ROSETTA BRANCH WASTE LOAD ALLOCATION MODEL

Noha Donia

Assistant Professor, Engineering Department, Ain Shams University
E-mail: ndonia00@hotmail.com

ABSTRACT

A Rosetta Branch waste load allocation model was built to define the total maximum daily loads for pollutants of concern especially to preserve aquatic life. This was achieved by carrying a study to assess the water quality of Rosetta water. Many loading scenarios were conducted using the developed model to improve the water quality condition of Rosetta Branch. Based on the results of these scenarios runs, the total maximum daily loads were established for Rosetta Branch. Applications demonstrate that the developed model can be used by decision makers as a tool to quality management.

Keywords: Waste Load Allocation, TMDL, Rosetta Branch, Water Quality Modeling

INTRODUCTION

The River Nile when reaches to the Delta, is divided into two branches Rosetta and Damietta Branches as shown in figure (1). The Rosetta Branch flows downstream Delta Barrage to the North-West where it ends with Edfina Barrage which releases excess water to the Mediterranean Sea. The Rosetta Branch water serves for a wide range of functions including agricultural, industrial and domestic water supply, fisheries and recreation.

Unfortunately the Rosetta Branch is impacted by the agricultural drains located along the branch and by the industrial companies at Kafr El-Zayat city. The drains are EL-Rahawy, Sabal, El Tahrir, Zaweit El-Bahr and Tala. These agricultural drains receive also domestic water from fifty five towns and villages distributed along the branch. The industrial outfalls are El-Maliya, Mobidat and Salt and Soda companies which are discharging directly at the east bank of the branch. These two sources of pollution potentially affect and deteriorate its quality of water.

Many research works had been conducted to assess River Nile water quality including the quality of its Rosetta Branch. Among these works are, (El-Gohary, [9], (El-Gohary and Nawar, [10]), (El-Gamal and Shafik, [8]), (El-Moattassem, [11]), (EL-Gohary, [8]), (El-Sherbini, [14], (El-Sherbini and El-Moattassem , [15], (El-Sherbini and El-Moattassem,

[16]), El-Shanshoury and Abdelbary, [12], (El-Shanshoury and Hassan, [13]), (El-Sherbini and El-Moattassem, [17] and (El-Bahrawy and Abu-Ela, [7]).

