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Maximize the Benefits of ElBoghdady Outlet in Water Quality Status of LAKE MANZALA, EGYPT

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A B S T R A C T

Lake Manzala is the largest coastal lake lies on the eastern north coast of Egypt and is considered the most valuable natural fish source. Water quality status and eutrophication levels of the lake had deteriorated due to the progressive increasing of polluted municipal, industrial and agricultural wastewater discharge from drains. The lake has many direct and indirect outlets to Mediterranean Sea but there were insufficient to the lake because of its great area. One of ineffective and indirect outlets to the sea is ElBoghdady outlet which lies 2.8 km away from the sea. The main objective of this work is to maximize the benefits of ElBoghdady outlet in lake water quality status by dredging 2.8 km radial channel to connect the outlet with the sea and other 10 km radial channel from outlet to inside the lake to increase water exchange between lake and sea. A hydrodynamic and water quality model for Lake Manzala was developed, calibrated and then modified to investigate the impact of this project in water quality status and eutrophication levels of the lake. The modified model simulated eight water quality parameters (BOD, DO, NO2, NH3, PO4, NO3, Chll_a and TP) as an indicator for water quality. The results show a significant improvement in lake water quality status and eutrophication levels. Significant decreases in the average concentrations of nutrients components by about 20%, were noticed, comparing to the original calibrated status of the lake (23.56%, 20.9%, 13.86%, 12.42% and 29.56% for PO4, NH3, NO2, NO3 and TP, respectively), While an increase in the average concentration of DO in the lake by about 1.74% was noticed.

1. INTRODUCTION

Water pollution of coastal lakes is considered as one of the most dangerous hazards which are affecting not only in Egypt but also in the majority of world countries because of its great importance environmentally, economically and human health. Pollution of Egyptian coastal lakes, especially Lake Manzala, will also affect in the whole aquatic system in the Mediterranean Sea basin. Lake Manzala is the largest of the Egyptian shallow coastal lakes which is located in the Northern-Eastern region of Egypt on the fringe of the Mediterranean Sea, Figure (1). Lake Manzala produced about 35% of the total country yield of inexpensive fish during the 1980's [1] in Egypt, but in the present, it produced about 44% (2004-2013) and increased to about 56% in 2013 from the total annual production, so Lake Manzala is considered as the most productive lake in Egypt, [2].

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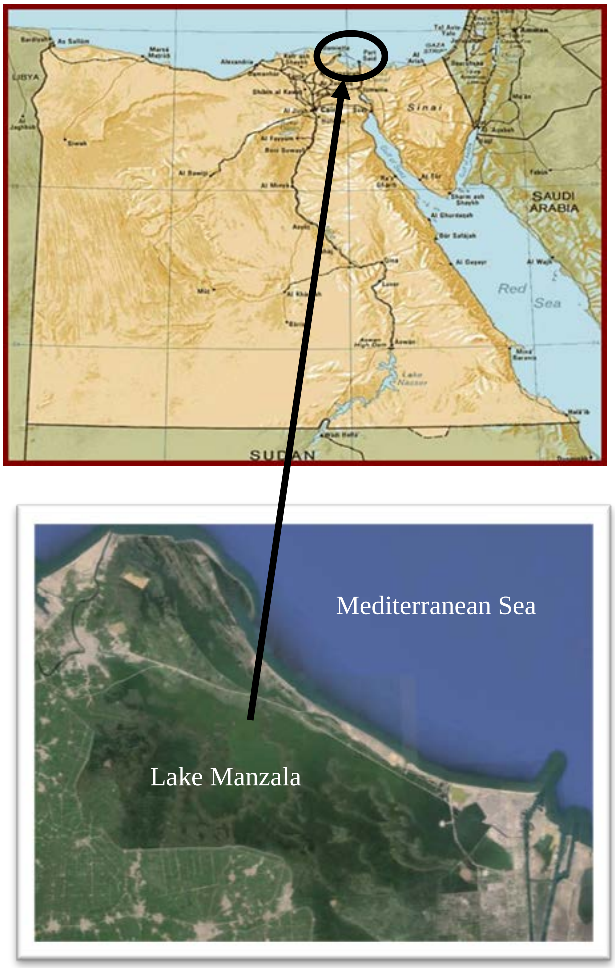

Figure (1): Lake Manzala, Egypt.

