Ecosystem Restoration Using Maintenance Dredging In Lake Qarun, Egypt

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Abstract: The rise in Lake Qarun level problem is essentially due to the excess of agricultural drainage water, as well as other types of drainage water. The excess of this drainage water causes the inundation of contiguous lands, in particular the southern floodplain tourism areas of the lake. The negative impacts of this problem are water logging of agricultural lands, water pollution and increasing salinity of lake. Drainage water has different types of heavy metals. These heavy metals cause the deterioration of ecosystem. Bottom sediment of lake is a basin for heavy metals. The reduction of heavy metals and consequently, improving ecosystem comes from reduction of bottom polluted sediment. Many studies had been carried out to alleviate water excess problem, but the problem still subsists. This paper assesses the probability of using the dredging technique as a possible solution for the excess of drainage water problems. The aim of this paper also is to demonstrate the total amounts of different heavy metals in bottom sediment of lake. These amounts of heavy metals can reveal the deterioration circumstance of ecosystem of lake. Achieving research objectives and as the lack of information about the flood plain areas and actual area of lake. The relation among water level, time in months and area of flood plains adjacent to lake should be derived as a tool to accomplish research goals. It could be concluded from the research that, dredging technique can be a possible solution for the excess of drainage water problems in Lake Qarun. The dredging of one meter from bottom sediment of eastern part can be applied firstly to reduce water level by 30 cm, after that the process can be repeated for the western and middle parts of lake to reduce water level by one meter. It could be recommended that, the huge amounts of different heavy metals for 17 elements of heavy metals in lake bed sediment (Na, K, Ca, Mg, Fe, Mn, Cd, Zn, Cr, Ni, As, Cu, Pb, Sn, Mo, V, and Co) can be used in minerals extraction industry. The physical environmental removal of heavy metals from Lake Qarun will reduce the contaminants and as a result will improve the ecosystem.

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1. Introduction

Qaroun Lake is one of the most important inland-aquatic ecosystems in Egypt. The lake receives the agricultural drainage water from the surrounding cultivated land. The drainage water reaches the lake by two maindrains, El-Batts drain (at the northeast corner), and El-Wadi drain (near mid-point of the southern shore) (Abdel-Satar *et al*., 2010). Although, Lake Qarun attracts attention of many authors because of its historical and scientifically importance to study its unique ecosystem but, the studies dealt with the accumulation of heavy metals in different ecosystem components are still scarce except some studies like Elewa *et al.* (2001), Ali (2002), Mansour and Sidky (2003), and Abdel-Satar *et al*., (2003).The excess of this drainage water causes the inundation of neighboring lands, specifically the southern floodplain tourism areas of the lake. The negative impacts of this problem are water logging of agricultural lands, water pollution and increasing salinity of lake. Water effluent to lake has different types of heavy metals. These heavy metals cause the deterioration of ecosystem. Sediments are important sinks for various pollutants like pesticides and heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediment. (Klavins *et al.,* 2000; Grosheva *et al.,* 2000).

Knowledge of concentration of heavy metals is desirable for the estimation of metal concentration in lake's water, sediment and biota. Metal accumulated in benthic organisms may be further bio accumulative in food webs. Barnacles have been shown to fulfill many of these characteristics and used to assess the bioavailability of metals in the coastal waters of many parts of the world (White and Walker, 1981; Powell and White, 1990). The pollutant concentrations in the organism are the result of the past as well as the recent pollution level of the environment in which the organism lives, while the pollutant concentrations in the water only indicate the situation at the time of sampling (Ravera *et al*., 2003). In the recent years, heavy metals have been greatly considered in the studies of water environments because of their potential toxic effect persistence, and bioaccumulation problems (Censi *et al.,* 2006 and Carr & Neary, 2008). Sediments, as one of the water ecosystem components, act as a reservoir of heavy metals (ECDG, 2002 and Mwamburi, 2003). Sediments reflect the environmental changes occurred in sedimentary basins and provide useful information about accumulation of heavy metals, reflecting the natural impacts. Oftentimes, mixtures of metals pollutants are present in the impacted sediments, which may result in severe contamination leading to destroying the entire aquatic life (Milenkovice *et al*., 2005). The extent of sediment contamination with heavy metals should be investigated extensively to avoid the serious environmental risks. Heavy metals concentration causes a serious threat because of their toxicity, long persistence, bioaccumulation and bio magnification in the food chain (Yilmaz *et al*., 2007). Fish are located at the end of the aquatic food chain and may accumulate metals and pass them to human beings through consumption causing chronic or acute diseases (Al-Yousuf *et al*., 2000).Growth of fish larvae and juveniles is very fast. Many environmental factors influence growth: temperature, accessible alimentary base and presence of toxicants. Under optimum conditions, at appropriate temperature and at sufficient quantities of food, the fish increase in both body length and mass. On the other hand, in the water polluted with toxicants, e.g. heavy metals, fish growth may be inhibited. Inhibition of growth is one of the most distinct symptoms of toxic action of metals on fish larvae. Therefore, fish body length and mass are indicators of environmental conditions (Sarnowski and Jezierska, 2007). The deposition of the suspended sediment creatures causes the death of the benthic organisms. As a result the number of living creatures in the dredging area decreases sharply. Moreover, the suspended solids in areas of fish spawning greatly decrease the successful spawning rate. Furthermore, sinking sediments bury the gravels, crushed stones and other similar irregular object on the bottom of the lake, which destroys the natural shelter for young fishes thus lowering their survival. While many heavy metals are nutrients at trace levels, Pb, Cd and Hg are non-essential and recognized as important industrial hazards, causing severe toxic effects in higher animals upon acute or chronic exposure. These three elements arc highly persistent and in the bivalent form stable inorganic and organic complexes in biological systems (Allah *et al.,* 2007).The reduction of heavy metals and consequently, improving ecosystem comes from reduction of bottom polluted sediment. Dredging is an excavation activity or operation usually carried out at least partly underwater, in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable. On-draining lakes and reservoirs are relatively closed water areas with a small environment capacity. With the increase in human activities and industrialization, the amount of discharged waste water is also increasing, which deteriorates the water quality in the general environment. Environmental protection dredging is a recent emerging interdisciplinary area where environmental engineering and dredge engineering overlap. The goal of environmental protection dredging is to clear the polluted sediment in water, eliminate the contaminant source in a polluted water body, and reduce the amount of pollutant released from the bottom sediment to the water body. Maintenance dredging removes silts in a specific water area to maintain or restore original channel dimensions, which increases the capacity and maintains the depth and width of the lake or reservoir for sailing. Maintenance: dredging to deepen or maintain navigable waterways or channels which are threatened to become silted with the passage of time, due to sediment sand and mud, possibly making them too shallow for navigation. This is often carried out with a trailing suction hopper dredge. Most dredging is for this purpose, and it may also be done to maintain the holding capacity of reservoirs or lakes. Thus in environmental dredging, prevention of the secondary pollution caused by suspended mud or sediments is of great importance. As a result, specific equipment and measures are necessary to assure good water quality. (Mohamed *et al.,* 2005, El-Sayed *et al.,* 2015) studied the bottom sediments, water quality, and heavy metal content in Qarun Lake. It is concluded from the study that it is a must to protect Lake Qarun from anthropogenic sources of pollution to reduce environmental risks. Eastern part of the lake usually has high concentrations of most metals. Such differences were apparent for iron, nickel, cadmium, lead. These differences may well be attributable to changes in anthropogenic input of metals or to changes in physicochemical factors such as salinity which affect the uptake of many trace metals.

