treated wastewater and desalination) water resources will have to be utilized to compensate the future demands.

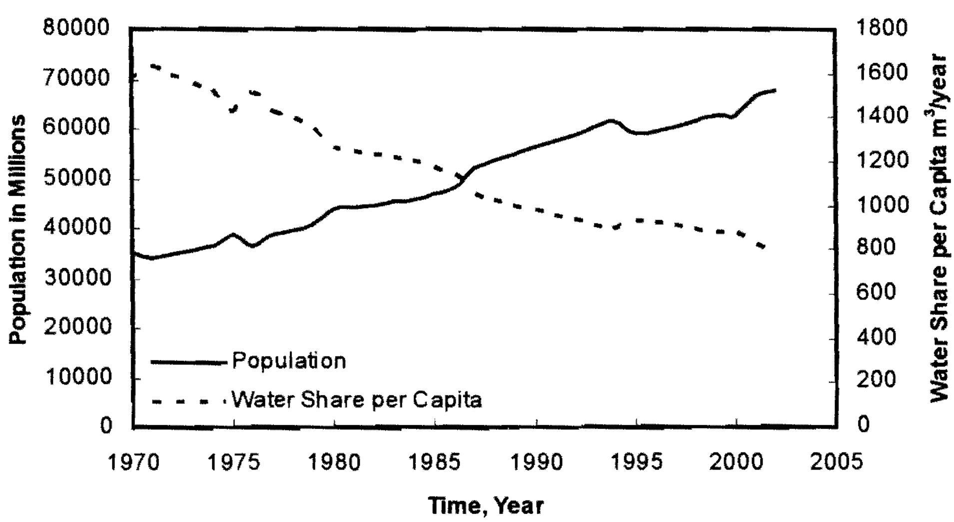

Figure (1) Population and available water supply per capita from the Nile River, Data Source: www.library.uu.nl/wesp/populstat/africa/egyptc.htm).

The non-conventional water resources in Egypt constitute treated wastewater, drainage water and desalinated water. Treated wastewater has been considered a usable source of water since the early 19th Century when it was used in agriculture. Egypt's water policy is still to maximize the usage of treated wastewater in agriculture with a current potential of 2.3 billion m^3/year. Brackish water or seawater desalination has evolved considerably in Egypt in the industrial sector, military bases and especially tourist resorts along the coastal areas of Egypt. The total demand has grown to some 150,000 m^3/day and expected to increase when the technology is made available to reduce the capital cost of the desalination process. The reuse of drainage water in agriculture either directly or after mixing with fresh water in the irrigation canal is a viable approach provided the water salinity is at an acceptable limit. In 1987, it was reported that a total of 13.5 billion m^3/year, (approximately 24% of the annual quota from the HAD), of drainage water was flowing directly to the Mediterranean Sea with an average salinity value of 2400 ppm (El-Quosy, D., 1989). This quantity was reduced in 1996 to 12.408 billion m^3/year due to the increase of the unofficial reuse of the drainage water, new projects that depend on drainage water and finally the irrigation improvement projects implemented at the farm scale that improve the water use efficiency. As a result of this flow reduction, an increase in the average water salinity to 2700 ppm was observed (Ramadan, 1999).

This paper analyzes the drainage water reuse policy in Egypt and reflects upon its safe use for agriculture. A case study will be presented from three pilot areas within the command area of the El-Salam Canal project where drainage water is reused after mixing with Nile water. The study included the monitoring of the agricultural, socio-economic and environmental characteristics of the pilot areas. Based on the analysis of the results, lessons learned will be addressed to help water resources managers improve land reclamation using low quality water and saline soils.

2. EGYPT WATER POLICY TO USE DRAINAGE WATER IN AGRICULTURE

Drainage water reuse in the Nile Delta started as early as the 1930's. In the late seventies, a policy was adopted to maximize the use of drainage water within permissible salinity levels. The policy committed the reuse of 8 billion m^3/year for agricultural projects by the year 2017. This policy did not consider its chemical, biological and bacterial properties and only focused on water salinity levels. Criteria were developed to identify the mixing ratio of drainage water and fresh water from the Nile River or the canals to meet the desired salinity standards. Drains with salinity levels higher than 3000 ppm or polluted with toxic substances are excluded from the reuse policy and flow directly to the Mediterranean Sea via the Lake Manzalla wetland area. A legal framework was developed in 1982 to protect all the water resources from pollution sources. The law is being enforced but a lot still needs to be done by the water users to protect this precious resource. In order to implement and evaluate the drainage water policy in Egypt, three major research projects were implemented. The first one was to establish an integrated water quality-monitoring program for conventional and non-conventional water resources. The second one was to develop guidelines for the safe use of drainage water in agriculture and the third was to predict the available drainage water and its quality using simulation models and then to link these models to environmental and socio-economic models to study the impact of using this low quality water on the different water users. The results of the monitoring program helped so far define drains with pollution problems. The worst drains were decommissioned from the reuse program. The prediction of drainage water availability and its impact on the environment, agriculture and socio-economic is still under investigation. All of the above mentioned activities are jointly funded by Egypt and Canada under the National Water Quality and Availability Management Project.