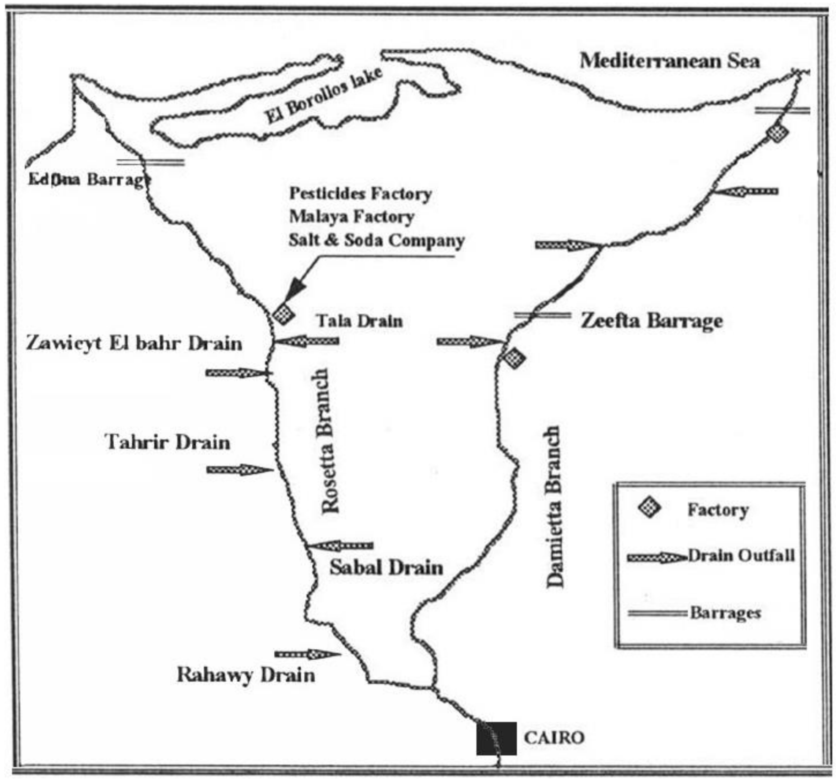

Fig. 1 Location Map for Rosetta Branch of the Nile River

Finally it is concluded that the main objective of most of the previous studies is to evaluate the present water quality of the river and potential effects of some pollutants with respect to certain uses; Almost no research work has focused on solving the problem by waste allocation principle or by specifying the total maximum daily loads allowed to be discharged into the river in order to maintain water quality within specification and hence the ecological balance in the river system.

Mathematical models have been used for many years to assist in the management of water quality, (Chapra, [3]). The total maximum daily load (TMDL) process is no exception; models represent the means by which the assimilative capacity of a water body can be quantified and a waste load allocation can be determined such that the assimilative capacity is not exceeded. This study describes how to use the waste allocation model to control the pollution of the river. The waste load allocation (WLA) is the portion of a receiving water's loading capacity that is allocated to existing or future point sources of pollution. Use of aquatic life criteria for developing water quality-based permit limits and for designing waste treatment facilities requires the selection of an appropriate wasteload allocation model (Thomann, [21].

The methodology to calculate Total Maximum Daily Loads (TMDLs) varies with the type of pollutant, with one method of calculation for pollutants which are generally classified as conservative and another method for pollutants generally classified as nonconservative. In this study we are concerned with the pollutants influencing the aquatic life (BOD, DO and Ammonia), (Stephan, [20]). These are nonconservative pollutants (such as organic compounds) decay or are otherwise removed over time. This decrease in concentration may be due to a number of factors including chemical breakdown and biodegradation.

Therefore, nonconservative pollutant TMDLs (N-TMDLs) are not as much an intrinsic property of a body of water as they are factors of the receiving body of water, flow from discharger, and the configuration of the discharge locations on the body of water. N-TMDLs are also affected by a number of factors including chemical and biological processes in the aquatic environment. Therefore, N-TMDLs can only be calculated with fairly sophisticated techniques such as mathematical modeling which takes these factors into account. Once a TMDL load has been calculated, the TMDL is allocated to a wasteload allocation to the point source, (Gu and Dong, [18]).

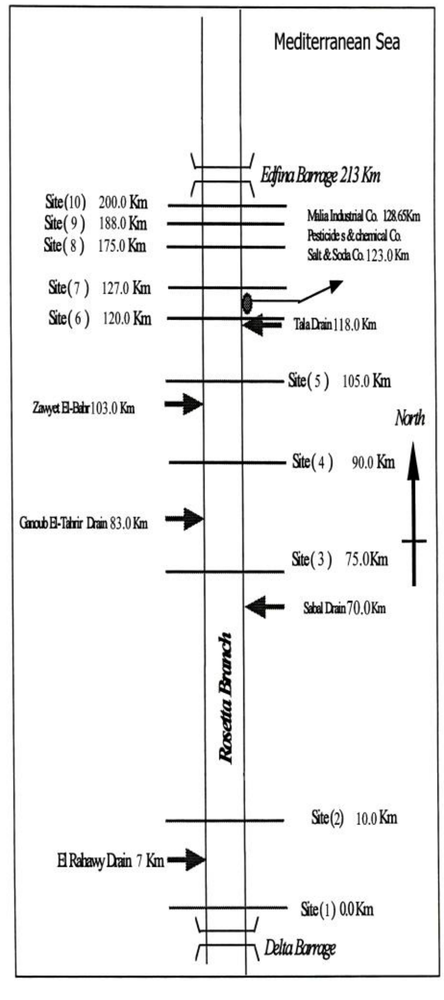

Fig. 2 Water Quality Sample Locations (September 2004)

WATER SAMPLING AND ANALYSIS

Water quality samples were taken from the Rosetta Branch at 10 sampling locations in low flow conditions (september 2004) as shown in figure (2). Also the samples were taken from the five major drains in the watershed for the same period. The analyses of water samples were carried out according to the standard methods for the examination of water and wastewater (APHA, [1]). Three major parameters Biochemical Oxygen Demand (BOD), ammonia (NH_4) and dissolved oxygen (DO) were taken into consideration due to their significance for aquatic life (Chapman, [4]). All the measurements were compared with EEC Coarse freshwater Standards (Tebbut, [22]) as shown in figures (3, 4 and 5).

