Computing the Water Budget Components for Lakes by Using Meteorological Data

Rawya Kansoh [a], Mohamed Abd-El-Mooty [a], Rania Abd-El-Baky [b*]

[a] Professor, Faculty of Engineering Alexandria University, Alexandria, Egypt.

[b] Assistant Lecturer, King Mariout Academy for Engineering & Technology, Alexandria, Egypt.

Abstract

Lake Mariout located between the longitudes of 29° 49′ and 29° 56′E and latitudes of 31° 04′ and 31° 08′N in Egypt. It is situated on the southern side of Alexandria City, Egypt. The land surrounding the lake is occupied by agriculture field, population zones and fish farms. This makes the lake to serve as a sink to drain different kinds of drainage waters from surrounding catchment areas of Alexandria City. The water of Lake Mariout is pumped to the Mediterranean Sea through El-Max pump station. The water budget was computed by measuring or estimating all of the lake's water gains and losses. Applying the hydrology budget balance for lakes takes the interaction between the inflow and the outflow water from lakes into account. It is very useful for conservation and better management of water resources. All water budget components of the lake are estimated. Groundwater amount is the most difficult component to be measured or estimated in the water budget equation. Most of the previous studies assumed that the residual of water budget to be the groundwater flow to the lake. The results show that the lake Mariout receives approximately 8.95 m^3/d from the main drains which represents the major part of the inflow water to lake. The discharge of El-max pump station is also one of the largest components of the outflow water (102 m^3/s), while the water loss by evaporation represents 3.2% of the outflow water from the lake. Moreover, the water gain by rainfall 0.38% of the inflow water. The Groundwater flow to/out the lake was estimated as a residual of the water budget equation. It represents 1.2% of the total inputs for the lake water budget. The result shows that the lake is under severe environmental pressure. One of that is the groundwater comes from catchments areas which may be affect the configuration and operating system management of El-Max pump station by the time running.

Keywords: Evaporation; Groundwater; Lake Mariout; Out/Inflow Water; Water Budget.

1. Introduction

The estimation and evaluation of all water budget components are extremely important for regional management and development of water resources, mitigating hazardous flow events and optimizing surface water and groundwater resources. Recently, many researchers are interested in investigations of water budget, because of the dependence of human life on aquatic life. Therefore, many efforts aiming to understand the interactions between inflow water and outflow water and their ecological implications for lakes. All water budget components were computed for lake Qarun, Egypt except ground-water component. He estimated the Ground-water component as a residual of the water budget [1]. The Water budget components and the vertical conductance were determined for Lowry (sand hill) lake in central of Florida, USA. The out/inflow water components were determined based on measurements but the leakage value was determined as a residual in water budget equation [2].

The groundwater volumes using Darcy's Law and used water temperatures were estimated to determine the inflow and leakage water [3]. Over 200 km in the northern section of the Tonle Sap Lake in Cambodia was surveyed – it is the largest freshwater lake in SE Asia – by using a customized system that measures natural (radon), temperature, conductivity, GPS coordinates, and water depth while underway [4]. His results showed that there were portions of the lake with significant enrichments in radon, indicating likely groundwater inputs.

The water budget components were estimated using different satellite data and Variable Infiltration Capacity (VIC) hydrological model after incorporating scaling issues. Study area is Ganga basin, India. Variable infiltration capacity (VIC) model has been used to obtain runoff, base flow, precipitation and ET. Their model considers sub-classes lying in a particular grid along with soil and vegetation parameters depending on soil type and Land Use/Land Cover class type respectively, and meteorological forcing files. With the run of VIC setup for the year 2004 to 2008, their results show that runoff is around 11-19%, ET around 62-80% and base flow around 6-20% of total average precipitation with decreasing trend in terrestrial water storage change for all five years [5] .

The water budget estimation was done on a monthly time step from 1991 to 2015, was developed in order to characterize the Ukiah Valley Groundwater Basin in California. Their Results suggest that the groundwater basin is not in overdraft, and that a portion of the Russian River is a gaining river (approximately 18,952 AF/y) from November to June, and a losing river (approximately 393 AF/y) from July to October [6].