3. QUANTITY AND QUALITY OF THE DRAINAGE WATER RESOURCES

Drainage water reuse in the Nile Delta has been increasing steadily since 1984 as shown in Figure (2) with an average salinity level that varies between 860 and 1170 ppm. In addition to the official reused drainage water, an estimated 2.8 billion m^3/year are used unofficially by farmers in irrigation and fish farms. The daily reuse of the drainage water is managed according to the daily operational plan of the High Aswan Dam (HAD). Therefore, the long term prediction of the quantity and quality of drainage water is not a straight forward procedure and is still under investigation by researchers. Historical records have revealed that there is a general increase in the reuse of drainage water as a result of the reuse expansion in the Delta, mainly from increased reuse in the Middle Delta in the 1990's and the newly reclaimed areas in the Eastern Delta along the El-Salam Canal.

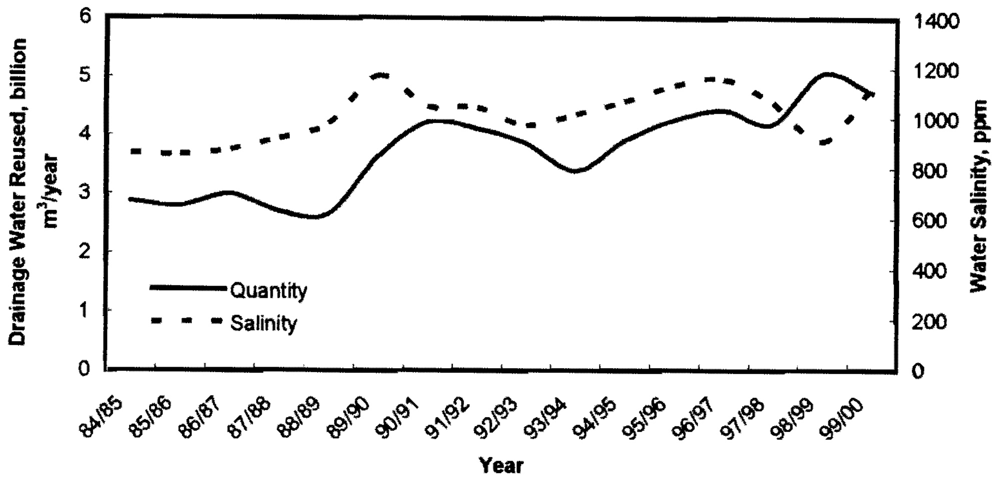

Figure (2) Quantity and quality of drainage water reused for irrigation in the Nile Delta (Source: Year Book, 2001. Drainage Research Institute, Egypt).

As Egypt is working hard to conserve and use its water resources efficiently, the current irrigation improvement project is expected to save one billion m^3 /year. As a result of this project, less drainage water will be available but with higher salinity levels. Beside this project, the national policy on installing tile drainage systems at the farm level is leading to an increase in the salinity of the drainage water. These two projects with the aid of the available historical records should be considered seriously in the planning process using the integrated water management approach.

The water flowing through the drainage system is not only agricultural drainage water carrying salts and pesticides from the soil but also a contribution from industrial, domestic and upward seepage from the brackish groundwater. These non agricultural sources contain, as well, chemicals and toxic substances that severely deteriorate the drainage water quality. The drainage water reuse strategy is only focusing on the drains that are suitable for agricultural use after mixing with fresh water from the Nile. In the past, the quality of the drainage water was not of any concern but recently, according to the water quality monitoring data, it was found that there is a major risk on human health, soil fertility deterioration and crop productivity when using this low quality water. The challenge that Egypt is now facing is how to ensure that the drainage water is available and suitable for irrigation purposes. A lot of efforts have been made to treat the sewage water and industrial wastes before entering the drainage system. These efforts are continuing with a long term plan to provide sanitary systems to small villages and to cover the open drains and canals to avoid dumping the wastes illegally in these waterways.

4. DRAINAGE WATER REUSE IN THE EL-SALAM CANAL PROJECT

The El-Salam Canal project located in the Northeastern part of the Nile Delta collects the excess water from the Damietta Branch of the Nile River at the Faraskur Barrage (the last Barrage before the Nile reaches the Mediterranean), the drainage water from the Lower Serw pumping station and the drainage water from the Bahr Hadus Drain. This Project started in 1980's and was designed to provide irrigation water to 624,000 fed. Phase 1 of the construction has been completed and is serving about 220,000 fed on the west side of the Suez Canal (Figure 3). The canal has a capacity of 18 Mm^3/d of which half is to be supplied directly by the Nile River. The remaining water comes from the two mentioned drains: El Serw Drain (2 Mm^3/d) and Hadus Drain (7 Mm^3/d)

