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Using Hydrological and Meteorological Data for Computing the Water Budget in Lake Qarun, Egypt

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Abstract: Lake Qarun (29°28.5'N-30°37.5'E) is an inland closed basin, located in Egypt. It has been used as a water reservoir for irrigation of agricultural areas in the Fayoum depression. The lake is under severe environmental pressure. One of that is the ground water comes from the immediate vicinity of the lake which drains agricultural lands from catchments areas directly into the lake. The water budget was computed by measuring or estimating all of the lake's water gains and losses. The discharge water via the main drains represents the major part of the inputs (85.88%). Evaporation is also one of the largest components of the water outputs (97.39%), while the water pumping to the Egyptian Company for Salts and Minerals (EMISAL) ponds represents 2.61%. Ground-water to the lake was estimated as a residual of the water budget and represent 14.12% from the total inputs for the lake water budget. Therefore, groundwater fluxes are inherently more important in the water budget of Lake Qarun because of the higher ratio of the lake perimeter to water storage.

Key words: Evaporation % Ground water % Lake Qarun % Water budget

INTRODUCTION

One of the major problems in the management of surface water lakes is the estimation of all water budget components [1]. Investigations of water budget are increasing rapidly, because of the dependence of human life on aquatic ecosystem [2]. The problem of ground water via surrounding lands is important to basin management efforts aiming at mitigating hazardous flow events and optimizing surface water and groundwater resources and also has significant ecological implications [3]. Ground water discharge to a lake is one of the most difficult components of the water balance to measure. In the case of lake systems, they may also be limited by very low hydraulic gradients, which can be difficult to accurately measure. Water balance methods that measure other components of the water balance and calculate groundwater inflow by difference are limited by the errors in the other water balance components, which may be larger than the groundwater inflow term [4].

Lake Qarun is located in the depth part of the Fayoum depression, under severe environmental pressure due to cultivated surrounding lands. One of that the ground water comes from the immediate vicinity of the lake which drains agricultural lands from catchments areas directly into the lake. Attempts at conservation and restoration of the lake require accurate understanding of many environmental factors, evaporation, water discharges and ground water, particularly that governing water budget [5]. Despite the importance of defining the ground water flux in Lake Qarun, knowledge of the state and trends of its hydrological regimes is decreasing. A few previous studies [6-7] have used water budget to estimate groundwater inflow to Lake Qarun. The present work addressed some fundamental problems related to structure and function of Lake Qarun, especially water budget of this Lake. The aim of this work was to measure and estimate the different components of the water budget for Lake Qarun.

Site Description: Lake Qarun (Fig. 1) is one of the most important lakes in Egypt. Its significance is actually surpasses the local boundaries of the country. In other words, the lake provides one of the oases for the migratory birds wintering from the Northern Hemisphere. 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 [8].

The lake, is an inland closed basin 44-43m below mean sea level, 40 km long, an area of about 240 km^2 and average volume is one km^3. It is bordered from its northern side by desert and by agricultural lands from its south and

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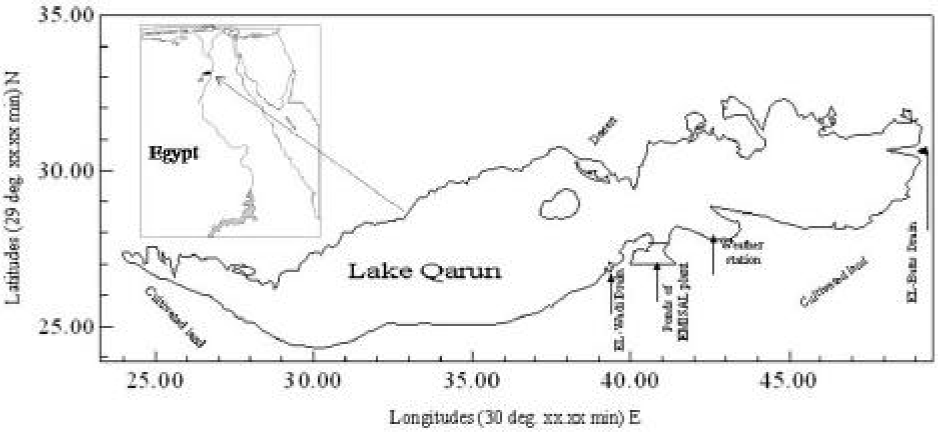

Fig. 1: Egypt and Lake Qarun map

south eastern sides[6]. The lake has been used as a water reservoir for irrigation of agricultural areas in the Fayoum depression, directly with main two drains (El-Batts and El-Wadi drains) and indirectly from the adjacent agricultural surrounding lands [7].