By comparing the measurements in 2000 and 2004, it is obvious that the water quality is deteriorating in the four previous years as shown in graphs (1, 2 and 3), due to the continuous discharge of Rahawy drain into the branch.

With respect to the 2004 measurements, It is noticed that BOD exceeds the standards about 5 times at 200m downstream Rahawy drain. BOD exceeds also the standard limit in Kafr El-Zayat area. Ammonia value exceeds the fishing standard about 20 times downstream Rahawy and Sabal drains. Also it exceeds the fishing standard about 10 times at Kafr el-Zayat Area. This increase in Ammonia level cause fish killing. DO value is about half the EEC Standard for fishing the downstream Rahawy drain due to discharging of domestic wastes through the drain. Also the DO concentration is below the standard at Kafr el Zayat Area. This is most probably due to discharging different waste loads from point sources of pollution such as industrial effluent and agriculture located just upstream of the measuring locations.

The previous analysis indicates that the highest levels of pollution is observed at the outfall of Rahawy drain , whereas the lowest levels of pollution is observed at Delta and Edfina Barrages. It is concluded that Rahawy drain effluent is the major factor influencing the water quality in Rosetta Branch. Therefore, it can be classified as water quality limited in which water quality does not meet applicable water quality standards, and/or is not expected to meet applicable standards, even after application of technology-based effluent limitations. This result ensures the necessity to conduct many scenarios for the waste load allocation in order to improve the water quality of Rosetta Branch.

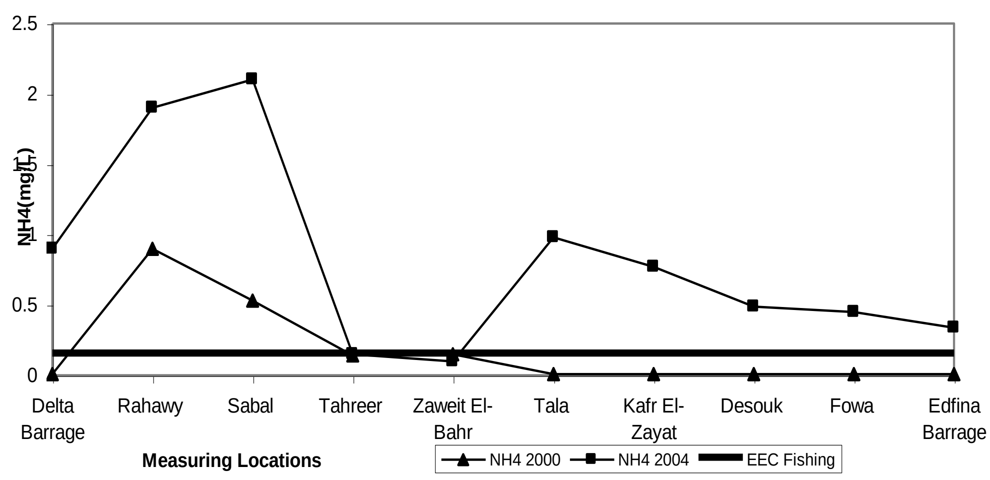

Fig. 3 Profile of Measured DO Parameter during low flow (2000 and 2004)