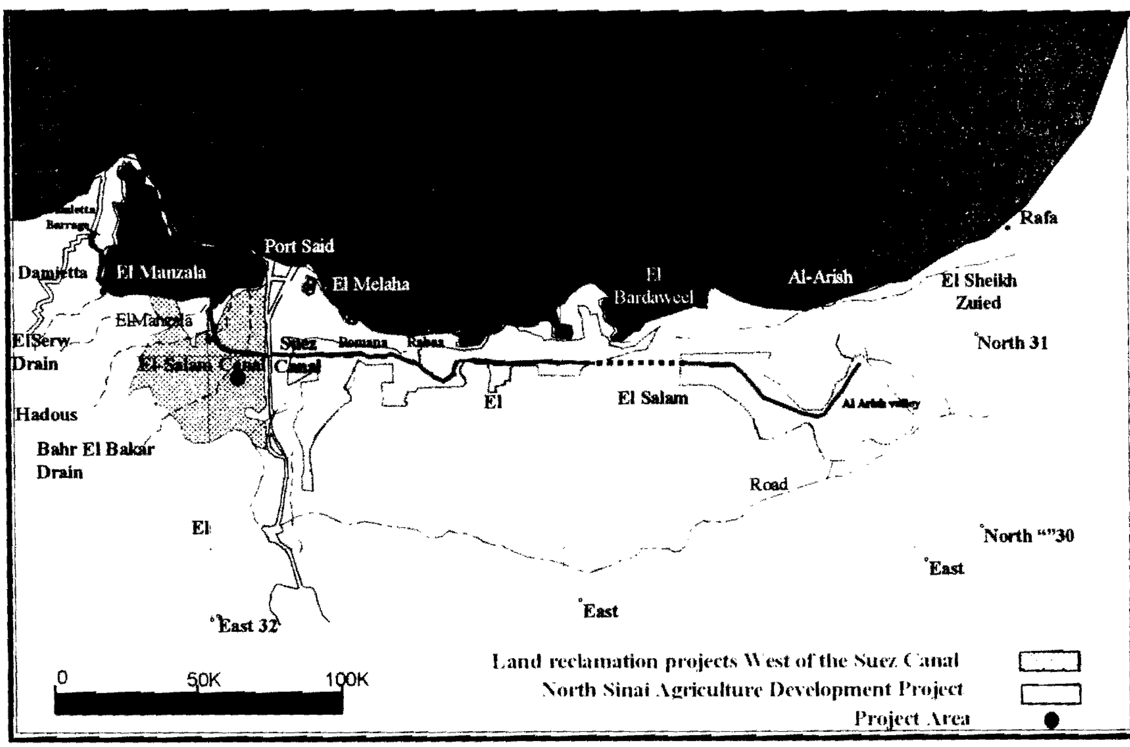

Figure (3) Schematic representation of the El-Salam Canal agricultural development project.

The drainage system of Bahr Hadus is relatively complicated where part of the drainage water is officially used in irrigation after mixing with the fresh water in the irrigation canals. At the same time, farmers are using the drainage water directly from the drains especially those located at the tail ends of the irrigation canals or when there is a water shortage problem during the summer period. Consequently, this unofficial reuse of the drainage water leads to less water availability at the drain outfall. For the Serw drain this unofficial reuse problem has not been reported so far. When this project was originally planned in 1977, there were not enough historical records to study the variability of the drainage water discharge and the water salinity in the two drains. Also, the assumption of the unofficial reuse was not considered and this lead to a drainage water shortage at the Hadus outfall. Since water resources planning is a dynamic process, the developed plan for the El-Salam Canal has to be monitored and evaluated on a regular basis. In the following section, an estimate of the average monthly discharge and the water salinity is calculated for the two drains using the past 20 years' records. The results will be compared next with the original plan for evaluation and recommendations.

The measured discharge and water salinity in the two drains (Serw and Hadus) showed temporal variability over the year. The effective drained agricultural areas, the effluent discharge rates and some other factors caused this variability. In order to estimate the monthly average discharge rates and water salinity levels (for such a population), the data are assumed to be normally distributed with unknown mean and variance. The interval for the population mean is given by $\overline{Y} \pm t S_{\overline{Y}}$, where $\overline{Y}$ is the sample mean, $S_{\overline{Y}} = \sqrt{\frac{S^2}{n}}$, S^2 is the sample variance and (t) is the tabulated value of Student's (t) corresponding to (n-1) degrees of freedom. For the problem under discussion, a confidence coefficient of 95% was used and the degrees of freedom 19 (n-1). Therefore, the tabulated (t) is 2.093 (Steel and Torrie, 1980). This leads to an interval estimate for the population mean of all data sets.