MATERIALS AND METHODS

All water balance equations are based on the premise that the difference between water inflow and water outflow over a given time period for the hydrologic system of a lake must equal the change in water storage in that system. A lake water budget is computed by measuring or estimating all of the lake's water gains and losses and measuring the corresponding change in the lake volume over the same time period [9-10]. Lake Qarun Basin is located in arid and subtropical zone. According the meteorological data, the rainfall is nearly rare. Therefore, the specific components of Lake Qarun water budget used for this study are shown in the following equation:

$$W_I - W_E - W_P \pm W_G = \Delta W_Q \qquad (1)$$

Where, W_I is the water discharge via the main drains; El-Batts and El-Wadi drains, W_E is the water losses by evaporation, W_P is the water pumping to EMISAL plant, W_G is the ground water discharge from or to the lake and ΔW_Q is the change in water storage of the lake. During 2006 year, the data of the lake level and consequently water area and storage was monthly recorded at Shakshouk Research Station. Water discharges via the main drains to the lake was determined by Flow-meter, Model 2000 (Flo-Mate, Marsh, McBiney, INC). Using the measurements drain cross –section and records of the water flow of different points along every cross-section enable the estimation of the water transport per unit time. The water pumping from the lake to the ponds was recorded by EMISAL plants staff members. The removal of water from the surface is only by evaporation. Evaporation from free water surfaces can be estimated by a number of methods, based on average monthly temperature and climatologic indices. Combining the energy budget and aerodynamic methods [10], the approach is formed as follows:

$$E = Q_R(\Delta / \Delta + \mu) + E_a(\mu / \Delta + \mu) \qquad (2)$$

Where, Q_r is the rate of effective radiation, Δ is the slop of the saturated vapor pressure curve at the air temperature, μ is the Psychrometric constant and E_a is the drying power of the air, $E_a = f(u)(e_0 - e_a)$, f(u) is the Penman's function of wind, e_o is the saturation vapor pressure and e_a is the actual vapor pressure.

RESULTS

The components of water budget for Lake Qarun are shown in Fig. 2. The monthly change in water storage of the lake was obvious. The change in lake storage ranged between +57.89 million m^3 in December and-40.93 million m^3 in June; with net annual of 38.33 million m^3. The monthly water discharges, via El-Batts and El-Wadi drains, range between 13.10 million m^3 in January and 48.89 million m^3 in September, with net annual water of 419.56 million m^3. Water loss due to evaporation has a minimum value of 7.93 million m^3 in December and a maximum value of 61.14 million m^3 in August, with net annual water of 438.45 million m^3. The water pumping to EMISAL ponds increases from 0.03 million m^3 to in

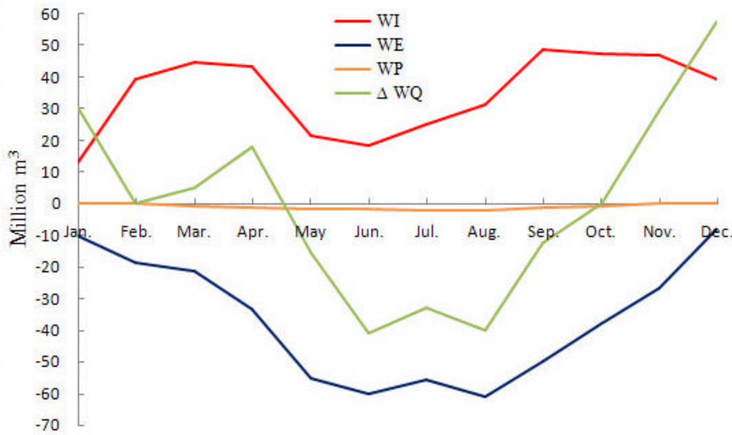

Fig. 2: The monthly components of water budget for Lake Qarun
WI is the water discharge via the main drains, WE is the water losses by evaporation, WP is the water pumping to EMISAL plant and) WQ is the change in water storage of the lake

February to 2.21 million m^3 in July, with net annual water pumping of 11.75 million m^3.