Several strategies to improve water budget closure were used in a small basin in Italy. The mean annual water budget for the Posina River basin is about 1269 ± 372 mm (76.4%) runoff, 503.5 ± 35.5 mm (30%) evapotranspiration, and −50±129 mm (-4.2%) basin storage from basin precipitation of 1730 ± 344 mm. The highest interannual variability is shown for precipitation, followed by discharge. Evapotranspiration shows less interannual variability and is less dependent on precipitation [7].

The groundwater towards the Lake Qarun were estimated by using Darcy's law. In addition, the groundwater analysis included net flow analysis conducted for El-Fayum depression region which acts as a lake watershed. The net flow analyses show that the direction of most groundwater flow is towards the lake from the El-Fayum depression region. Their results show that the lake Qarun receive approximately 47.92 million m^3 groundwater annually [8].

Groundwater discharge to a lake is one of the most difficult components to measure or to estimate in the water balance equation. In many circumstances, there are many reasons which make the groundwater measurements are very difficult or not accurate. Such as limited data about the water table levels or very low hydraulic gradients or significant diversity in soil texture in the study region.

Lake Mariout is located in the south of the Alexandria city, under severe environmental pressure due to receiving huge amounts of contaminated drainage waters and untreated domestic and industrial wastes. Moreover, the lake receives the agriculture wastewater from cultivated surrounding lands which are loaded with pesticide and fertilizer.

The present work addressed some fundamental calculations related to the structure and function of Lake Mariout, especially the water budget of this Lake by using metrological data and some properties of the lake. Moreover, it presented some factors which affect the water budget components. This study was aimed to evaluate the contribution of groundwater to Lake Mariout because it has a significant effect on the configuration and operating system management of El-Max pump station by the time running.

2. Site Description

Lake Mariout is one of the northern delta lakes. It is different from the other lakes .It is located in a unique zone characterized by the presence of limestone barriers. The lake is impounded between the delta and one of these barriers.

It is located in the North Western of the Egyptian Mediterranean sea coast. Lake Mariout lies between Latitude 31° 07' N and Longitude 29° 57' E along the Mediterranean coast of Egypt. It is situated on the southern side of Alexandria City with an elevation ~ 3m below sea level. It had a total area of about 65 km^2 with an average water depth of about 1 m [9]. The land surrounding the lake is occupied by agriculture field, population zones and fish farms (Figure 1) [10]. This makes the lake to serve as a sink to drain different kinds of drainage waters from surrounding catchment areas of Alexandria City.

Lake Mariout has a variety of population activities and the most important the commercial fishing which remains an important economic activity on the lake, salt extraction and recreation, and the areas of the weeds scattered in the lake which attracts rare species of birds. Given the geographic location of the lake and its biodiversity, it is believed to be of special importance to some migratory species. Lake Mariout also used as a recreational lake for wild duck hunting.

Nationally the lake is extremely important, its importance related to some factors, as a receptor for agricultural drainage water, a source of salts, fish, and tourism.

Lake Mariout receives inflow water from three main sources: namely, Omoum Drain, Kalaa Drain, and Nubariya canal. El-Max Pumping Station was created to pump excess water from the lake to the Mediterranean Sea.

Figure 1. The satellite image of the lake Mariout

3. Materials and Methods

3.1. Water Budget Components

The calculations of water budget component of the lake require an accurate understanding of many environmental factors such as temperature, net radiation, wind speed, humidity and precipitation rates. In addition, many of water body characteristics are required such as, surface area, water depth and level, salinity, catchment size and lake stage.

The inflow components are rainfall, direct runoff, surface-water, water discharges into the lake, and groundwater flows into the lake. The outflow components are evaporation, water discharges out the lake, and groundwater flows out the lake (Figure 2). The hydrologic water balance for lakes can be expressed as:

$$Change\ in\ storage = Inflow - Outflow \qquad OR \qquad \Delta S = P + R + Q_i - EEB \pm Q_{gw} - Q_O \qquad (1)$$

Where; P: is the precipitation over a lake surface; R: is the runoff to a lake from its drainage basin; Q_i: is the inflow water into the lake (e.g drainage water); Q_{gw} is the groundwater flow in or out the lake; Q_o: is the outflow water from the lake; EEB: is the amount of water evaporated; ΔS: is the change in water body storage.