2. Objectives

This paper assesses the probability of using the dredging technique as a possible solution for the excess of drainage water problems. The total amounts of different heavy metals in bottom sediment of lake are one of present research goals. These amounts of heavy metals can reveal the deterioration circumstance of ecosystem of lake. Achieving research objectives needs some information about the flood plain areas and actual area of lake. Improving the previous empirical formulae related to water surface area of Lake is also one of the main goals of present research. An empirical equation should be derived for the relation between water level and the area of flood plains adjacent to lake as a tool for dredging calculations.

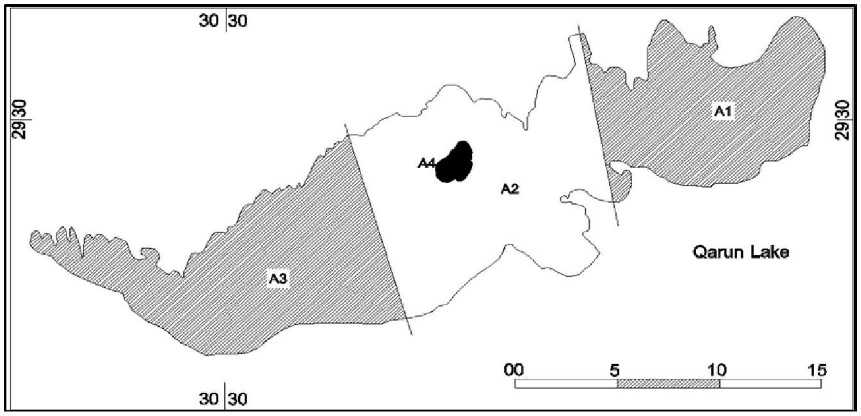
3. Material and methods

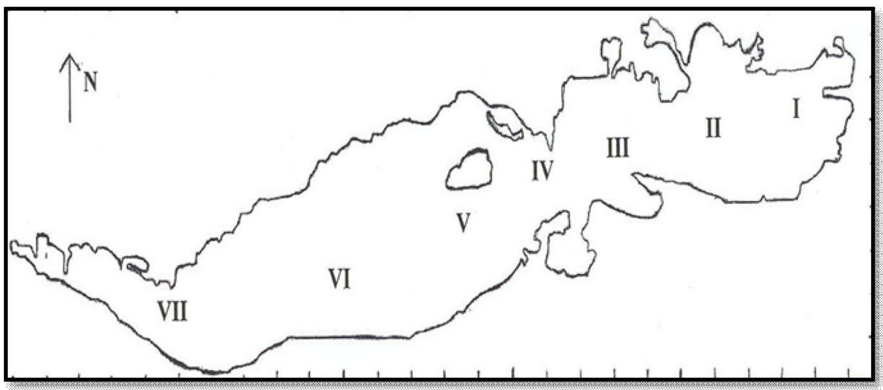
3.1 Description of the study area

Lake Qarun is the only enclosed saline lake in Egypt. It is located in the western desert part of Fayoum depression and lies 83 km southwest of Cairo. The lake is located between longitudes of 30° 24\` &30° 49\` E and latitude of 29° 24\` &29° 33\` N. It is bordered from its northern side by the desert and by cultivated land from its south and southeastern side (Abdel-Satar *et al.,* 2010). Qaroun Lake has an elongated rectangular shape with average dimensions 45 km length, 5.7 km width and 4.2 m depth in average (Gohar, 2002). It is bounded from the south and east by the urban and cultivated areas and from the north and west by the unoccupied desert areas. The drainage in El-Fayoum depression is mainly by gravity. The drainage network consists of three main drains (El-Bats, El Mashroah and El-Wadi drains) and a number of small drains, which terminate into the lake. The lake receives huge mixture of untreated agricultural, industrial, sewage, and household effluents (about 450 million m3/year) from El-Fayoum province (Gohar, 2002).Lake Qarun as it is known now has shrunk in size and is presently nearly 44 meters below sea level. It plays an important part in the agriculture and ecology of Fayoum region as it receives the drainage water from the irrigation canals. It is land locked and doesn't have any outlet. When a fresh water lake starts turning gradually saline most of the fresh water flora and fauna die some adapt and survive for some time until the salinity increases beyond their ability to adapt and these also disappear. The surrounding flora also starts disappearing until the whole area is dead. Thus an ecological disaster happens and entire area becomes inhabitable for nature as well as men. The salinity of Lake Qarun rose from 3.5 g/litre in 1890's to 26 g/liter in 1950, and it had been reached almost 50 g/liter by 2010.It was noticed in the studies done as early as 1930's that the Lake was turning into a salt water lake from a fresh water lake. As result of more intensive cultivation and irrigation the situation has been aggravated and it was predicted that if action is not taken it will become a dead lake.