Lake Manzala was surrounded by five provinces and provides important habitats for a variety of aquatic wildlife and endangered bird species and also is considered as a feeding area for migrating birds. The lake receives about 5.5 BCM/year of fresh water through five main drains namely; Bahr El-Baqar, Hadous, El-Serw, Mataria, and Faresquer drains [3]. This huge amount of polluted fresh water leads to the deterioration of the water quality status of the lake. These drains carry industrial wastes, agricultural drainage and municipal wastes from 6 governorates namely; Port Said, Demietta, El-Sharqia, El-Daqahlia, El-Qalubia and the great Cairo. These drains are discharging huge amounts of heavy metals and other toxic materials into Lake Manzala causing severe contamination to the whole aquatic system. Heavy metals and other toxins appear at high concentrations in water, sediment and fish [4]. According to all previous studies on Lake Manzala, the major problems of the lake are:-

- Increasing heavy metal concentrations in water, sediments and fish.
- Increasing the nutrients loading comes to the lake from drains and accelerates the eutrophication process within the lake.
- Fish in lake are contaminated with a very high amount of TVB (total viable bacteria) and FCB (fecal coliform bacteria).
- “Fish is highly polluted and dangerous for human health” [5].
- Water circulations are limited in Lake Manzala because of fish farms and vegetated islands.
- Fewness of lake outlets to the sea.
- Data scarcity and multi responsibilities.

Lake Manzala has gradually transformed, with time, from a brackish environment to eutrophic fresh water [6]. Because of the great importance of Lake Manzala, many investigations were carried out on Lake Manzala [7 - 5] and it was selected to be the main objective of many international and local projects where it was selected to be one of three studied cases in the southern Mediterranean region for the MELMARINA Project [8 - 3], and to be one of nine primary sites of North Africa wetlands to be biodiversity studied within the CASSARINA Project [9] and also selected from united nations development program (UNDP) to construct Lake Manzala Engineered Wetland in 1997 to treat about 250000 m³/day from Bahr ElBaqar drain before discharging into Lake Manzala [10]. Environmental effects of Bahr ElBaqar drain on Lake Manzala was studied through a project was financially supported by the Swedish Research Council (SIDA) from September (2008) to April (2009) [5]. The lake has many direct and indirect outlets to Mediterranean Sea but there were insufficient to the lake because of its great area. Despite of the large previous studies carried out on the lake, the developed hydrodynamic and water quality models on lake are very scarce and most of them are not available to researchers. In 2011, Bek et al. [11] constructed a hydrodynamic model for the lake using the Finite Volume Coastal Ocean Model (FVCOM) to characterize the hydrodynamics characteristics of the lake and to assess the impact of El-Salam Canal Project on the lake. Rasmussn et al. [12] in 2009 had developed a hydrodynamic-ecological model for Lake Manzala, based on MIKE 21, to analyze the development of water quality as a function of the load of organic material and nutrients. Also Elshemy et al. [13 - 14] used MIKE21 modelling system to build a hydrodynamic and water quality model for Lake Manzala in 2016 to study the future impacts of climate change on the lake. Finally, A Elhamaimi in 2018 developed a hydrodynamic and water quality model for Lake Manzala using MIKE21 code to assess water quality status of the lake and to test ten water quality management scenarios on Lake Manzala, [15]. The Lake has indirect and ineffective connection to the sea called ElBoghdady outlet. The main objective of this research work is to maximize the benefits of ElBoghdady outlet by developing a radial channel project on ElBoghdady outlet and using the calibrated model for Lake Manzala, Hassan et al. [16] to assess the impact of this project on water quality status of Lake Manzala.

2. MATERIALS AND METHODS

2.1. Study Area.

Lake Manzala is the largest Egyptian costal lakes, lies on the northern boundary. It is semi rectangular in shape, about 47 km long and 30 km wide with area about 600 km² and about 23% of the lake total area is islands [17]. The lake water depth ranges from 0.7 to 3.5 m with average depth 1.0 m, so it is classified as a shallow lake. Salinity ranges from low salinity in the south and west to brackish water over the most of its area to saline water in the extreme north east [18]. The lake lies in semi-arid zone where is annual precipitation is about 78.4 mm/yr and annual evaporation 1100.2 mm/yr. The northern boundary of the lake is the Mediterranean Sea while other boundaries are lands. The lake pollution comes from many sources, industrial activities, human activities such as land cultivation, human settlements, drains polluted inflows, sewage inflows and few lake outlets. These pollutants are transformed the lake water quality status from a marine estuary environment to a eutrophic freshwater system composed of about 30 basins which are varying in their hydrological and water quality characteristics (Rashad and Abdel-Azeem 2010) [17]. In spite of the great area of the lake, it has only two direct connections to the sea (outlets), are El-Gamil 1 and the New El-Gamil 2 outlets in addition to a very narrow canal (El-Qabuty) which connects between the lake and Suez Canal at the east, Figure (2).There are also two ineffective outlets; Eldiba outlet which is in the northern edge of the lake in a salt extraction area and ElBoghdady outlet which in the middle sector of the lake and lies three kilometers away from the sea.

