EFFECT OF EXPECTED CLIMATE CHANGES ON EVAPORATION LOSSES FROM ASWAN HIGH DAM RESERVOIR (AHDR)

H. A. Badawy

Assistant Professor, National Water Research Center, Cairo, Egypt

ABSTRACT

At present, it appears that there is a gradual increase in the atmospheric concentration of carbon dioxide (CO_2) and other greenhouse gasses. The continuous increase of such gases will cause global warming during the 21st century. Although most of the scientists are fully aware of such facts but there are still uncertainties about the increasing rate of atmospheric temperature in order to take counter measures. By applying sophisticated models, some scientists have estimated the global temperature increase between 1.5-3.0 °C during the present century, if the countries all over the world did not take serious measures to decrease the generation rate of the carbon dioxide and the other greenhouse gases. However no body has predicted the exact values of the expected temperature increase.

The increase in air temperature will be accompanied by global changes in other meteorological parameters such as wind speed, sunshine hours, humidity, precipitation, radiation and other parameters.

In Egypt, temperature increase will have direct effect on the agriculture and domestic water demand. In the same time losses of water by evaporation from Aswan High Dam Reservoir (AHDR) may be changed.

The aim of the present paper is to estimate the evaporation losses from (AHDR) at 2050 due to the expected climate changes. Data concerning temperature, humidity, wind speed, evaporation rate, and radiation of the shore metrological station on the left bank of AHDR are obtained from the Water Nile Sector, Ministry of Water Resources and Irrigation covering the period from 1986-2006. Data of 3 raft stations which are Aswan, Allaquy, and Abu-Simble are also obtained from Aswan High Dam for the period from 1998-2005. These data have been statistically analyzed and the trend of all the meteorological parameters has been estimated for the shore station during the period 1986-2006. The obtained trend was used for estimating the meteorological parameters for the three raft stations at 2050. Monthly evaporation rate from (AHDR) have been estimated by seven methods ($Frere_1$, $Frere_2$, $Bulk_1$, $Bulk_2$, Sadek, Doorenbos, and McIlroy) for the years 2000 and 2050.

Although it was expected that due to the climate change, temperature will be increased in 2050 upon which water losses by evaporation will be also increased, however, results showed that the evaporation rate will not be affected. This could be explained

due to the expected air temperature rise and the increase in humidity, followed by decrease in wind speed which has not changed much the evaporation rate.

INTRODUCTION

Evaporation from the land surface includes evaporation from open water surface, soil, shallow groundwater, and water stored in vegetation along with transpiration through plants. The rate of evaporation from the land surface is driven essentially by meteorological controls, mediated by the characteristics of vegetation and soils, and constrained by the amount of water available. Climate change has the potential to affect all of these factors-in a combined way that is not yet clearly understood-with different components of evaporation affected differently.

The primary meteorological controls on evaporation from a well-watered surface (potential evaporation) are the amount of energy available (characterized by net radiation), the moisture content of the air (humidity), and the rate of movement of air across the surface (wind speed). Increasing temperature generally results in an increase in potential evaporation, largely because the water-holding capacity of air is increased. Changes in other meteorological controls may exaggerate or offset the rise in temperature, and it is possible that increased water vapor content and decreased net radiation could lead to lower evaporative demands. The relative importance of different meteorological controls, however, varies geographically. In dry regions, for example, potential evaporation is driven by energy and is not constrained by atmospheric moisture content, so changes in humidity are relatively unimportant. In humid regions, however, atmospheric moisture content is a major limitation to evaporation, so changes in humidity have a very large effect on the rate of evaporation.

Several studies have assessed the effect of the changes in the meteorological parameters on evaporation, using models of the evaporation process. It was found that the projected increase in potential evaporation is largely related to the increase in the vapor deficit resulting from higher temperature (Chattopadhyary et al 1997). It is important to emphasize, however, that the different equations for calculating the evaporation give different estimates for the absolute evaporation rates. Therefore, it could rather be difficult to compare results from different studies. Equations that do not consider the explicitly of all meteorological controls may give very misleading estimates of change.

The aim of this study is to estimate the water losses by evaporation from the AHDR at 2050 due to the expected climate changes upon which the policy of water management and cultivated crops could be reconsidered.