The water budget components in Equation 1 can be expressed in dimensionally consist volumetric or length unites over the time period.
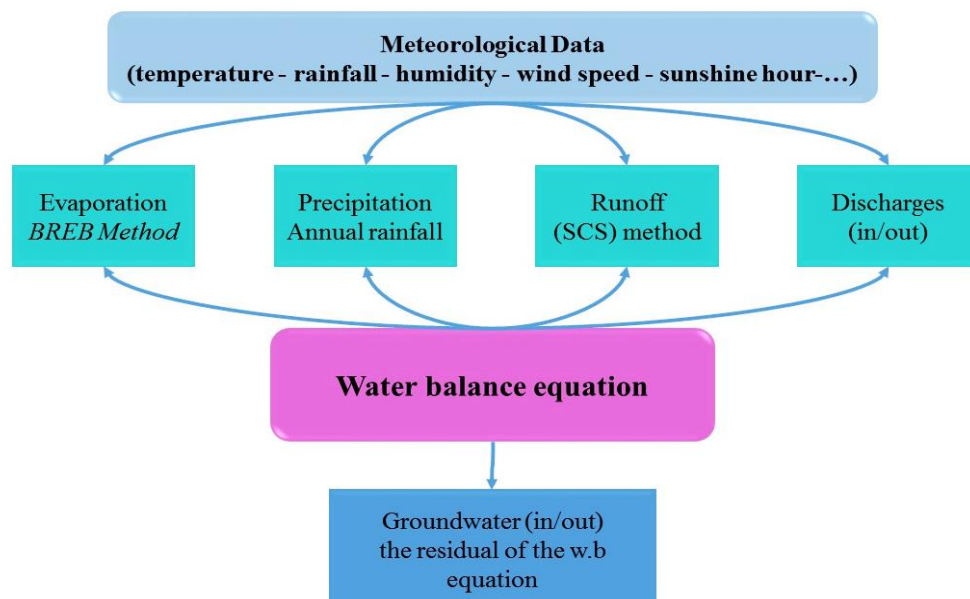

Figure 2. Water budget components

3.2. Evaporation (EEB)

Evaporation occurs when liquid water is converted into water vapor. Evaporation is one of the components in the water budget of lakes. Knowing the rate of evaporation from surface water lake is essential for precise management of the water balance. Evaporation from lakes depends on the availability of energy and the mechanism of mass and energy transfer, depth, and the surface area of the lake. Evaporation is a function of net radiation, temperature, wind speed, air humidity, vapor pressure deficit, atmospheric pressure, and the surrounding environment [11]. In addition to meteorological factors, the physical characteristics of a lake or reservoir also influence the rates of evaporation from the surface such as the depth, salinity, and topography for the lake.

3.2.1. Evaporation Estimation

There are several methods to estimate evaporation rates Current methods of estimating open water evaporation vary between and, in some cases, within Regions; there is no generally adopted the best method. There is, therefore, a need to review the requirements and the factors affecting for estimating open water evaporation in relation to the methods and data available. In this paper, the most recommended method and best available practicable will be applied for estimating lake evaporation. The observational studies of lake evaporation have used a variety of different methods to estimate evaporation rates such as, Bowen Ratio Energy Budget (BREB) method and eddy correlation techniques, the water-budget method, methods of the so-called Dalton group such as the bulk aerodynamic method, the methods in the so-called combination group such as the Penman, Priestley–Taylor, and de Bruin–Keijman methods, and the methods in the temperature group such as the Papadakis method. Another method that is used in numerous studies is the mass transfer method. In general, however, the BREB and eddy-correlation techniques are considered to be the most accurate methods, albeit at the cost of additional, high quality instrumentation data. As reported by Sene et al. (1991) [12] and Stannard and Rosenberry (1991) [13]. The energy-budget method is being the preferred technique for evaporation estimation based on accurate, long-term monitoring data [14, 15].