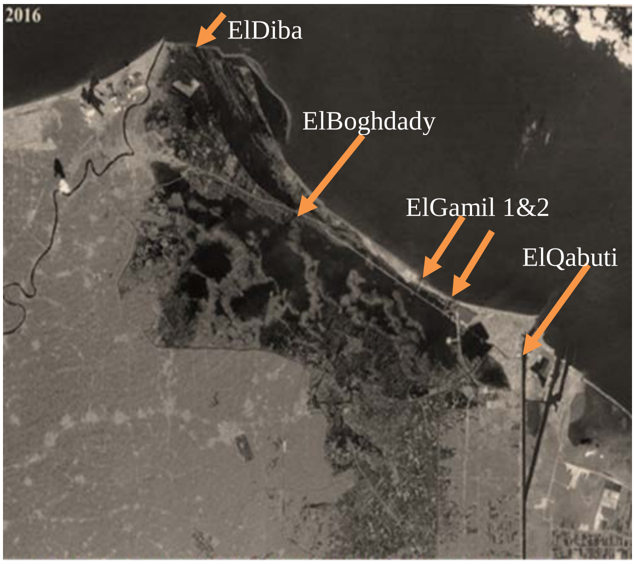

Figure (2): Lake Manzala Outlets [15].

2.2. ElBoghdady Radial Channels Project

Lake outlets are responsible for water exchange between lake and sea, and one of deterioration reasons in lake water quality status is the limited water exchange due to lack of outlets and the exist of international coastal road passing through the lake. ElBoghdady outlet lies under the international coastal road, Figure (2), but not at the coast and with neglected effect in water circulation on Lake Manzala. The outlet was 200 m width and bed level (-3.00). The aim of this work is to make ElBoghdady outlet useful to water exchange between lake and sea by connecting the outlet directly to the sea and then connecting the outlet to the middle sector of the lake. The proposed project is to dredge two radial channels, one from ElBoghdady outlet to the sea with 2.8 kilometers long and 200 m bottom width [19]. And the other radial channel from ElBoghdady outlet to inside the lake with 10 kilometres long and 200 m bottom width passing between big islands based on Lake Bathymetry to let sea water arrives to the middle and the south sectors of the lake where there is a high level of pollution, Figure (3). The radial channels are dredged at the same level of the outlet.

2.3. Data Collection

Physical, chemical and biological data were collected by the Egyptian Environmental Affairs Agency (EEAA) from eleven field record stations, Figure (4).

Figure (3): Proposed Radial Channel.

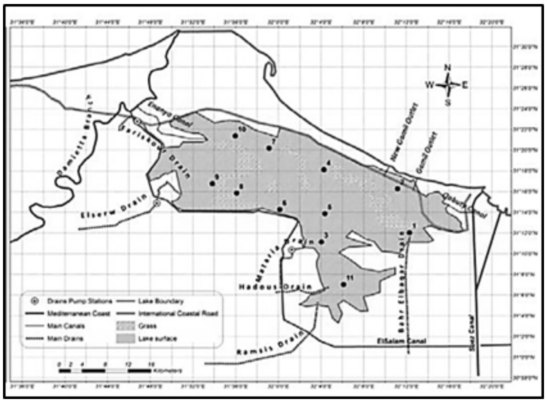
Figure (4): Field record stations in Lake Manzala for EEAA [15].

Water depths and water levels were collected from five stations in the Lake Manzala, Figure (5).

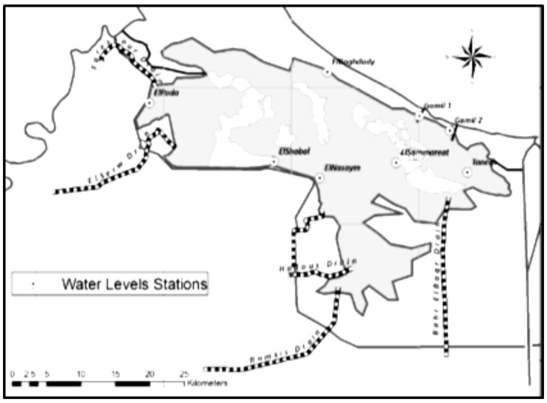

Figure (5): Water levels stations in Lake Manzala for EEAA [15].