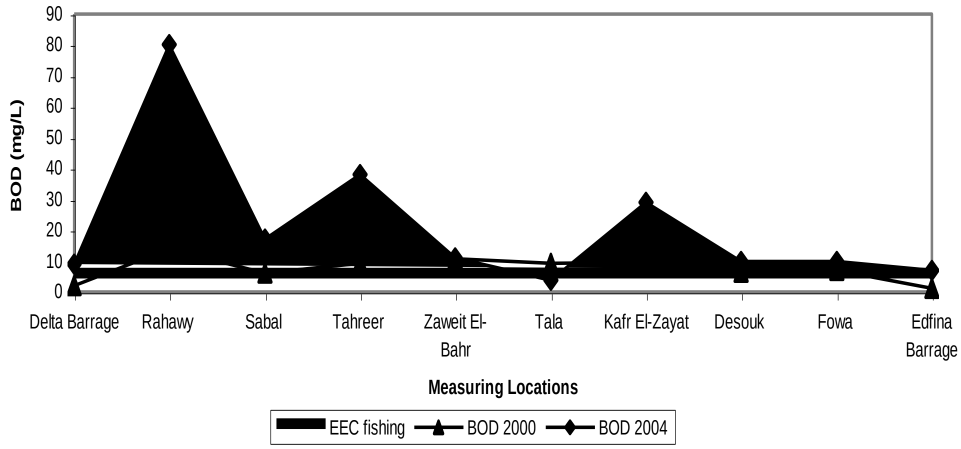

Fig. 4 P Graph 3 Profile of NH4 Measured Parameters in low flow (2000 and 2004)

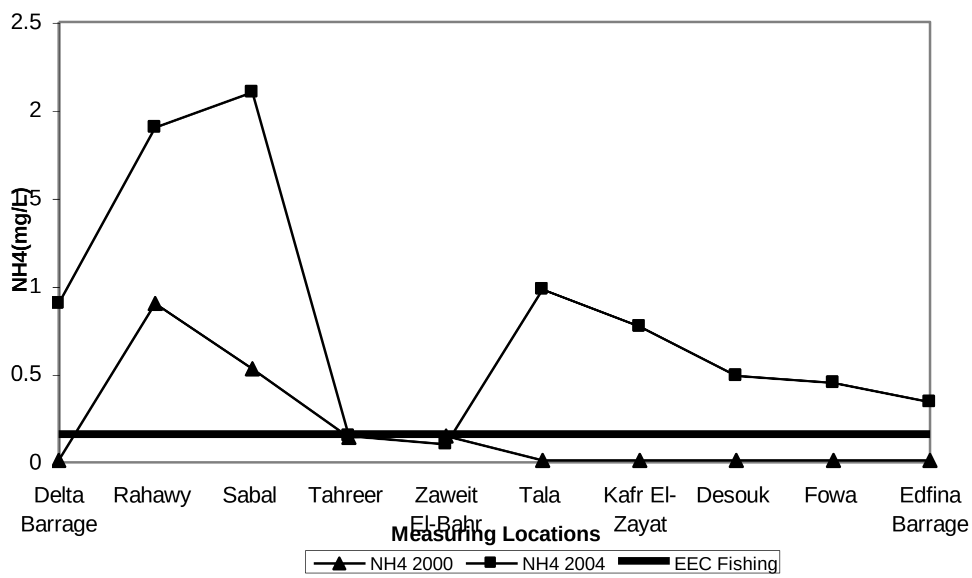

Fig. 5 Profile of Measured NH4 during low flow (2000 and 2004)

MODELING STUDY

1. Load/ Respose Relations

The analysis of the assimilative capacity of a water body has been accomplished by developing a quantitative relationship between the loading and the relevant response (concentration of pollutant of concern) of the system. This quantitative relationship was illustrated via a load-response curve that has been developed. For BOD, NH4 and DO assumed to be non-conservative pollutants, the one-dimensional unsteady flow model in open channel (The DUFLOW package, Version 2.05) was utilized to determine the TMDL, (ICIM, [19]).) The previously calibrated model by (Donia, [6]) was used to simulate the BOD, DO and NH4 concentrations along the branch for the period of field measurements (September 2004) at different loads of Rahawy drain.