3.2.2. BREB Method

The BREB method presented by Lee Swancar (1997) and Rosenberry et al. (2007) for calculating open-water evaporation can be stated as [16, 17]:

$$E_{EB} = \frac{Q_n + Q_v - Q_x}{\rho_w [L(1+BR) + c(T_O - T_b)]} \times 8.64 \times 10^7 \tag{2}$$

Where; EEB: Volume of evaporating water by the BREB method (mm/ d); ρ_w: Density of evaporating water (assume 998 kg/m³); L: Latent heat of vaporization (J/kg); c: Specific heat capacity of water (4,186 J/kg/⁰C); T_b: Reference base temperature (C); T_o: Daily average temperature of water outflow (⁰C); BR: The Bowen ratio; Q_n: The net radiation; Q_v: The net energy advected; Q_x: The change in stored energy; The multiplier 8.64×107 that appears in the equation is to convert output to (mm/d).

Bowen Ratio:

The Bowen Ratio (BR) variable can be seen as the proportion of the energy utilized for evaporation. As neither the energy conducted and converted from the lake to the atmosphere as sensible heat nor the energy used for evaporation can be measured directly, the BR has been widely calculated using:

$$BR = \frac{c_{pa} \, P_a}{0.662 \, L} \frac{T_O - T_a}{e_O - e_a} \tag{3}$$

Where; c_{pa}: The specific heat of air at constant pressure (1,011 J/kg/°C); e_0: Saturation vapor pressure at the water-surface temperature (Pa); e_a: Vapor pressure at 2 m above the lake (Pa); p_a: Atmospheric pressure at the lake surface (kPa); T_a: air temperature at 2m above the lake surface (°C); T_o: lake surface temperature (°C).

Net Radiation (Q_n):

The net shortwave radiation resulting from the balance between incoming and reflected solar radiation. The data are filled using empirical equations described by (Food and Agriculture Organization of the United Nations) the FAO-56 procedure [18]. This method requires measurements of air temperature, humidity, and cloudiness to estimate net radiation. Radiation data (relative to a theoretical clear sky). Reflected solar radiation is adjusted using an Albedo reflection coefficient of 0.23.

Net Energy Advected (Q_v):

Q_v is considered one of the most important inputs for the energy-budget equation. Advected heat (Q_v) enters lakes from rainfall, surface-water, and ground-water inflow, and it leaves through surface-water and ground-water outflow. Qv may be a difficult component to measure accurately in a lake or reservoir. It depends on the amount of water inflow and outflow, and the error in this measurement can be a limiting factor to a successful application of the energy budget method.

$$Q_v = \frac{c\,\rho_w\,q_i(T_i - T_b) - c\,\rho_w\,q_o(T_o - T_b)}{A} \tag{4}$$

Where; q_i: Inflow to the lake (m^3); q_o: Outflow from the lake (m^3).

Change in stored energy (Q_x):

The change in stored energy (Q_x) is an essential component of the energy budget because the large specific heat capacity of water allows even a small lake to store and exchange large amounts of heat energy. The daily stored heat was computed from the water temperature measurements of each water layer.

$$Q_x = \frac{c\,\rho_w\,\sum_{i=1}^{n}(T_{2i} - T_b)\Delta V_{2i} - c\,\rho_w\,\sum_{i=1}^{m}(T_{1i} - T_b)\Delta V_{1i}}{A} \tag{5}$$

Where; 1 *and* 2: Refers to conditions at the beginning and the end of the period (d); n *and* m: Refers to the water layer number; T_{1i}: Temperature of layer (water body) i at the beginning of the day (^{o}C); T_{2i}: Temperature of layer (water body) i at the end of the day (^{o}C); ΔV_{1i}: Volume of water in the layer i at the beginning of the day (m^3); ΔV_{2i}: Volume of water in the layer i at the end of the day (m^3). Multiplication of Equation 5 by 11.6×10^{-6} is required to convert the unit of Q_x to W m^{-2}.

The evaporation rate from water surface depends on the net radiation and temperature degrees for the study region. The maximum temperature occurs in the summer (it reaches to 31°C in Jul) and the minimum temperature occurs in the winter (it reaches to 14°C in Jan). By using metrological data (Table 1), for 12 month period from Jan 2017 to Dec 2017, of temperature, rainfall, humidity, wind speed and using Bowen ratio energy budget (BREB) method to estimate evaporation from Lake Mariout. The net radiation (Q_n) empirical equations are solved according to FAO 56 guidelines [18]. The monthly net radiation is calculated using Equation 2 and Q_n values are shown in (Figure 3) in Wm^{-2}.