Figures (4) and (5) show, respectively, the estimated interval and the average monthly discharge and water salinity level El Serw drain. The planned quantity from this drain is still valid with more water available for future use or to compensate for any undesired water shortage from Hadus Drain. For the water salinity, the estimated average salinity violates the original plan during the low flow periods in winter and the month of May. Similarly, for Hadus Drain (Figure 6), except for the winter closure period in February where there is no irrigation, the available water in this drain needs more attention where the estimated available discharge is much less than the original plan all year long. For the estimated average water salinity, Figure (7) shows that the water salinity in this drain is always a bit higher than the planned values during the winter time (September to February).

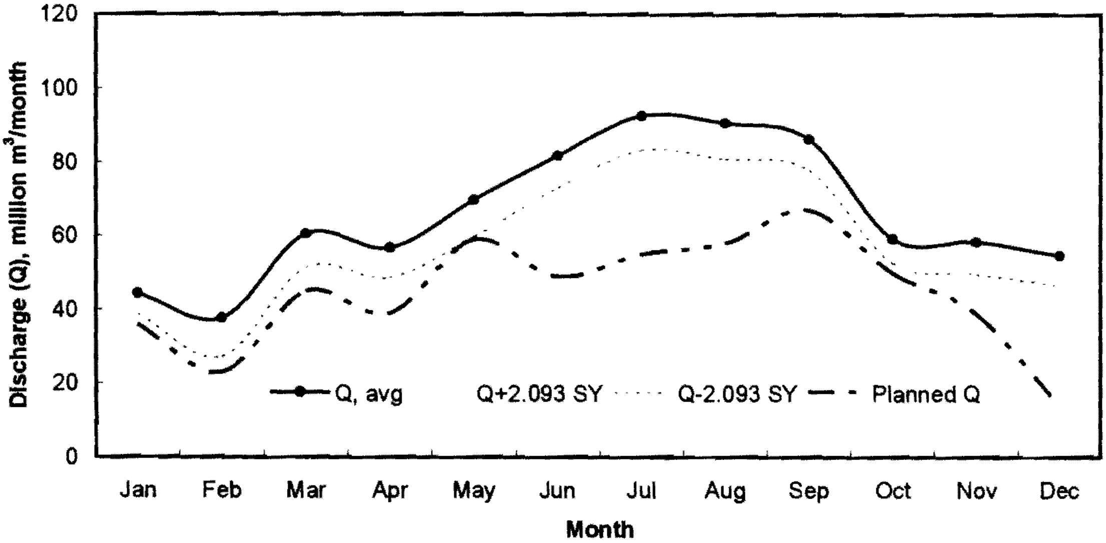

Figure (4) El Serw Drain: estimated average monthly flow rate (1982-2002) and planned discharge.

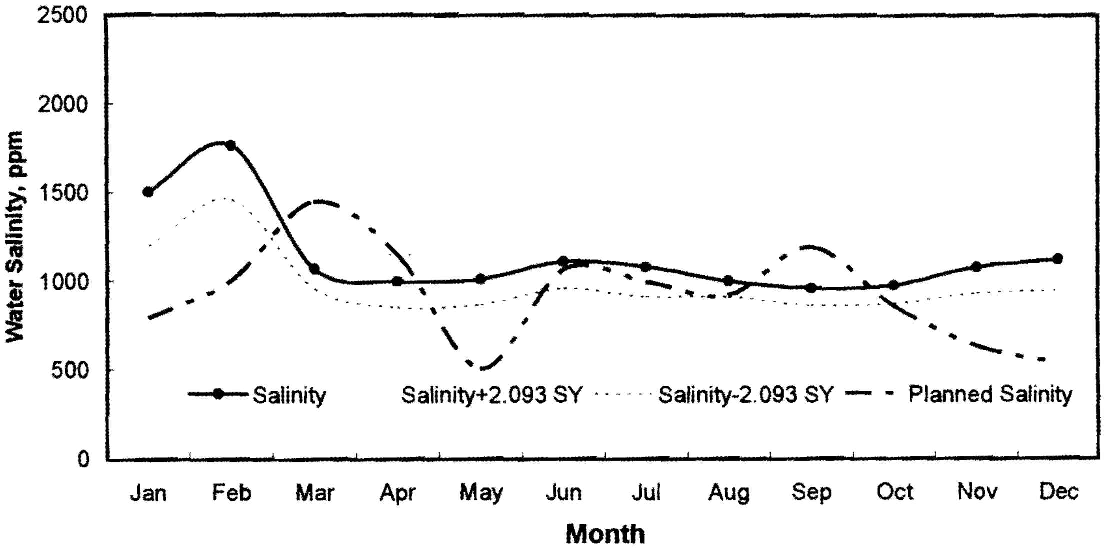

Figure (5) El Serw Drain: estimated average monthly water salinity (1982-2002) and planned salinity.