Hydrological records and drain discharges were collected by National Water Research Center (NWRC), Egypt. Meteorological data were obtained from the internet (Weather Underground [20] and Info space [21]) at Port Said Airport station which is the nearest meteorological station to Lake Manzala.

2.4. The Calibrated Model for Lake Manzala

Elhamaimi had developed a hydrodynamic (HD), advection dispersion (AD) and Ecolab models for Lake Manzala in 2018, [15 - 16] and these models were modified in this study to investigate the impacts of ElBoghdady Radial Channel on Lake Manzala water quality status. The lake model has been developed on three dependent stages. First, (HD) model was developed and calibrated using the water levels records from the five water level stations. Second, (AD) model was developed, based on the calibrated (HD) model. Two parameters were simulated, water temperature and salinity. The developed (AD) model was calibrated using the records of water temperature and salinity from the eleven water quality record stations for of the lake. Third, the Eco-Lab model was developed based on the developed (HD) and (AD) models of the lake. Eight water quality variables were simulated. These variables are Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Nitrite (NO2), Nitrate (NO3), Ammonia (NH3), Phosphate (PO4), Chlorophyll-a (Chll_a) and Total Phosphorus (TP). These eight variables are used as indicators for water quality status of Lake Manzala. The Eco-Lab model was calibrated using the records of the eleven water quality record stations. The calibrated model was simulated for one year (1st Aug. 2010 –1st Aug. 2011). The calibrated model results of this model were used as a base case for this study. To consider the impacts of ElBoghdady radial channels on the lake, the model bathymetry has been modified according to the new bed levels and dimensions, Figure (6).

2.5. Evaluation the Results

The modified model has been run using the same conditions and coefficients of the calibrated model, [15 - 16]. The result simulated data will be compared with the calibrated data for every day all over the year (from 1/8/2010 to 1/8/2011) for every parameter at each station from the eleven water quality record stations and then change (Δ) will be calculated from the following equation:-

$$\Delta = \frac{\text{average simulated} - \text{average calibrated}}{\text{average calibrated}} * 100 \qquad (1)$$

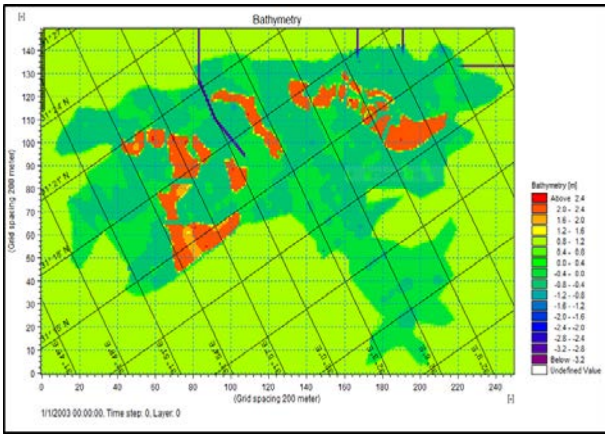

Figure (6): The modified bathymetry for Lake Manzala HD, AD and Eco-Lab model.

Δ will refer to the result, if positive it means increasing in the variable which means that the lake water quality status (LWQS) get worst except in DO only which increasing in the variable means improving in (LWQS), if negative it means decreasing in the variable and improving in (LWQS). Δ will be calculated for every variable at each station and then the average (Δ) for the variable all over the lake will be calculated. Due to data scarcity, there are a lot of missing parameters not included in simulation, so trophic index (TRIX) is suitable to evaluate eutrophication level for lake in calibrated state and proposed ElBoghdady Radial Channel [15, 22 and 23]. After conducting the trophic index (TRIX), the results were compared with the Classification of Trophic and water quality status of water bodies according to (TRIX) index where the values above 5 is considered in a bad water quality status and high eutrophication level [24].

3. Results and Discussion

Figures (7) and (8) show the calibrated model against the modified model profiles of the considered water quality parameters for a typical simulation year at different stations, as examples: (Δ) for BOD at station no.1 was (-20.51%), DO at station no.9 was (-0.86%) and Chll_a at station no.2 (-42%), figure (7). For nutrient components, NO2 at station no.5 was (-39.27%), NO3 at station no.4 was (-5.92%), NH3 at station no.6 was (-62.67%), PO4 at station no. 3 (-83.22%) and TP at station no.8 was (-16.55%), Figure (8).