Table 1. Monthly average rates of meteorological elements by observation station in Alexandria city (2017)

Month	Max. Temp (^{o}C)	Min. Temp (^{o}C)	Humidity %
Jan	14	7.0	70
Feb	18.6	10	68
Mar	21.9	13.4	66
Apr	24.3	14.8	65
May	27.1	19.5	67
Jun	29.4	22.3	69
Jul	31.9	25.2	71
Aug	31.4	24.2	71
Sep	30.3	23.2	68
Oct	27.5	19.2	68
Nov	23.6	15.4	69
Dec	21.4	13.8	70

Data source: Weather station: Alexandria/Nouzha at 4.8 km of Alexandria
Station location: Lat 31.167 Lon 29.933 Altitude 7 m.
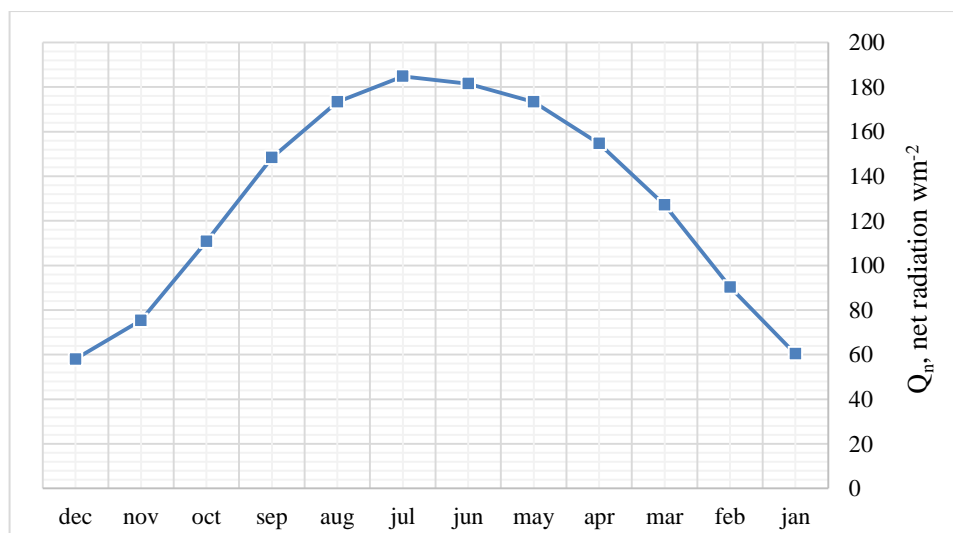

Figure 3. The calculated value of net radiation for Lake Mariout

The groundwater and wastewater are assumed to be the source of advected heat to Lake Mariout. Advected heat energy (Q_v) from rainfall water is considered for this study because the rainfall over the lake is extremely more than 15 mm annually. The advected heat energy (Q_v) is calculated using Equation 3. It is equal to 0.9598 W m^{-2} for Lake Qarun.

The change in stored energy (Q_x) is an essential component of the energy budget because the large specific heat capacity of water allows even a small lake to store and exchange large amounts of heat energy. The stored heat energy was computed using Equation 4 the water temperature was measured at depths (0, 0.1, 0. 2, 0.3, 0.4 and 0.5 m). Since the temperature varies with depth in the lake, the stored heat was numerically integrated using increments of volume for each of the five layers. The change in stored energy (Q_x) equal to 0.0068 W m^{-2}. The mean BR value is computed using the monthly temperature values which are measured from Lake Mariout stations. The BR value of every month of the year 2017 is given in (Table 2) by using Equation 2.