3.2 Sample collection and analysis

Using satellite photos from March to August 2015, the Lake area was measured and it gave total area of 244.84 km^2. The total area of lake was divided into four small areas according to locations of sediment samples as shown in Figure (1). The area A_1 for eastern part of Lake Qarun equals 72.46 km^2. The area A_2 for Middle part of Lake equals 92.94 km^2, the area A_3 for western part of Lake equals 81.58, and the area A_4 for El-Qarn Island equals 2.14 km^2. Where total area (A_t) will equal the areas of three parts (A_1, A_2, and A_3) minus area (A_4). El-Sayed, *et al*., (2015), studied the evaluation of heavy metal content in Qaroun Lake bottom sediments. Qaroun Lake sediments with heavy metals were evaluated using some of geochemical tools. The lake was divided geographically into three parts (east, middle and west) according to the presence of the relevant drains. Fourteen samples were taken from the bottom sediments of the lake for grain size and heavy metal analysis. Their distribution is as follows: 6 samples from the eastern part of the lake, 4 samples from the central part and 4 samples from the western part (Figure2). Nine samples were collected from the relevant drain bottom sediments and analyzed for heavy metals to reveal their impact on the lake. All samples were taken from 0.0 to 10 cm depth using a suitable grab sampler. The collected samples were put directly in air sealed polyethylene bags and kept at 4C^o until analyses. The sediment samples were analyzed for arsenic (As), chrome (Cr), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn), tin (Sn), molybdenum (Mo), vanadium (V) and cobalt (Co) metals, using X-Ray Fluorescence (XRF) spectrometry. Ten heavy metals were determined (in ppm) by X-Ray Fluorescence Spectrometry. The average concentration values in sediments are 2.99 (As), 124.89 (Cr), 38.91(Cu), 14.21 (Pb), 54.74 (Ni), 58.76 (Zn), 3.27 (Sn), 6.77 (Mo), 162.77 (V) and 11.70 (Co). Another study had been carried out by Mohamed, et al., (2005). Samples of water and sediment were taken from seven stations covering the whole lake area (Figure3). At the same time, benthic invertebrate and fish species were collected from three main sectors (east, middle and west) of the lake. The water was preserved in plastic bottles by the addition of a few drops of nitric acid. Sediments were preserved in plastic bags. Benthic fauna were collected by dredge, careful washing with lake water to remove sand and mud particles then were preserved in plastic bags. The levels of Ca, Mg, Na, K, Fe, Mn, Zn, Cu, Cd, Pb, Co, Cr, and Ni in digests were determined using atomic absorption (Perkin Elemer Model 3700) with flameless graphite furnace (GA-2).





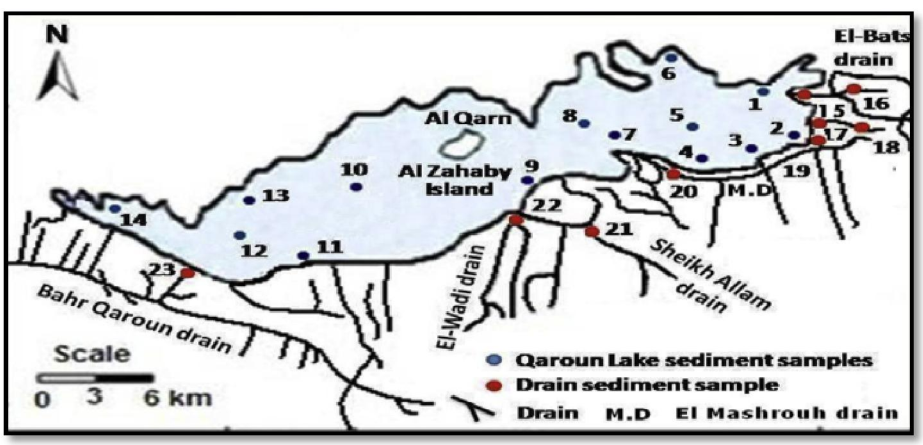


Figure (3) Lake Qarun locations of samples (El-Sayed, et al. 2015)

4. Results and discussion

4.1 Lake Area and Water Levels

The average area is about 240 km^2, the lake is not deep, with mean depth of 4.2m. Nearly, most of the lake's area has a depth ranging between 5 to 8 meters. The water level of the lake changes between 43 to 45 meters below mean sea level (Meshal, 1973). The maximum depth of lake is 8.5 meters to the west of EI-Oarn Island and the eastern part is shallower with depth of about 3 meters.

Ball (1939) established two empirical formulae for the calculation of area of the lake and its volume, where A= 166 + 24(47-L), and V = 422 + 166(47-L) + $12(47 - L)^2$ Where A is the area in sq. km and V is the volume in 10^6 m^3. If the volume tends to zero then as per the formula L = -53.92 meters, indicating depth of 9.92 meters at a datum of -44. The maximum depth mentioned by Abdel-Malek and Fouda (1990) is 8.7 meters. Soliman (1989) mentioned depth of 8.4 meters. Use of this formula for level of -42.95 gives area value of 263.2 sq. km. an error of +8.1 % and the volume is 1291.1 x 10^6 m³ an error of +39.7%.