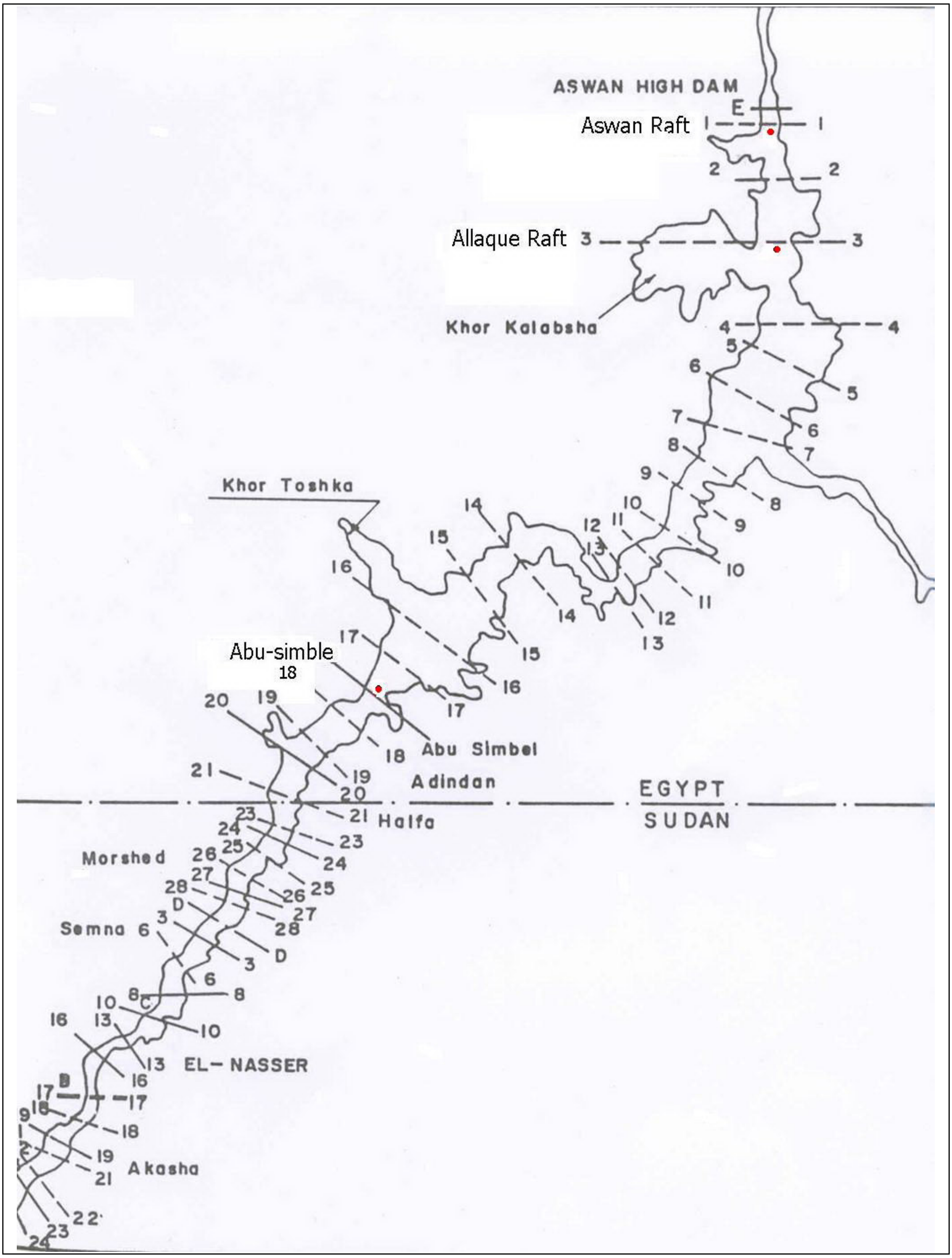

Fig. 1 Lake Nasser

Detection of Climate Change on Aswan High Dam Reservoir

The capacity of Lake Nasser (fig 1) is reaching 162 billion m^3 at level 182.0 m. The lake lies between latitudes 23° 58/ N and 20° 27/ N, and longitudes 30° 07/ E and 33° 15/ E, with about 500 km long, 150 km in Sudan and 350 km in Egypt. The maximum width of the lake is about 60 km, with average width of about 12 km. The lake has a surface area of 6500 km^2 at the 182 m level (above mean sea level). The maximum depth of the lake is 90 m with average depth of 25 m. The lake lies in a hot and extremely arid climate.

A study of climate change implies the investigation of the parameters that determine the climate of the region was conducted. Consequently, all the available meteorological data which have the effect in estimating the lake evaporation were analyzed in order to find the trends over the past two decades. Data of maximum and minimum temperature, daily mean temperature, air relative humidity, global radiation, and wind speed have been used in the present investigation. The collected data from the shore station at Aswan covered the period 1986-2006 were analyzed by using statistical technique. This type of analysis could be the best for regional climatic variability's and change.