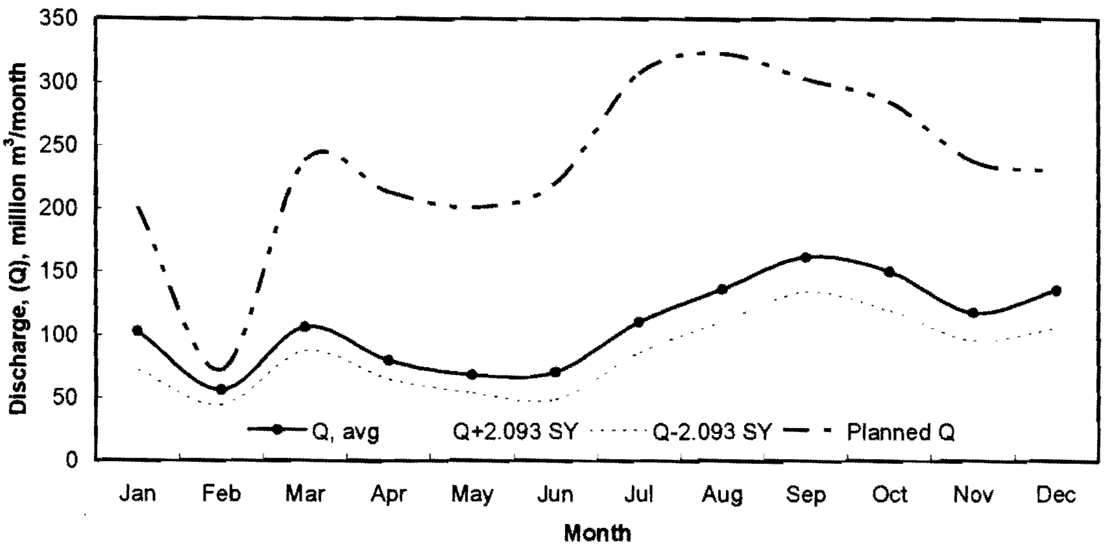

Figure (6) Hadus Drain – estimated average monthly flow rate (1982-2002) and planned discharge.

To evaluate the designed operational plan for the El-Salam Canal, the discharge rates from the two drains and the fresh water from the Nile River should be integrated using the mass and salt balance principles. As shown in Figure (8), the total available discharge for the El-Salam Canal is in deficit during the Summer time (May-August). For the water salinity as shown in Figure (9), the estimated water salinity is in close agreement with the original plan although the drain flow discharge is lower than the planned one. This finding indicates that the drainage water salinity is not of major concern compared to its availability.

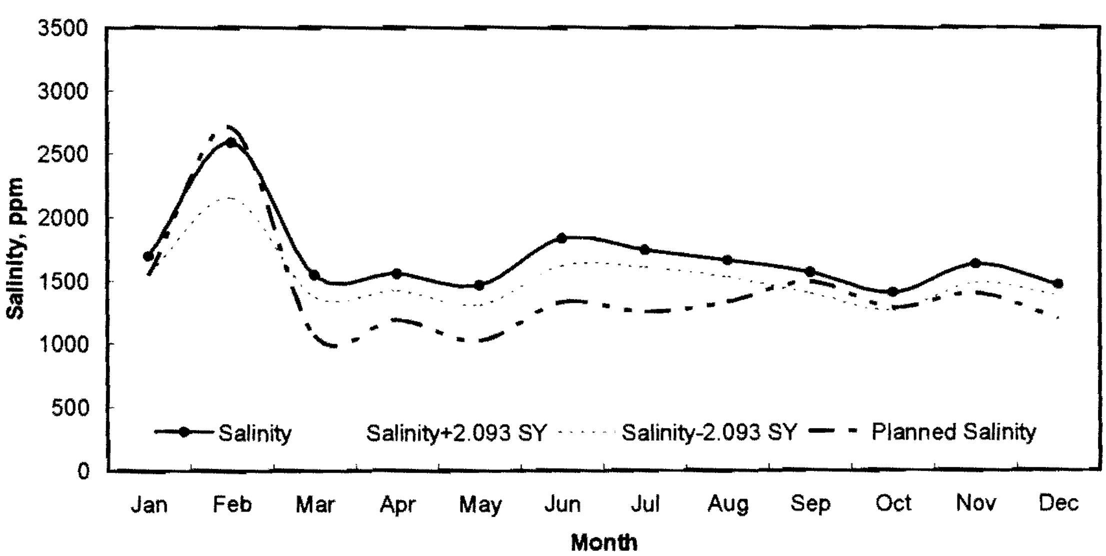

Figure (7) Hadus Drain – estimated average monthly water salinity (1982-2002) and planned salinity.