An example of a load-response plot for a steady-state linear model is shown in figure (6) for DO, figure (7) for NH4 and figure (8) for BOD. The figures describe the response of the model to the change of load of Rahawy drain. From these plots one can then determine the maximum allowable load to achieve a given ambient water quality target by determining the load on the plot corresponding to the ambient target, (Depinto et.al, [5]). Also it is obvious from the figures that the Rahawy drain effluent is the main source of pollution which affect the water quality of the branch and by controlling the Rahawy drain discharge, the water quality will be improved significantly as illustrated by the response of the water quality mathematical model.

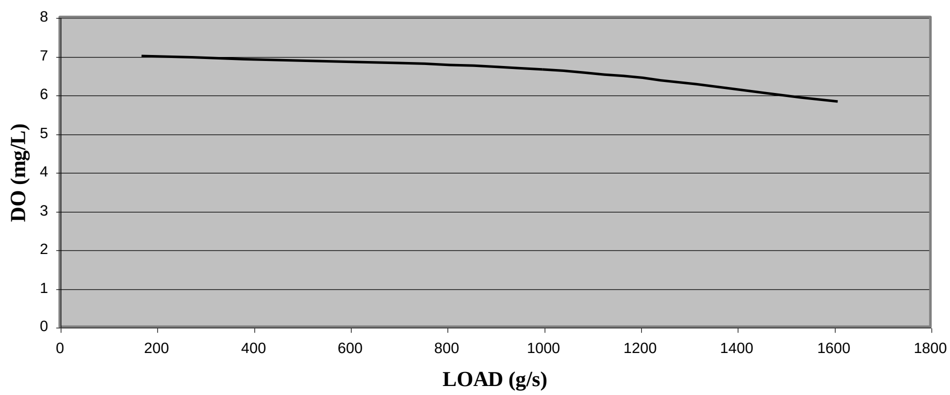

Fig. 6 Load/ Response Graph for DO Parameter (Rahawy Drain)

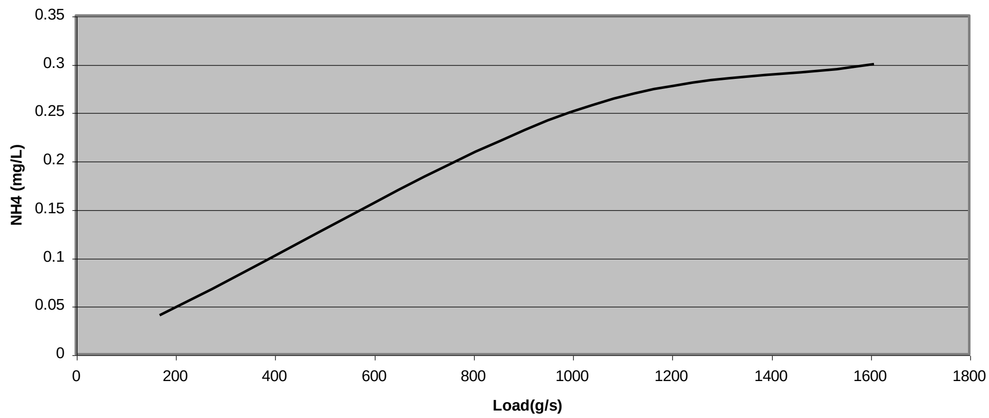

Fig. 7 Load/ Response Graph for NH4 Parameter (Rahawy Drain)

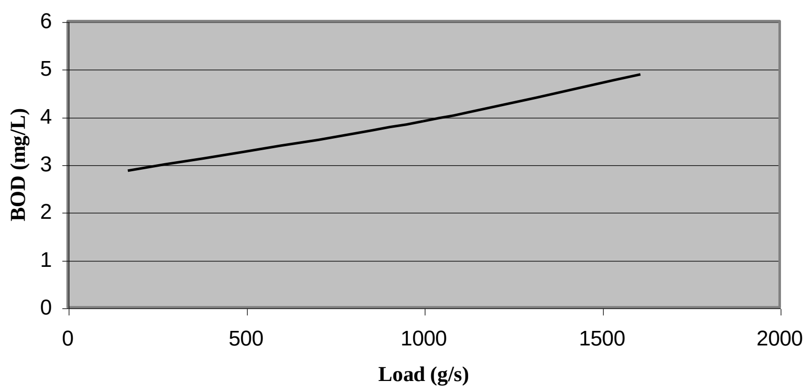

Fig. 8 Load/ Response Graph for BOD(Rahawy Drain)

2. Waste Load Calculations

The model was designed to simulate a system where polluting substances are entering the stream from point source effluents. Model scenarios were run varying the loads from different sources. The details of simulation are shown in figures (9, 10 and 11) for BOD, DO and NH4 parameters. The compliance with the fishing water quality standards as input constraints can be identified from the graphs.