Mohunta (2008) studied the area of lake using satellite photo august 2003, the area was measured and it gave area of 241.3 Sq. km. and a length of 41 km. The empirical formulae of Ball (1939) had been reworked based on previous observations and are given below $A = 194.5 + 26.557(45.07\text{-}L)$, and $V = 695 + 194.5(45.07\text{-}L) + 13.6(45.07\text{-} L)^2$ In these equations the volume and area will be nil for a depth of 8.394 meters. As per Mohunta (2008) study the average depth at -42.95 is 3.8 meters whereas the data of Ball indicates an average depth at the same level as 4.905 meters.

It should be noted that the lake area fluctuates year round due to changes in evaporation rates with the weather conditions and the drainage input to the lake. Khalil (1990) indicated that for the years 1969-89 the mean level of the lake was -43.64 meters and the level fluctuated by (+ or -0.39)meters. Soliman (1989) studied annual variation of lake level as shown in Figure (4). It is noticed that the water levels fluctuate between -43 and -44 below mean sea level. These levels fluctuate from January to March, from March to June and from June to November. Then there is a relation between time and water levels. The previous studies deserted the effect of time in water level and the area. The present study will take the effect of time in preparation of the present formula. Annual time will be divided into three periods of time (t_1, t_2, and t_3) according to the variation in water level changes. Using data of annual time (after Soliman, 1989) to find the relation between water level (W.L) and time in months. The general form and deduced formulae are as follows:

W.L= a-b (t), a, and b are constants. $1 \leq t \leq 12$, January equals (1), September equals (9).

$W.L_1 = 43.89 - 0.202\ (time_1)$, $R^2 = 0.95$, time (from January to March)

$W.L_2 = 0.126\ (time_2) + 43.01$, $R^2 = 0.91$, time (from March to September)

$W.L_3 = 45.20 - 0.123\ (time_3)$, $R^2 = 0.93$, time (from September to December)

The measured water levels compared with calculated water levels from present equations and the percentages of errors are verified as shown in table (1).

Using measured data of area and the bathymetric data of Lake as shown in Figure (5) to get the relation between water level (W.L) and projected surface area of Lake (A_p). The general form and deduced formulae are as follows:

Area (A_p) = c-m (W.L). (c), and (m) are constants. WL= f (t), $1 \leq t \leq 12$, January equals 1, November equals 11.where (c) equals 1391, and (m) equals 26.5

$(A_p)_1 = c - m\ (W.L_1)$, $R^2 = 0.93$, time (from January to March)

$(A_p)_2 = c - m\ (W.L_2)$, $R^2 = 0.88$, time (from March to September)

$(A_p)_3 = c - m\ (W.L_3)$, $R^2 = 0.92$, time (from September to December)

Comparing the present formulae with Ball (1939), the maximum water depth at zero surface water area of Lake for Ball (1939) formula was 9.92 meters at a datum of -44 meters, and WL = -53.92 meters. While present formula indicates that at zero water area the maximum depth is 8.49 meters at a datum of -44 meters. Abdel-Malek and Fouda (1990) mentioned that, the maximum depth of Lake Qarun is 8.7 meters. The error in present formulae, for month (March) as an exampleis2.4%using maximum water depth (8.7 meters) for comparison. The formula of Mohunta (2008) showed that, the error is 3.5% at zero water area and maximum depth 8.394 meters at the same datum (-44 meters).The comparison between previous and present work reveals that the previous formulae of Ball (1939) and Mohunta (2008) are linear equations describe the relation between water level and water surface area of Lake. But it didn't take time into considerations, while the water level fluctuates with time. The present equations in this research which describe the relation between water level and time respected the fluctuation of water level with time. The equation for this reason was divided into three equations with respect to months of year. Finally the derived formulae can predict the area of Lake more accurate than the previous formulae. Flood plains area (A_s) can be obtained as shown in Figures from (6) to (8) using the present derived formulae for Lake projected area (A_p) and total Lake area, Where $(A_s) = (A_t) - (A_p)$

4.2Dredging Volume and Reduction of Lake Levels

In this research the proposed physical removal for contaminated sediment is maintenance dredging (environmental dredging) to conserve environment. The thickness of contaminated sediments is usually thin in water with a depth of 10 to 50 centimeters. The digging scope depends on the distribution of polluted sediment and the digging surface must match the distribution of polluted sediments. In order to avoid removing natural lake sediments, reducing the processing quantity, and to lower disposal expenses, it needs to remove the polluted sediments and to reduce the excess digging of non-polluted sediments as much as possible as shown in Figure (9).The reduction in water levels of Lake Qarun can be obtained using the above present formulae of flood plain area (A_s).

Because the wetted side slope of Lake bed is very small (0.00265), where the angle (Ø) is very small (0° 9° 6.6\`), then (sine Ø) equals (tan Ø). For this reason the difference in water levels (h_d) equals dredging thickness (t) as shown in Figure (10).The volume of dredging (V_d) will be as follows:

(V_d) = (A_s) x (h_d), and difference in water levels will be (h_d) = (V_d) / (A_s).