Statistical models are generally attempt to represent the observed data by model consisting of a deterministic trend plus "residuals" about the trend, which represent natural variability.

The model takes the form:

$$Y_t = \alpha + \beta t + \zeta \tag{1}$$

Where α is the expectation of Y_o where Y_o is the value of y at time zero, β the trend, Y_t the meteorological parameter under consideration, t represents time, and ζ is a zero mean time series of disturbances which may be auto-correlated and may display stochastic behavior with long memory. This method was applied for every parameter on monthly and annual basis.

Meteorological Stations and Data

For estimating the water losses by evaporation from AHDR, the meteorological data for the last 20 years (1986-2006) of a shore station of the lake at Aswan were obtained from the Water Nile Sector, Ministry of Water Resources and Irrigation. The data has included temperature, humidity, wind speed and radiation. These data were recorded daily from which the average monthly was calculated. Beside this station there are another three automatic raft metrological stations have been installed along the lake in order to measure the meteorological raft parameters. These four stations are described in the following:

a) **Shore Land Station**

This station was instituted in 1986 near the Head Quarter of High Dam Authority, at 23° 59′ N and 32° 48′ E at elevation of 192 m above the mean sea level. The monthly average of maximum, mean, and minimum air temperature, relative humidity are measured at 1.5-2 m above ground. Wind speed is measured by a Lambrecht Cup-counter at 2 meter level. Global Radiation is also recorded at Aswan Airport Meteorological Station (4 km to the north 0f the lake station). Maximum and minimum air temperatures were observed in Stevenson screen. Measurements of evaporation from a "Class A" pan were carried out in the station. The period of data series covered the period 1986-2006, with 4 months missing of each parameter.

b) **Automatic floating Station**

Three automatic buoy stations – belong to the High Aswan Dam Authority were installed in 1995, the stations were located upstream of the dam, at Aswan (2 km), El-Allaquey (75 km) and Abu-Simble (280 km).

The automatic system is recording hourly data of maximum, minimum and mean air temperature, relative humidity, surface water temperature and 2 m depth water temperature, wind speed and wind direction. The sensor has been fixed at 2m height above water surface. The system is operated by chargeable batteries through solar panels. The data have been collected and stored through a data-collecting unit during the period from 1998 to 2005.

METHODOLOGY AND RESULTS

Estimation of evaporation rate is of utmost importance in many hydrologic problems associated with planning and management of reservoirs and irrigation systems. In arid and semi arid zones such estimation is particularly important to conserve scarce water resources. However, the exact measurements of evaporation rate from water bodies are indeed one of the most difficult tasks.

In order to estimate the expected meteorological parameters at AHDR in 2050; the change of such parameters trends should be first obtained. However, since the data collected from the three raft stations are covering a period of less than ten years (1998-2005), variations trend for the meteorological parameters were estimated according to the data collected from Aswan Shore Station for a period ≥ 20 years.

Estimations were carried out for four meteorological parameters as follows:

a) Monthly mean air temperature (°C),
b) Monthly mean air relative humidity (%),
c) Monthly mean air wind speed (m/sec), and,
d) Monthly mean global radiation (MJ/m^2).

Table (1) presents the annual correlation coefficient, trend, and level of significance for Aswan Shore.

Table (1) Trends and Correlation Coefficient for Meteorological Parameters for Aswan Shore Station

Net. Parameter	Correlation Coefficient r	Significant level	Trend β
Ta	0.0551	0.813	0.00475
R_H	o.5326	0.0129	0.168
WS	0.0163	0.9440	0.00036
RG	-0.0177	0.9428	-0.00146
T_x	-0.3815	0.08	-0.02
T_n	0.2126	0.3547	0.0136
Class A	-0.4464	-0.0425	-0.04161

Amount of water evaporated from a water surface is estimated by the following methods:

a) Evaporation gauges, (atmometers, Class "A" pan, GGI-3000,….etc)
b) Empirical evaporation equations, (Bulk aerodynamic equation)
c) Analytical methods, (water-budget, energy-balance, combination of energy-balance and Bulk aerodynamic).

The monthly evaporation values were estimated using seven different methods (Empirical and Analytical) which are widely used as listed in the followings:

EMPIRICAL METHODS

1. Bulk₁ Aerodynamic Equation (El-Bakry, 1993)

$$E_{Bulk1} = 0.126 * U_2 * (e_s - e_d) \qquad (2)$$

where

E_{Bulk1} = lake evaporation in mm/day
e_s = saturated vapor pressure at water surface temperature
e_d = actual vapor pressure of overlying air at a specified height
U_2 is wind speed in m/sec at 2 m height.