Based on the results of these scenario runs, The total BOD maximum daily loads for the Rosetta Branch from the Rahawy drain must be reduced from the current permitted load of 324 g/s to 162 g/s. Also the ammonia load must be reduced from 16 g/s to 12 g/s. For the remaining drains and wastewater treatment plants in the watershed, discharge of BOD and NH4 loads shall be capped at their current permitted loads. These loads are kilograms per day of BOD and kilograms per day of Ammonia in order to satisfy with the fishing standards.

Using the developed model, it was concluded that the total maximum daily loads for the Rosetta Branch from the Rahawy drain must be reduced from the current permitted load for the drains. This reduction of load can be done by using the biofilm with aeration option as an efficient treatment alternative, whereas to comply with the permitted load the wetland option can be used as drain treatment alternative, (Arceivela, [2]).

CONCLUSIONS

The water flow and quality of Rosetta Branch could be successfully simulated using the deterministic water quality model DUFLOW. The evaluated model was calibrated successfully until an agreement was reached between the simulated and the measured data. Then by sensitivity analysis, it was obvious that the Rahawy drain was the most important pollution source affecting Rosetta Branch. The load response curves assure that different control scenarios of Rahawy drain upstream will ensure better water quality upstream especially for aquatic life.

The developed model assists in water quality management by relating the emissions of chemical pollutants to corresponding concentrations in the water, sediment and biota. When environmental quality guide-lines or target levels are available, the emission concentration relationships developed by the model are used to derive the maximum daily loadings that are expected not to exceed the guidelines for aquatic life standards.