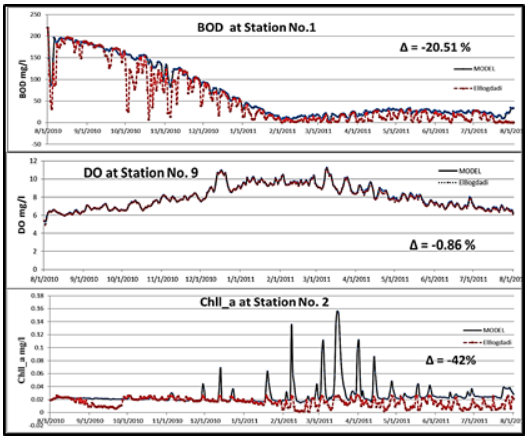

Figure (7): Calibrated and Simulated DO, BOD and Chll_a profiles at different stations in Lake Manzala for a typical year due to ElBogdadi Radial Channel.

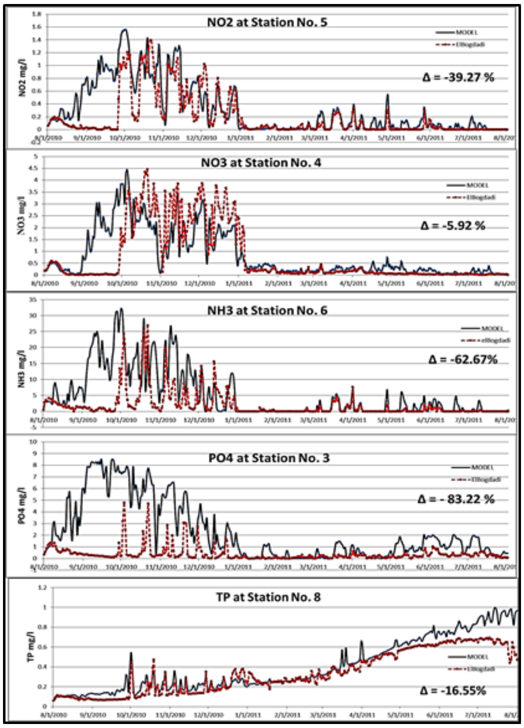

Figure (8): Calibrated and Simulated nutrients components profiles at different stations in Lake Manzala for a typical year due to ElBogdadi Radial Channel.

The average percentage ratios for each considered water quality parameters at the eleven record stations can be seen in Figure (9) and the average (Δ) for the eight variables at each record station can be seen in Figure (10).

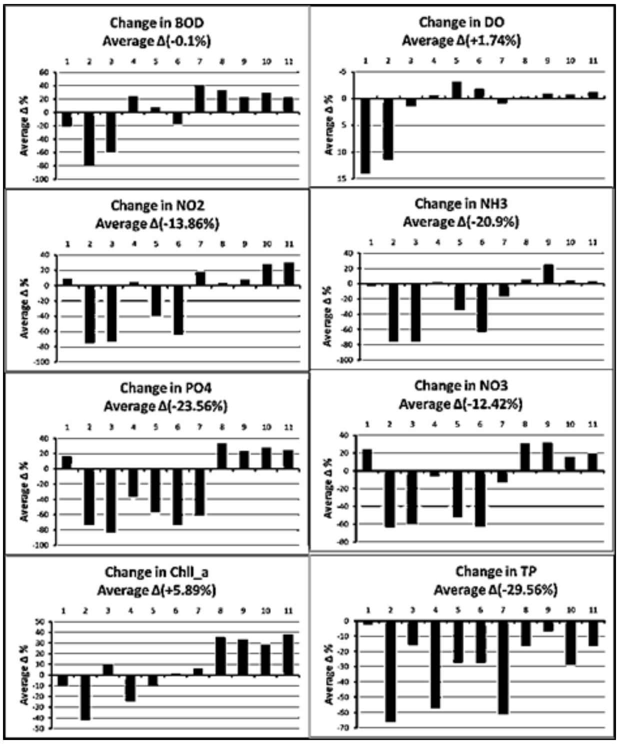

Figure (9): Av. (Δ) in 8 Variables for ElBogdadi Radial Channel.