Using the above present derived formulae, the thickness of dredging layer is suggested to be from 10 cm to 100 cm. The dredging thickness from 10 cm to 30 cm is for removal of heavy metals keep in grestoration of Lake. Tables from (2) to (7) show the calculated volumes of sediment for three parts of Lake Qarun. Calculations showed that the sediment volume (V_d) of proposed eastern area is 7.2 million cubic meters for(A_s) 72 km^2 and (h_d) 10 cm. the sediment volume (V_d) of proposed middle area is 9.1 million cubic meters for (A_s) 91 km^2 and (h_d) 10 cm. the sediment volume (V_d) of proposed western area is 8.2 million cubic meters for (A_s) 82 km^2 and (h_d) 10 cm. using the above formula sediment volume (V_d) can be obtained for any thickness (h_d), also the reduction in water level of Lake can be reduced by 10 cm if the dredging will be 24.48 million cubic meters of bed sediment. The amounts of sediment can be increased using different thickness of dredging as the decision maker wants. The reduction of water excess problems in Lake Qarun, also can be achieved using different thickness of dredging. The dredged sediment can be used for construction purposes.

4.3 Amounts of Heavy Metals in Bottom Sediment of Lake

The data of Mohamed *et al.* (2005), and El-Sayed *et al.* (2015) were taken as a preliminary database for calculation of heavy metals in tons for bottom sediment of Lake Qarun. The amounts of seventeen elements of heavy metals in lake bed sediment (Na, K, Ca, Mg, Fe, Mn, Cd, Zn, Cr, Ni, As, Cu, Pb, Sn, Mo, V, and Co) were calculated in tons per cubic meters of sediment. The calculations of heavy metals are based on contaminated sediment, which is usually thin in water with a depth of 10 to 50 centimeters. The average dry density of sediments is 1.5 ton per cubic meters. All samples were taken from 0.0 to 10 cm depth using a suitable grab sampler. The Lake area is 244.84 km^2. The total area of lake was divided into four small areas according to locations of sediment samples as shown in Figure (4). The area A_1 for eastern part of Lake Qarun equals 72.46 km^2. The area A_2 for middle part of Lake equals 92.94 km^2, the area A_3 for western part of Lake equals 81.58, and the area A_4 for El-Qarn Island equals 2.14 km^2. Where net total area (A_t) will equal the areas of three parts (A_1, A_2, and A_3) minus area (A_4). Calculation of heavy metals revealed that the amounts of different heavy metals in tons for eastern part of Lake Qarun are (373350 Na, 87060 K , 518510 Ca,131730Mg, 295550 Fe, 4668290 Mn, 1709150 Zn, 170160 Cr, 14020 Cd, 757790 Ni, 33590AS, 1322320Cr, 400520Cu, 172270pb, 468240Zn, 39350Sn, 77930Mo, 1173310V, and 211080Co). The amounts of different heavy metals in tons for middle part of Lake Qarun are (475790 Na, 109550 K , 1072810 Ca ,236450 Mg, 222680 Fe, 4403780 Mn, 1599570 Zn,191720 Cr , 19010 Cd, 773660 Ni, 45500 AS, 1572410 Cr, 494480 Cu, 194620pb, 1046140 Zn, 46040Sn, 67910 Mo, 3214890 V , and 4020 Co). The amounts of different heavy metals in tons for western part of Lake Qarun are (464390 Na, 120230 K, 704550Ca, 184960 Mg, 171750 Fe, 2746900Mn, 918330 Zn,167770 Cr, 12300 Cd , 482750 Ni , 31080 AS , 1679410 Cr, 531940Cu , 152230pb , 686860 Zn , 34260Sn, 99610 Mo, 1765000 V , and 155650 Co).

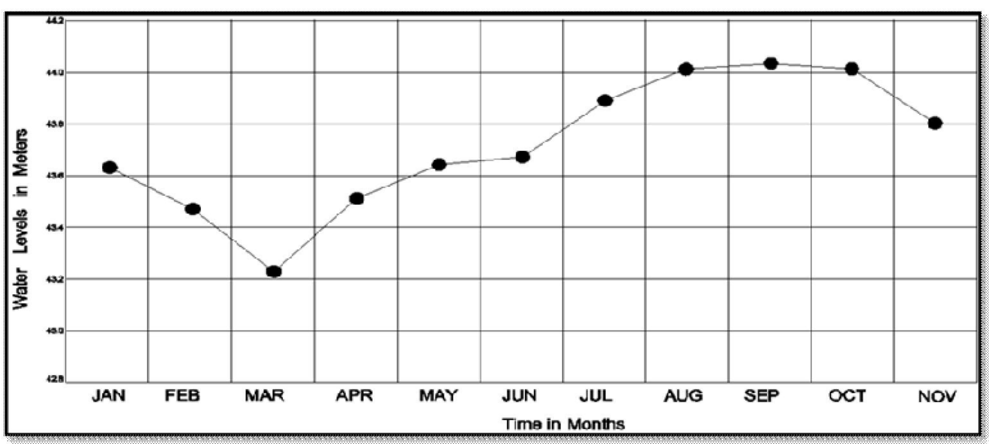


Figure (4) Sketch shows water levels with time of Lake Qarun (Soliman, 1989)