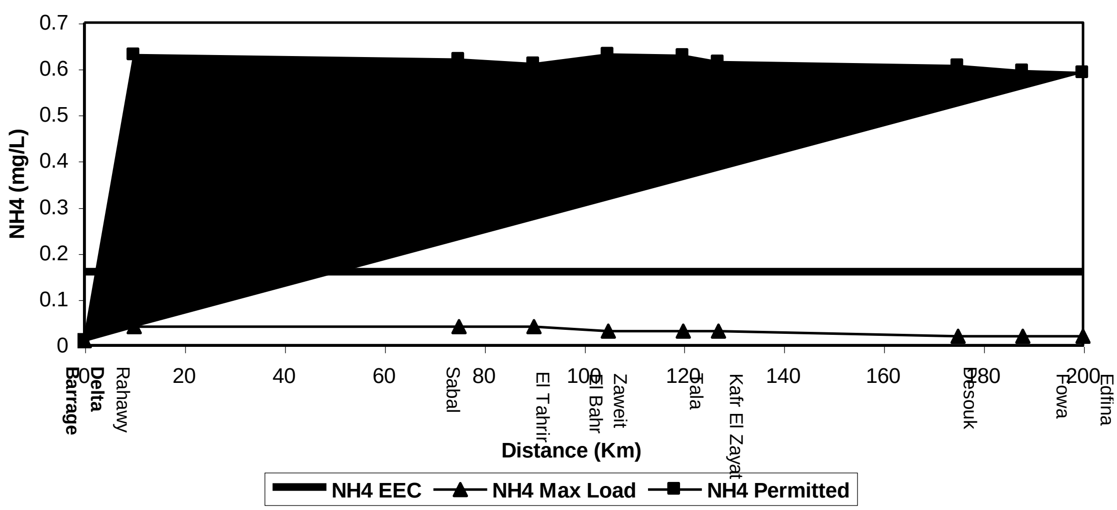

Fig. 9 Simulated NH4 at maximum and permitted loads

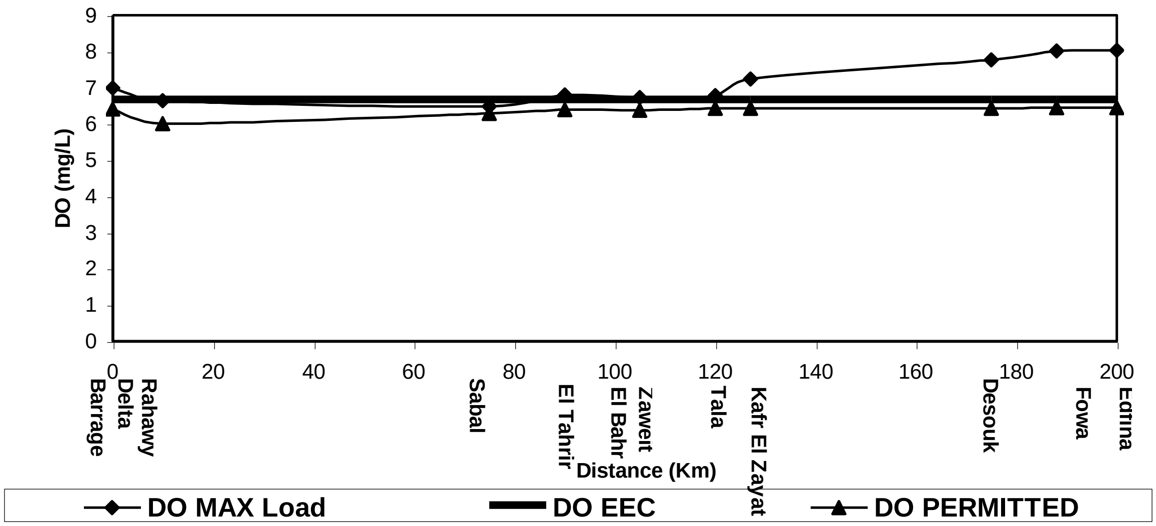

Fig. 10 Simulated DO at maximum and permitted loads

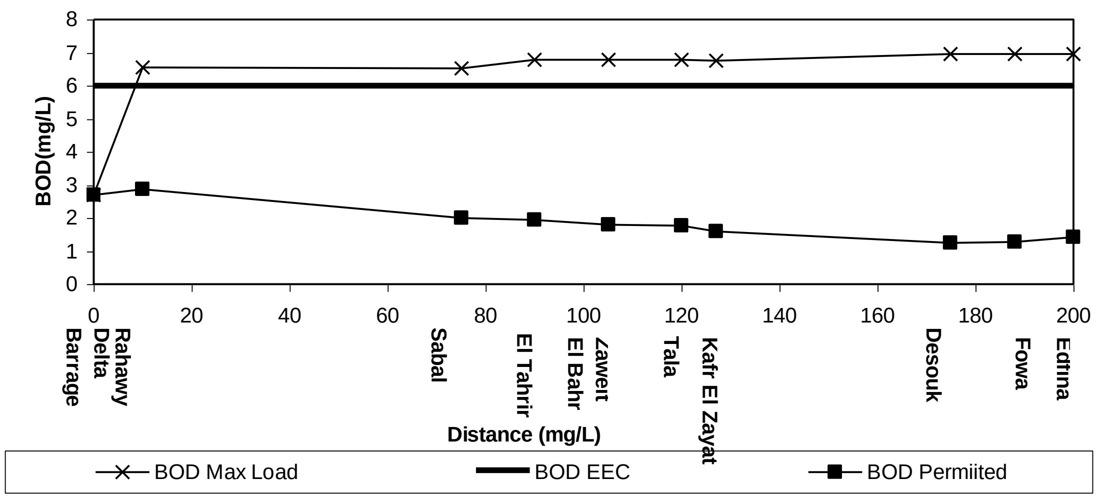

Fig. 11 Simulated BOD at maximum and permitted loads

REFERENCES

1. APHA "American Public Health Association", Standard Methods for the Examination of Water and Wastewater 17th edition. Washington DC., USA, 1989.