Table 2. The BR value of every month of the year 2017 for Lake Mariout

Month	BR
Jan	-0.0740
Feb	-0.0587
Mar	-0.0490
Apr	-0.0439
May	-0.0344
Jun	-0.0287
Jul	-0.0239
Aug	-0.0249
Sep	-0.0277
Oct	-0.0336
Nov	-0.0419
Dec	-0.0466

The BREB monthly evaporation rates, as shown in (Figure 4), ranging from 2.09 to 6.47 mm/d and averaged 4.55 mm/d during the 12-month study period. The maximum evaporation rates occurred during Jul and the minimum evaporation rates occurred during Dec.
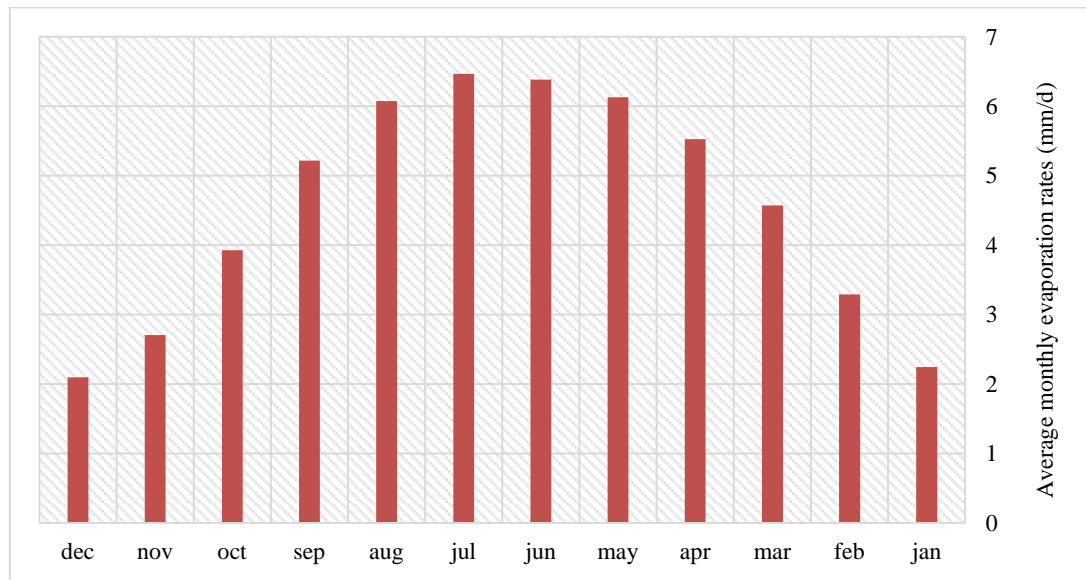

Figure 4. The BREB monthly evaporation rates (mm/d) for Lake Mariout

3.3. Rainfall (p)

If the rainfall acts a major part of inflows to the lake. Even large, shallow lakes can undergo major climate-driven fluctuations and loss by a major contraction in the lake area. The changes of the annual rainfall affect directly in the water balance of the lake. Shifts in precipitation relative to evaporation cause changes in the water budget and hydraulic residence time of lakes, as well as in their depth and areal extent. Reduced precipitation and inflows can result in increased phosphorus accumulation (internal phosphorus loading) and eutrophication. Conversely, in regions

that experience increased precipitation and water flow, the increased flushing of nutrients and phytoplankton may result in reduced algal production. Increased temperature and decreased precipitation (or inflow water) will lead to decrease water level, oxygen depletion, reduction of Sulphate concentration, and increasing of total organic carbon and salinity.

The rainfall estimation is according to metrological data for the study region. Lake Mariout zone is dry with very low rainfall and high evapotranspiration in the summer. Monthly average rates of rainfall by observation stations in Alexandria city are shown in (Table 3).

Table 3. Monthly average rates of rainfall by observation stations in Alexandria city 2017

Month	Rainfall mm/month
Jan	29.6
Feb	8.2
Mar	0
Apr	54.2
May	0
Jun	0
Jul	0
Aug	0
Sep	0
Oct	29.8
Nov	65.5
Dec	14.8

Data source: Weather station: ALEXANDRIA/NOUZHA at 4.8 km of
Alexandria Station location: Lat 31.167 Lon 29.933 Altitude 7m

The annual rainfall over the lake equal to 13.16 million m^3 according to the previous metrological data.

3.4. Runoff (R)

Runoff is a rain flows off or irrigation water excess from the land into streams. Thus, the runoff is a part of water resources for the lake inflow. The runoff will help to understand the water cycle laws and characteristics of water resources. Usually, the major factor of increasing runoff is human activities and development. In fact, the rapid increase of human population, the expansion of cultivated land, the development and expansion of irrigation practices and the construction of reservoirs can affect the yearly runoff [19].