DISCUSSION

Lake Qarun water storage appears to be relatively stable (±4%) from one year to the other and monthly variations are less than 8%, with the lake high and low stands, respectively [11]. The lake receives its water only from the agricultural drainage water, within the irrigation system in the Fayoum [12]. Evaporation is one of the main components in the water budget of lakes and a primary process of water loss for most of them [13]. Knowing the rate of evaporation from surface water lake is essential for precise management of the water balance [1]. The second item assists in the same manner by water loss, the pumping to EMISAL plant pounds. The water pumping to EMISAL ponds stops entirely in January and the most time of operating is concentrated in summer season.

Most components of a water budget unless ground water are easily measured or estimated. In water lakes, it may be relatively easy to measure inflow as well as outflow [14]. The water budget of Lake Qarun, as one would suppose, has both input and output. The net water budget is of 68.98 million m^3. Usually groundwater inputs and outputs are the most difficult to be measured or estimated, therefore it could be assumed that the residual of water budget to be groundwater flow.

Ground water flow is the exception and is an important and largely overlooked component of water budgets because it is the most difficult to quantify as it cannot be measured directly [15]. The ground water has significantly varied mirroring the changes in cultivated surrounding lands in the region. The believed ground water is an important part of the water budget, as confirmed by the present study and all other previous studies. The net ground water was recorded as 65.2 million m^3 [6] and 96.33 million m^3 [7]. The results compared well against independent estimates from previous estimating, but the values imply changes. However, in steady state of Lake Qarun (Fig. 3), the main drains are of 85.9% for the water inputs to the lake and the residual comes through the ground water (14.1%). On the contrary, the water output from the lake is by evaporation which represent the major portion (97.4%) and water pumping to EMISAL ponds (2.6%).

Shifts in the hydrological regime are likely with the environmental changes expected [16]. Understanding also those variations and the role of climate is important for water basin management as well as predicting future change in a lake hydrology as a result of climate change [17-18].

It could be concluded that, Lake Qarun is under severe environmental pressure due to a serious problem in the lake, as changes agriculture surrounding lands. Attempts at conservation and restoration of the lake require accurate understanding of the many environmental factors, particularly those water budgets. However groundwater fluxes are inherently more important in the water budget of Lake Qarun because of the higher ratio of the lake perimeter to water storage.

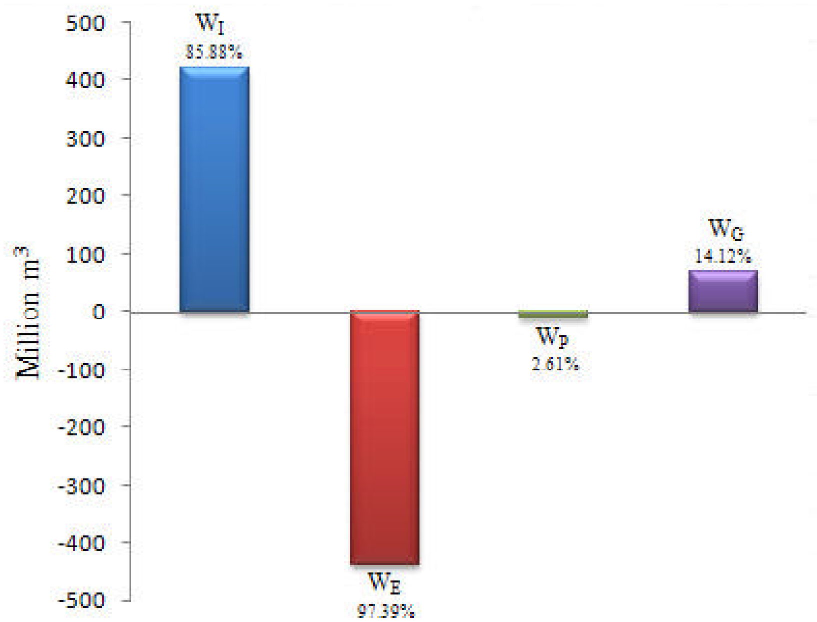

Fig. 3: The percentage of the components for the water inputs and outputs to/from Lake Qarun

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