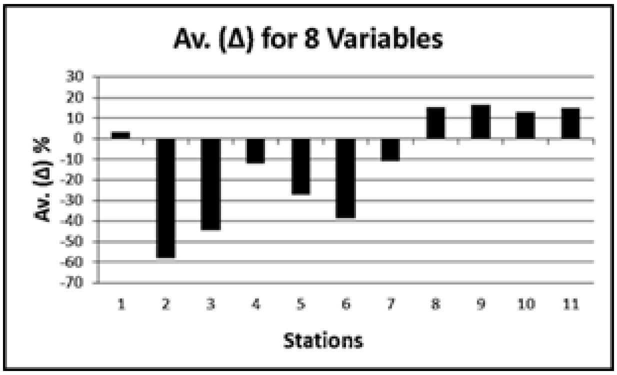

Figure (10): Av. (Δ) for 8 variables at each station for ElBogdadi Radial Channel.

The results show a significant improvement in water quality status of the lake. The nutrients components have significant decrease in their concentrations compared with the base case as can be seen in figure (9) where the average decreases ratios are about 23.56%, 20.9%, 13.86%, 12.42% and 29.56% for PO4, NH3, NO2, NO3 and TP, respectively and the average decrease in all nutrients components was about (20%). The average decrease ratio in BOD was about 0.1% while the average concentrations ratios for Chll_a was increased by about 5.89% and DO average concentrations was increased by about 1.74%.

Significant changes in the investigated water quality parameters can be noticed at Stations no. 2, 3, 4, 5, 6 and 7 where these stations are represent the middle and east sectors of the lake and these sectors was influenced with ElBoghdady Radial Channel, figure (4). Station no. 1 wasn´t influenced because it is far away from radial channel and still influenced with polluted Bahr ElBaqar drain while station no.11 didn´t improve because it is in a semi closed basin and isolated from radial channel and still influenced with Hadous and Ramsis drains. Regarding to stations at west sector of the lake (no. 8, 9 and 10), there was no improvement because this sector is far away from lake boundaries and ElBoghdady radial channel and still influenced with Fariskour and Elserw drains and this sector is full with fish farms which obstruct water circulation in Lake Manzala. These odd values at both stations for most parameters may return to their location and the flow circulation due to the changes in outlets boundaries. From the simulation results, trophic index (TRIX) was calculated at every station and compared with the base case as shown in figure (11) all stations were enhanced except no. 1,9 and 11 because the reasons discussed before and five stations were lied under 5 limit for high eutrophication level.

Generally, the proposed project for ElBoghdady Radial Channel will improve Lake Manzala water quality status especially in the middle and eastern sectors of the lake where the high pollution rate exist.

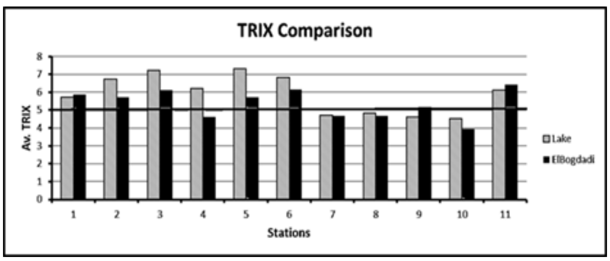

Figure (11): TRIX Comparison between Lake and ElBogdadi Radial Channel.

4. Conclusions

The impact of ElBoghdady outlet on water quality status of Lake Manzala now could be neglected because it hasn´t direct connection to the sea and the international coastal road separates the lake from the sea [15 - 16]. To maximize the benefit of the outlet, a 2.8 km radial channel was dredged to connect the outlet with the sea and other 10 km radial channel to spread sea water through the lake. A hydrodynamic and water quality model for Lake Manzala was developed and calibrated, and then the calibrated model was modified to investigate the impact of this project in water quality status and eutrophication level of the lake. The modified model simulated eight water quality parameters (BOD, DO, NO2, NH3, PO4, NO3, Chll_a and TP) as an indicator for water quality status of the lake. This project will improve the water quality status of the lake, particularly for the middle and northern zone of the lake with an average decrease in the nutrients components concentrations by about 20%, compared to the calibrated case, while the average decreased ratios were about 23.56%, 20.9%, 13.86%, 12.42% and 29.56% for PO4, NH3, NO2, NO3 and TP, respectively and the average increased in DO was about 1.74% and for eutrophication level, eight stations from eleven were enhanced. According to the results, it is clear that the impact of ElBoghdady Radial Channels on water quality status of Lake Manzala and eutrophication level is good; this project allows the sea-lake exchange to be better through ElBoghdady outlet and makes sea water arrives to south and east sectors of the lake. This work supports the decision makers to take action and initiate such water quality management scenarios for Lake Manzala.

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