Factors Affecting Surface Runoff:

The amount of rainfall lost by runoff depends on the intensity of rainfall; the slope of land; the soil type, its hydraulic conditions and antecedent moisture content; and the land use and cover.

Runoff Estimation:

The rainfall values were considered as separate storm events, soil conservation service (SCS) method was used to estimate direct runoff flow into the lake. The direct runoff for each day was calculated from

$$R = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} \tag{6}$$

$$S = \frac{1000}{CN} - 10 \tag{7}$$

Where; R: The actual run off; P: Precipitation for a storm event; S: Potential maximum retention; CN: SCS curve number.

Runoff from agricultural crops will be channeled from a higher elevation to a lower elevation. Thus, the Agricultural runoff drained from the north-west part of the delta to the lake. Also the magnitude of run off extremely depend on the intensity of rainfall and the evapotranspiration in the study area. The average monthly rainfall over the study area equal to 16.84 mm/month and the average monthly evapotranspiration (ET_o) equal to 15.04 mm/month. Thus, the Daily precipitation in amounts more than about 0.2 daily evapotranspiration (ET_o).

Hence, there is a reliable evidence that the rainfall is not normally entirely evaporated and the magnitude of run off cannot be ignored in the water balance calculations according to [18]. The rainfall values were considered as separate storm events, Soil Conservation Service (SCS) method was used to estimate direct runoff flow into the lake. The annual runoff which flows into lake Mariout equal to 0.0152 million m^3.

3.5. The Inflow Drainage Water (Q_i)

The lake receives the different types of wastes; sanitary, industrial and agricultural wastes. The drainage water reaches the lake by three main sources: namely, Kalaa Drain, Omoum Drain, and Nubariya canal (Figure 5). The daily water discharges, via Kalaa Drain, Omoum Drain, and Nubariya canal "According to the reports of Central Administration of West Delta Region" (Table 4).

Figure 5. The three major drains for Mariout Lake

Table 4. The daily water discharges of Kalaa Drain, Omoum Drain, and Nubariya canal

Water Source	Discharge (Million m³/d)
Kalaa Drain	0.457
Omoum Drain	7.3
Nubariya Canal	1.19
Total	8.95

According to the reports of Central Administration of West Delta Region

3.6. The outflow Drainage Water (Q_o)

The water level in Lake Mariout is managed to maintain the water level at ~ 2.8 m below sea level by pumping the overflow from the lake directly to the sea through El-Max pumping station [9]. This station is considered the only outlet of Lake Mariout. El-Max pump station consists of 12 unit with 14.5 m³/s for each one and the discharge of the whole station is 102 m³/s, according to the reports of Central Administration of West Delta Region.

3.7. The Groundwater In / Out Flow of Lake (Q_{gw})

The surrounding lands around Lake Mariout are mostly occupied by cultivated land, fish farms and population zones. The magnitude of groundwater which in/outflows of Lake depend on the land use which is surrounding the study region and the amount of water that penetrates the ground surface and reaches the upper aquifer then flows underground through different flow paths to reach finally into the lake. Therefore, in this case, the groundwater discharge to Lake Mariout is considered the most difficult component of water budget to measure or to estimate. Actually, the groundwater measurements are related to the water flow under the ground. Thus, this study presents sufficient calculation using the water balance equation to estimate ground-water inflow or outflow of Lake Mariout. This paper presents the full estimation of groundwater inflow or outflow as a residual of water balance equation.

4. Results and Discussion

Attempts to conservation and restoration of the lake require an accurate understanding of many environmental factors, evaporation, water discharges and groundwater, particularly that governing water budget.