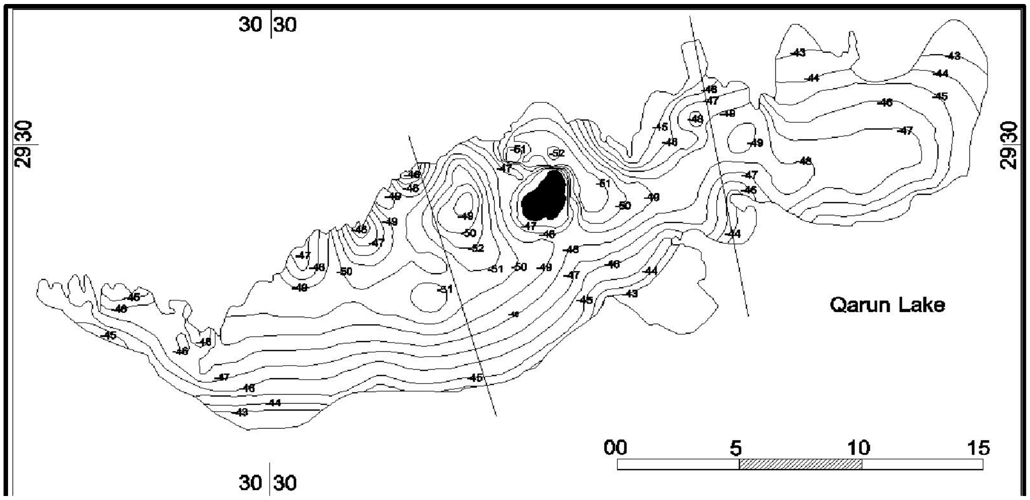


Figure (5) Bathymetric map of Lake Qarun

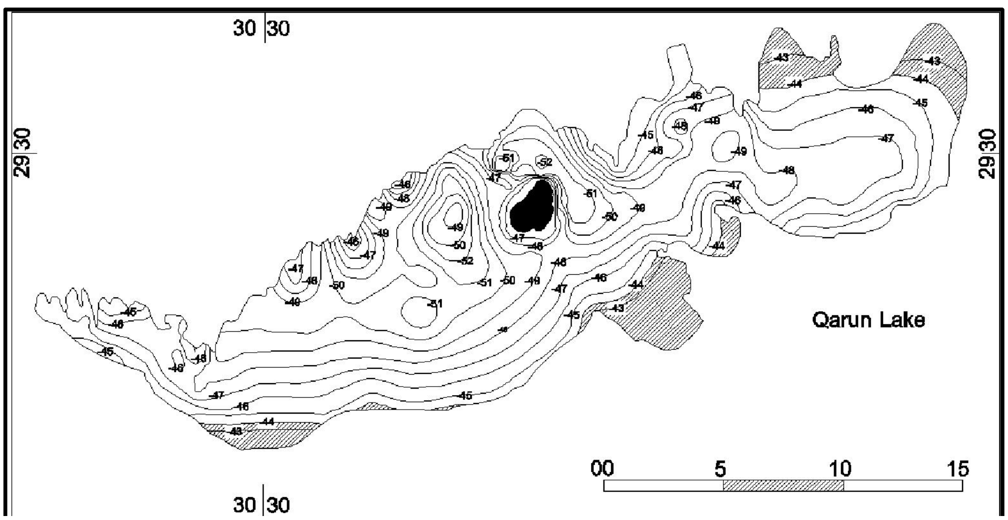


Figure (6) Sketch shows flood plain areas at water level (-44)

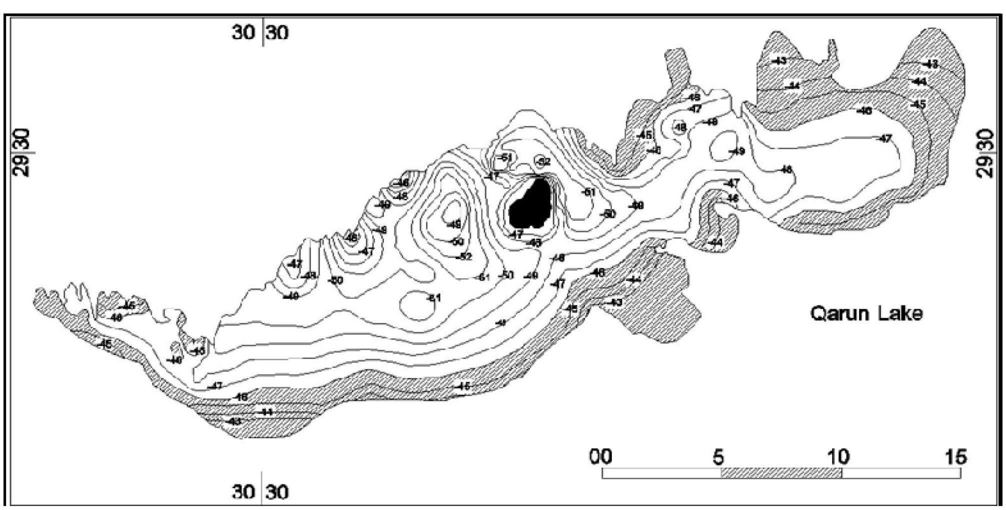


Figure (7) Sketch shows flood plain areas at water level (-46)

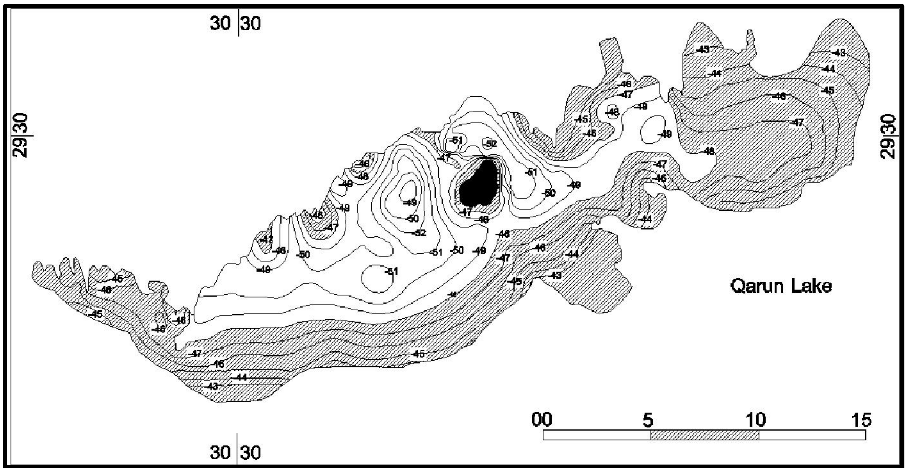


Figure (8) Sketch shows flood plain areas at water level (-48)