2. Arceivala, Wastewater Treatment for Pollution Control. Tata McGraw-Hill Publishing Company Limited, New Delhi, 1996.

3. Chapra, S. C., Surface Water Quality Modeling. McGraw-Hill, pp. 345-502, 1997.

4. Chapman, D., Water Quality Assessments, A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. Chapman and Hall, 1992.

5. DePinto, J. V., David, M. D., Wendy, M. L., Paul, L. F., Limno-Tech Guiding Principles For Modeling in a TMDL Process, Inc.501 Avis DriveAnn Arbor, MI 48108 National TMDL Science and Policy, 2002.

6. Donia, N. S., Water Quality Control of Rosetta Branch, Unpublished Thesis, Institute of Environmental Studies and Research, Ain Shams University, 2002.

7. El-Bahrawy, N. and Abu Elaa, S., Pollution in the Nile River: Assessment and Control Case Study. Nile 2002 International Conference on Comprehensive Resources Development in the River Basin, Cairo, Egypt, P.VI.2.1-VI.2.15, 1993.

8. El-Gamal, A., Shafik, Y., A Study on the Monitoring of Pollutants Discharging to the River Nile and their Effect on Rivers Water Quality. Water Quality Bulletin, Vol. 10 (3), 1986.

9. El-Gohary, F. A., Water Quality Changes in the River Nile and Impacts of Waste Discharges. Water Pollution Control Laboratories, National Research Center, Dokki, Cairo, Egypt, 1987.

10. El-Gohary, F. A. and Nawar, S. S., Change in Nile River Water Quality and Wastewater Discharge. Symposium on Environmental Technology for Developing Countries, Istanbul, Turkey, 1982.

11. El- Moattassem, M., A Study on Water Quality in the River Nile Starting from the High Dam to the Mediterranean Sea for the Period 1976 to 1985. Environmental and Occupational Health Centre of Imbaba, Cairo, Egypt, 1987.

12. El-Shanshoury, M. and Abdelbary, M., The Impact of Industrial Waste Effluent on the River Nile Water Quality. National Seminar on Physical Responses of the River Nile to Interventions, Cairo, 12-13 November, 1990.

13. El-Shanshoury, M. and Hassan, S.K., Quality of Water Released in Rosetta Br. in Mahmoudia Canal. Nile 2000 Conference in Protection and Development of the Major River, Cairo, Egypt, p.7.2, 1992.

14. El-Sherbini, A. M. H., Surface Water Quality Monitoring. Egypt Water Quality Impact Assessment: Phase I, Annex D, 1990.

15. El-Sherbini, A. and El-Moattassem, M., River Nile Water Quality Monitoring. Proceeding of the National Seminar on Physical Response of the River Nile to Interventions. Nile Research Institute, Egypt,1990.

16. El-Sherbini, A. and El-Moattassem, M., River Nile Water in Egypt: a Case Study. Proceedings of the International Symposium on Management of River for the Future. Department of Irrigation and Drainage, Malaysia, 1993.

17. El-Sherbini, A. and El-Moattassem, M., River Nile Water Quality Index during High and Low Flow Conditions. National Conference on the River Nile, Assiut University Center for Environmental Studies (AUCES), 1994.

18. Gu, R. and Dong, M., Water Quality Modeling in the Watershed-Based Approach for Waste Load Allocations. Water Science and Technology, Vol. 38, No. 10, pp. 165-172, 1998.

19. ICIM, DUFLOW-a Micro Computer Package for the Simulation of One Dimensional Unsteady Flow and Water Quality in Open Channel Systems. Bureau ICIM, Rijswijk, The Netherlands, 1995.

20. Stephan, C.E., D.I. Mount, D.J, Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs, Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses, 1985.

21. Thomann, R. V. and John A. Muller, Principles of Water Quality Modeling and Control. HarperCollins Publishers, New York, 1987.

22. Tebbut, T. H. Y., 1998. Principles of Water Quality Control. Butterworth-Heinemann edition.