4.1. The Summary of Water Budget Calculations

The value for each component was summed for 12- month period in unit million m³/yr. On an annualized 12-month basis, the drainage inflow water from Kalaa drain, Omoum drain, and Nubariya Canal were 166.8, 2664.5, 434.35 million m³/yr respectively, the rainfall was 13.16 million m³/yr, the runoff was 0.0152 million m³/yr, the evaporation was 106.68 million m³/yr and the outflow water through El-Max p.s was 3212 million m³/yr. After estimating all water budget components, using water budget equation to estimate the groundwater flow as the residual of the water budget equation which equals to 39.85 million m³/yr, which is equivalent to 1.2 % of inflow water. The total discharge of

outflow water is larger than the total discharge of inflow water, which means that the net discharge of groundwater flows into not out the lake (Table 5 and Figure 6).
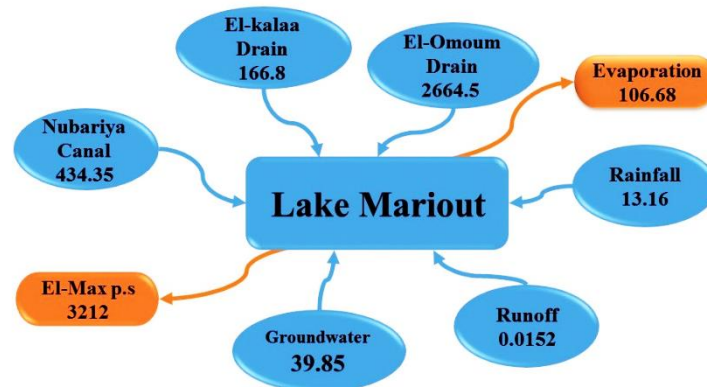
- **The unit of discharge = Million m³/year**

Figure 6. The resources and discharges of inflow and outflow water for Lake Mariout

Table 5. The water budget components for Mariout Lake

Water budget component	Discharge (million m³/yr)	Percent of inflow (%)	Percent of outflow (%)
Drainage Inflow Water	3265.65	98.40	---
Rainfall	13.16	0.39	---
Runoff	0.0152	0.001	---
Groundwater	39.85	1.2	---
Evaporation	106.68	---	3.2
El-Max P.S	3212	---	96.8

The Marriot Lake Basin is fed from various water sources. The main sources are the agricultural drains and wastewater treatment plants. In addition, rainfall, runoff and groundwater leakage from the surrounding fields. This is resulting in an increase in surface water level which is controlled by El-Max pump station. Also, the surface water level fluctuates widely according to the seasons. In the winter season, the rainfall, runoff, and groundwater contribution are resulting in increasing the surface water level, while in the dry summer season, high rates of evaporation contribute to lowering the water level. Therefore, over the year, El-Max pump station was operated to control or maintain the surface water level of the lake. El-Max pump station controls the water level by operating an adequate number of pumps.

The lake is under severe environmental pressure not only by the groundwater which comes from catchments areas to the Lake but also, by suffering from pollution. It is considered one of the heavily polluted basins in Egypt because it is receiving huge amounts of contaminated drainage waters and untreated domestic and industrial wastes. To diminish this pollution, especially in the water of the eastern basin should be renewed. This may be accomplished by lowering the level of Omoum drain to be lower than that of the lake and allow the water of the eastern basin to flow into it. This basin can be refilled with fresh water through a suitable pumping station. This renewal of water will not solve the problem completely, but it will decrease the pollution load which is carried into the lake and helps in the self-purification process.

The water which is collected from surrounding lands penetrates the ground surface and reaches the upper aquifer then flows underground through different flow paths to reach finally into the lake. Therefore, groundwater fluxes are extremely important in the water budget of Lake Mariout because the lake has a large perimeter much larger compared to its depth. Also, it has a significant effect on the configuration and operating system management of El-Max pump station by the time running.

5. Conclusion

The estimation and evaluation of all water budget components of Lake Mariout are extremely important to make adequate management of the operating system of El-Max pump station, surface water, mitigating hazardous flow events and optimizing surface water and groundwater resources. The water budget of the lake shows that an amount of groundwater reaches the lake. The water which is collected from surrounding lands penetrates the ground surface and reaches the upper aquifer then flows underground through different flow paths to reach finally into the lake. Therefore,

groundwater fluxes are extremely important in the water budget of Lake Mariout because the lake has a large perimeter much larger compared to its depth. Also, it has a significant effect on the configuration and operating system management of El-Max pump station by the time running. However, improving the whole environmental conditions of the lake to encourage investments around the lake which will reflect positively on the socio-economic aspects for the study region.

6. Conflicts of Interest

The authors declare no conflict of interest.

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