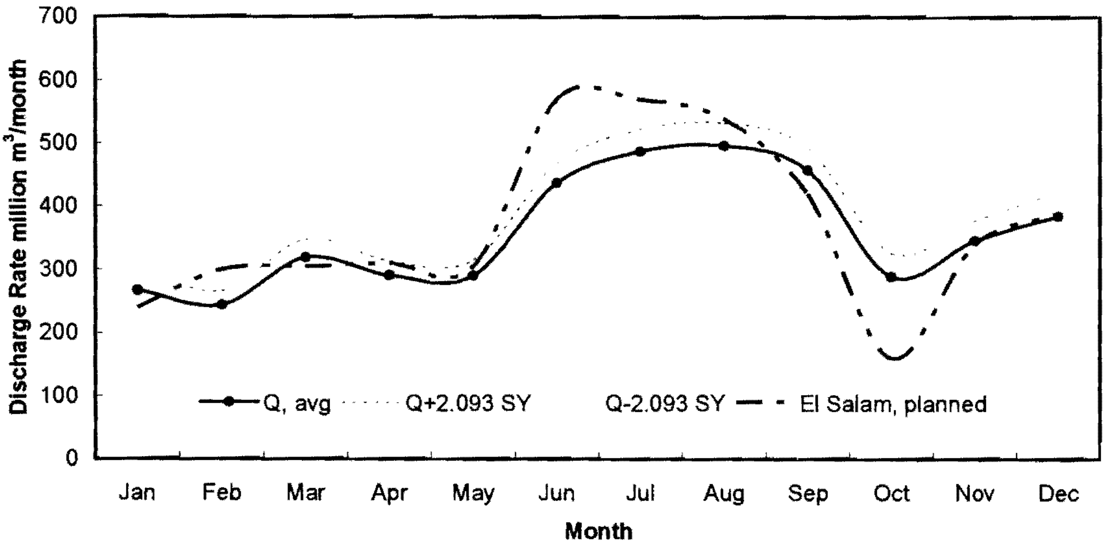

Figure (8) Comparison between the estimated and the planned discharge in the El-Salam Canal.

Options to compensate for the water deficit in the El-Salam Canal are multiple and the optimal scenario is to use all the available drainage water from the Faraskur drain and/or augment the Nile water. Having the available measurements for the drainage water discharge of the Faraskur drain, Figure (10), the required flow from the Nile is shown in Figure (11) and the impact on the overall salinity is shown in Figure (12). The additional water from the Nile is only required during the months of June and July, where the crop water consumption is the highest. If this water quantity can not be made available, crop restriction could be another alternative to minimize the crop water consumption or restrict the reclamation in some areas to the winter crops.

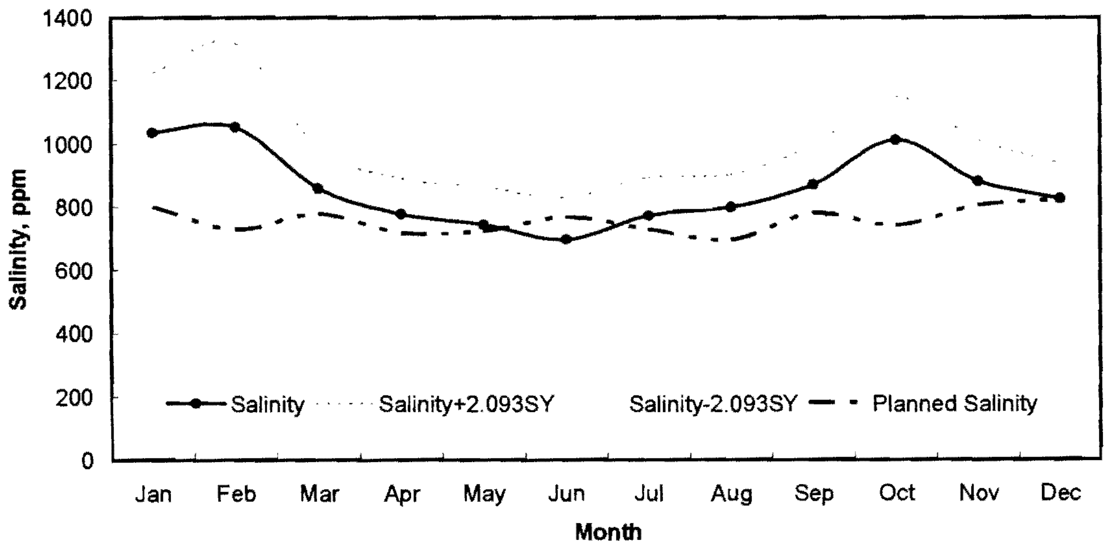

Figure (9) Comparison between the estimated and the planned water Salinity in the El-Salam Canal.