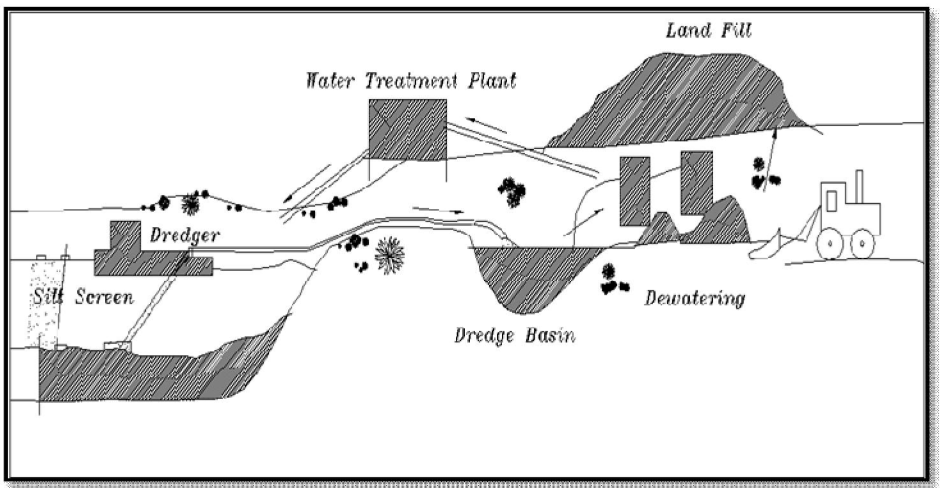


Figure (9) Sketch shows environmental dredging process at flood plain areas

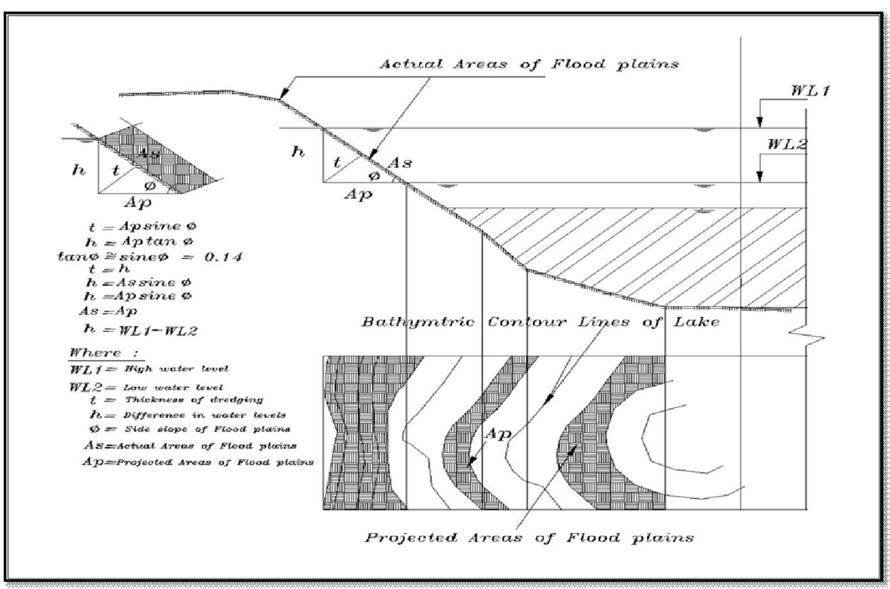


Figure (10) Sketch shows assumptions of flood plain areas and water levels of Lake Qarun

Table (1) Water Levels with respect to time in months of Lake Qarun

Month	No.	WL_1	WL_2	WL_3	Measured WL	Difference	Error%	R^2
Jan	1	43.69			43.66	-0.03	-0.06	0.95
Feb	2	43.49			43.54	0.05	0.13	0.95
March	3	43.28			43.26	-0.03	-0.06	0.95
April	4		43.51		43.62	0.11	0.25	0.91
May	5		43.64		43.69	0.05	0.10	0.91
Jun	6		43.77		43.75	-0.02	-0.05	0.91
July	7		43.89		43.98	0.09	0.20	0.91
August	8		44.02		44.02	0.01	0.01	0.91
Sept.	9		44.14		44.07	-0.07	-0.17	0.91
October	10			43.97	44.03	0.06	0.13	0.93
Nov.	11			43.85	43.81	-0.04	-0.09	0.93
Dec.	12			43.72	43.73	0.01	0.02	0.93

Table (2) Amounts of heavy metals in eastern area of Lake

East Area	Na mg/g	K mg/g	Ca mg/g	Mg mg/g	Fe mg/g	Mn µ g/g	Zn µ g/g	Cr µ g/g	Cd µ g/g	Ni µ g/g
SampL I ppm	33	8	36	12	26	403	180	18	1	84
SampLII ppm	36	8	59	12	21	456	134	14	1	56
Mean ppm	34	8	48	12	24	430	157	16	1	70
Area km^2	72	72	72	72	72	72	72	72	72	72
Depth m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Volume m. m^3	7	7	7	7	7	7	7	7	7	7
Amounts 1000 tons	373.35	87.06	518.51	131.73	259.55	4668.29	1709.15	170.15	14.02	757.79