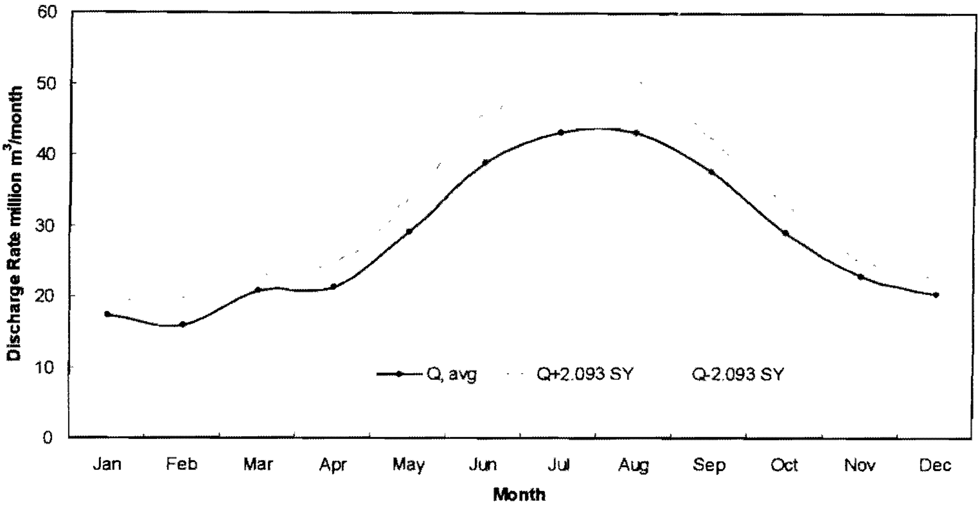

Figure (10) Estimated average monthly flow rate from Faraskur drain (1992-2002).

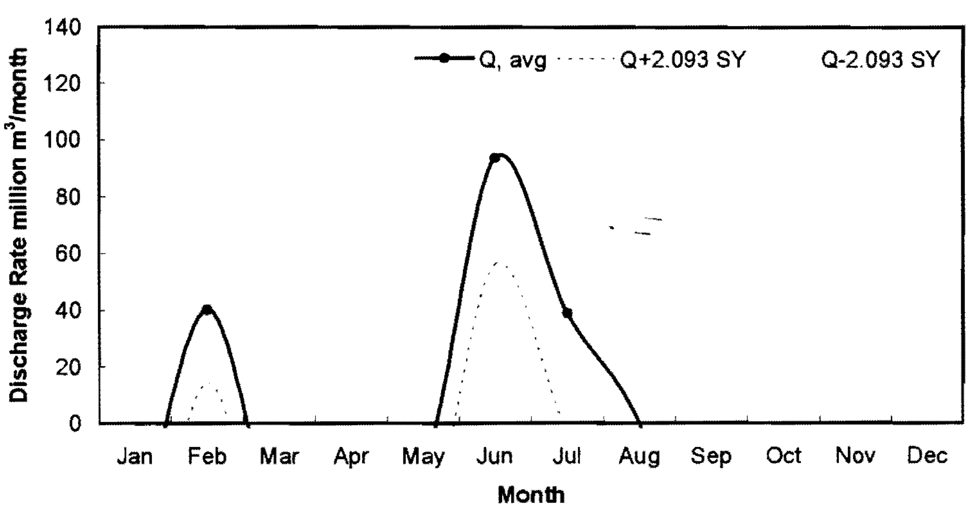

Figure (11) Additional discharge rate required from the Nile River to compensate for the water deficit in the El-Salam Canal.

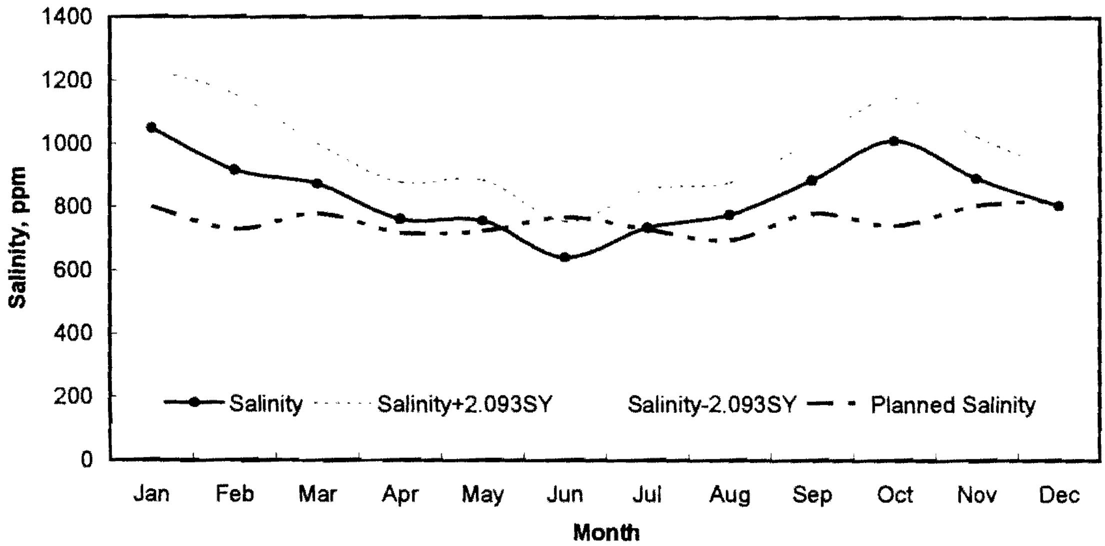

Figure (12) Impact of adding more water from the Nile River and the Faraskur Drain on the El-Salam Canal water salinity.