Table (3) Amounts of heavy metals in middle area of Lake

Middel Area	Na mg/g	K mg/g	Ca mg/g	Mg mg/g	Fe mg/g	Mn µ g/g	Zn µ g/g	Cr µ g/g	Cd µ g/g	Ni µ g/g
Sampl III ppm	35	8	74	17	20	374	156	14	2	56
Sampl IV ppm	37	8	82	16	11	302	77	13	1	48
Sampl V ppm	33	8	81	19	18	297	120	15	1	66
Mean ppm	35	8	79	17	16	324	118	14	1	57
Area km^2	91	91	91	91	91	91	91	91	91	91
Depth m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Volume m. m^3	9	9	9	9	9	9	9	9	9	9
Amounts 1000 tons	475.79	109.55	1072.81	236.45	222.68	4403.78	1599.57	191.72	19.01	773.66

Table (4) Amounts of heavy metals in western area of Lake

West Area	Na mg/g	K mg/g	Ca mg/g	Mg mg/g	Fe mg/g	Mn µ g/g	Zn µ g/g	Cr µ g/g	Cd µ g/g	Ni µ g/g
Sampl VI ppm	37	10	47	13	16	235	73	14	1	40
Sampl VII ppm	39	10	68	17	13	214	78	14	1	39
Mean ppm	38	10	58	15	14	224	75	14	1	39
Area km^2	82	82	82	82	82	82	82	82	82	82
Depth m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Volume m. m^3	8	8	8	8	8	8	8	8	8	8
Amounts 1000 ton	464.39	120.23	704.55	184.96	171.75	2746.90	918.33	167.77	12.30	482.75

Table (5) Amounts of heavy metals in eastern area of Lake

East Area	AS µ g/g	Cr µ g/g	Cu µ g/g	pb µ g/g	Zn µ g/g	Sn µ g/g	Mo µ g/g	V µ g/g	Co µ g/g
Sampl 1 ppm	5	227	60	30	13	4	15	34	15
Sampl 2 ppm	1	89	18	12	18	4	7	56	35
Sampl 3 ppm	3	98	29	12	57	4	3	151	18
Sampl 4 ppm	3	79	33	11	59	3	3	136	18
Sampl 5 ppm	5	109	45	16	88	3	7	214	7
Sampl 6 ppm	1	127	36	14	25	4	9	58	24
Mean ppm	3	122	37	16	43	4	7	108	19
Area km^2	72	72	72	72	72	72	72	72	72
Depth m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Volume m. m^3	7	7	7	7	7	7	7	7	7
Amounts tons	33.59	1322.32	400.52	172.27	468.24	39.35	77.93	1173.31	211.08

Table (6) Amounts of heavy metals in middle area of Lake

Middel Area	AS µ g/g	Cr µ g/g	Cu µ g/g	pb µ g/g	Zn µ g/g	Sn µ g/g	Mo µ g/g	V µ g/g	Co µ g/g
Sampl 1 ppm	3.6	97.9	45.6	16.3	91.7	3.3	1.9	257.6	0.6
Sampl 2 ppm	4.3	87.4	4.1	18.6	77.1	3.9	3.1	226.7	2.7
Sampl 3 ppm	2.2	139.6	53.8	12.1	76.4	2.4	6.7	254.9	0.8
Sampl 4 ppm	3.4	138.2	42.2	10.4	62.9	4.1	8.4	207.8	7.8
Mean ppm	3.4	115.8	36.4	14.3	77.0	3.4	5.0	236.7	3.0
Area km^2	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5	90.5
Depth m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Volume m. m^3	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Amounts tons	45.50	1572.41	494.48	194.62	1046.14	46.04	67.91	3214.89	40.20

Table (7) Amounts of heavy metals in western area of Lake

West Area	AS µ g/g	Cr µ g/g	Cu µ g/g	pb µ g/g	Zn µ g/g	Sn µ g/g	Mo µ g/g	V µ g/g	Co µ g/g
Sampl 1 ppm	3.1	98.1	28.7	11.7	56.6	3.9	2.5	150.8	18.0
Sampl 2 ppm	3.0	142.8	47.3	11.7	72.0	3.4	7.9	220.2	7.2
Sampl 3 ppm	2.8	145.7	46.9	13.3	72.3	1.5	10.1	162.6	6.4
Sampl 4 ppm	1.3	162.4	51.0	13.0	23.7	2.4	12.1	43.4	19.3
Mean ppm	2.5	137.2	43.5	12.4	56.1	2.8	8.1	144.2	12.7
Area km^2	81.6	81.6	81.6	81.6	81.6	81.6	81.6	81.6	81.6
Depth m	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Volume m. m^3	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Amounts tons	31.08	1679.41	531.94	152.23	686.86	34.26	99.61	1765.0	155.65

5. Conclusion and Recommendation

It could be concluded from the research that,

- Dredging technique can be a possible solution for the excess of drainage water problems in Qarun Lake.
- Because the sediments may have pollutants, it has been suggested that the environmental dredging and conventional dredging can be combined in a lake maintenance dredging.
- The dredge itself can be sold as an added value to lessening dredging process cost.
- The dredging of 10 cm from bottom sediment of total area can be applied to reduce water level by 10 cm, after that the process can be repeated every 10 cm to remove all pollutants in Lake Bed sediment to reserve ecosystem.
- The dredging of one meter from bottom sediment of eastern part can be applied firstly to reduce water level by 30 cm. After that the process can be repeated for the western and middle parts of lake to reduce water level by one meter.
- An empirical equation is derived for the relation between water level and the area of flood plains adjacent to lake as a tool for dredging calculations.

It could be recommended that, the huge amounts of different heavy metals can be used in minerals extraction industry, and the dredges can be used in construction purposes. Making and enhancing green belts in conjunction with lakes, reinforcing dikes by resisting wind, and retaining water. Non-polluted sediment from the bottom of lakes is a kind of good organic nourishment since it has nitrogen, phosphorus, potassium chemical element, and other various minerals that are scarce in common mineral fertilizers. The physical environmental removal of heavy metals from Lake Qarun is a must and will reduce the contaminants and as a result will improve the ecosystem.

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