The previous analysis is a good example of how important monitoring and evaluation of water resources projects are for the planning process. The acquired data can be used to revise the original plan and recommendations for any modification for the design can then be made.

Away from the water resources availability and its quality, other factors to be considered when using low quality water in agriculture are the social and environmental parameters. To evaluate the socio-economic impacts on the landholders, three pilot areas were selected along the El-Salam Canal and an extensive socio-economic survey was conducted to understand the developed communities in terms of structure, dynamics, resources and program needs related to usage of low quality drainage water. The socio-economic along with the environmental and agricultural parameters will help in the development of guidelines for reuse of drainage water for land reclamation and irrigation to maximize the effectiveness of the project.

The three pilot areas of Tarek Ibn Ziad, El-Rowad and El-Eman consist of 1500 feddans in total. The pilot areas were selected using specific criteria to ensure that conditions were representative and accessible. The pilot areas represent different socio-economic conditions: Tarek Ibn Ziad consists of small landholders, most university graduates; El-Rowad consists of small landholders, many with high school graduation or farming experience elsewhere in the Delta and El-Eman consists of large investor landholders. There are a total of 159 landholders in the three pilot areas. A detailed questionnaire was designed and tested for conducting the survey of landholders. Responses to the questionnaires were obtained from 97 landholders which represents 61% of the total landholders in the three pilot areas. The survey data were analyzed using the SPSS software. The major output of the analysis is the frequency distributions for all the parameters measured by the questionnaire (Desukki et al., 2002).

The interpretation of the frequency distribution of the socio-economic parameters revealed that farming experience is a key element in the reclamation process. Educated landholders with no farming experience are less progressing in land reclamation. Males and young landholders are advanced in land reclamation, irrigation and establishment of cropping systems compared to females and older landholders. Due to their access to funds from saving and other resources, investors are less concerned about their financial situation compared to the small landholders. As concluded from the over all analysis of the three pilot areas, the priority issues to advance the socio-economic conditions of the landholders are: health issues related to dissatisfaction with drinking water supply and quality, as well as, unsuitable satisfactory sanitary conditions; land management problems related to high soil salinity and low soil fertility; access to agriculture credits; infrastructure related to canal and drain conditions, irrigation water supply and roads; extension, cooperative and marketing services; family training and employment and improvement of opportunities for women.

5. CONCLUSION

Water resources planning and management is a dynamic process and needs to be evaluated through a monitoring system using the proper indicators. In this paper, the original plan for using the drainage water in agriculture after mixing with the fresh water from the Nile River was evaluated. Both the discharge rates from the drains and the Nile and the water salinity were monitored over the past 20 years. The monitoring data revealed that there will be a water shortage problem over the long term when the project is fully operational. An alternative plan was proposed to use the available water from another drain after mixing with some additional water from the Nile. The water salinity levels of the mixed water are not seriously affected by the total discharge. Other factors that should be considered when using the low quality water in agriculture are the social and environmental parameters. The results of a comprehensive socio-economic questionnaire revealed that landholders are concerned about health issues and land management problems using this low quality water. Access to agricultural credits; infrastructure related to canal and drain conditions, irrigation water supply and roads; extension, cooperative and marketing services; family training and employment and improvement of opportunities for women are among the other factors affecting the advancement of the development process.

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REFERENCES

Drainage Research Institute. (2002). Drainage water status in the Nile Delta Year Book 1999-2000, Monitoring and analysis of drainage water quality project, Technical Report No. 51. Ministry of Water Resources and Irrigation, National Water Research Center. El-Kanater El-Khairya, Egypt.

El Desukki, H., Hussein, A., Crain, J., and Pearson, G. (2002). Drainage Water Reuse and Pilot Schemes Component. National Water Quality and Availability Management Project (NAWQAM), Report No. DR-TE-0212-009-FN.

El-Quosy, D. (1989). Drainage water reuse Projects in the Nile Delta: the past, the present and the future. *In* Land Drainage in Egypt, edited by Amer, H. and de Ridder, N.A. Drainage Research Institute, NWRC, Cairo, Egypt.

Ministry of Water Resources and Irrigation (MWRI), Planning Sector and Ministry of Foreign Affairs, the Netherlands, Directorate General for International Cooperation. (2001). Water for the future, National Water Resources Plan (NWRP) for Egypt. Interim Report No. 1.

Personal communication. (2003). Average monthly flow rates and salinity for the El-Salam Canal System, Drainage Research Institute. National Water Research Center. El-Kanater El-Khairya, Egypt.

Ramadan, F. M. (1999). Drainage Water Availability and Quality. National Water Quality and Availability Management Project (NAWQAM). (Unpublished report)

Steel, R.G.D. and Torrie, J.H. (1980). Principles and procedures of statistics: A biometrical approach. Second edition. McGraw –Hill Book Company.

www.library.uu.nl/wesp/populstat/africa/egyptc.htm). Population and available water supply per capita from the Nile River.