2. Bulk₂ Aerodynamic Equation (USSR)

$$E_{Bulk2} = 0.13 * (0.5 + 0.7 * U_2) * (e_s - e_d) \qquad (3)$$

where

E_{Bulk2} = lake evaporation in mm/day
e_s = saturated vapor pressure at water surface temperature

e_d = actual vapor pressure of overlying air at a specified height
U_2 is wind speed in m/sec at 2 m height.

ANALYTICAL METHODS

1. Doorenbos et al. (1977)

Dorembos et al equation read as;

$$E_{Doorenbos} = \frac{\Delta * [0.94 R_G - \sigma T_K{}^4 * 0.97 * (0.34 - 0.044\sqrt{e_d}\,)(0.1 + 09 n / N)] + 0.67 E_a}{\Delta + 0.67} \tag{4}$$

where,

$E_{Doorenbos}$ = Lake evaporation in mm/day
Δ = de/dT= Slope of saturation vapor pressure curve at air temperature T
γ = psychrometer constant = 0.67 for ^oC
R= mean extraterrestrial radiation expressed in equivalent (mm/day)
σ = Stefan – Boltztman constant
T_k = absolute mean air temperature (^oK)
(n/N) = ratio of actual to possible hours of sunshine duration
e_d = actual vapor pressure at the same temperature
e_s = Saturation vapor pressure at water surface temperature
U_2 = wind speed at 2m (mile/day)
E_a= the so- called aerodynamic term

$$E_a = 0.27 * (0.5 + 0.864 * U_2) * (e_s - e_d) \qquad where;\ U_2\ (m/\sec)$$

2. Frere$_1$ et al. (1986)

Frere$_1$ et al. equation read as;

$$E_{Frere1} = \frac{(P_o / P) * \Delta\,[0.94 R_G - 6 T_k{}^4 (0.56 - 0.079\sqrt{e_d}\,)(0.1 + 0.9\, n / N)] + 0.67\, E_a}{(P_O / P) * \Delta + 0.67} \tag{5}$$

where,

E_{Frere1}= Lake evaporation in mm/day

$$E_a = 0.26 (0.5 + 0.7 * u_2) * (e_a - e_d) \quad ; \quad u_2 \text{ m/sec}$$

3. Frere$_2$ et al.

In case of neglecting atmospheric pressure, the formula becomes;

$$E_{frere2} = \frac{\Delta\,[0.94R_G - \sigma T_K^{\,4}(0.56 - 0.079\sqrt{e_d}\,)\;(0.1 + 0.9n/N)] + 0.67E_a}{\Delta + 0.67} \tag{6}$$

4. Sadek et al. (1997)

Sadek et al. equation read as;

$$E_{sadek} = \frac{\Delta\,[\,0.94R_G - 0.97\,\sigma T_k^{\,4} * (0.1 + 0.9n/N) * (1 - 1.24\,(e_a/T_k)^{1/7}\,] + 0.67\,E_a}{\Delta + 0.67} \tag{7}$$

where,

E_{Sadek}= Lake evaporation in mm/day

$E_a = (\,0.13 + 0.14 * u_2\,) * (\,e_s - e_d\,)$; u_2 m/sec

5. McIlroy formula (Slatyer&McIlroy 1961)

McIlroy formula read as;

$$E_{McIlroy} = \frac{S}{S + 0.67}\left[0.94R_G - 0.97(5.998 - 0.195\,\sigma T_K^{\,4})\,(0.1 + 0.9\,n/N) + 3.88\,\sigma T_K^{\,3}\right] + 0.08\,u_2(T_a - T_w) \tag{8}$$

where,

S = slope of saturation vapor pressure curve at wet bulb air temperature.
= (de/dTw)
T_a = mean air temperature
T_w = wet air temperature

RESULTS AND DISCUSSION

In the present study, daily observations of temperature, humidity, wind speed, evaporation rate, and radiation of the shore meteorological station of AHDR are obtained for the period from 1998 to 2006 as well as data of 3 raft stations which are Aswan, Allaquy, and Abu-Simble are also obtained for the period from 1998 to 2005. The average monthly of the data of 3 raft stations were calculated. The average and monthly and annual values are considered as the meteorological data for the year 2000. These data have been statistically analyzed and the trend of all the meteorological parameters has been estimated for the shore station. The obtained trend was used for estimating the meteorological parameters for the three raft stations at year 2050.

Seven equations ($Bulk_1$, $Bulk_2$, Doorenbos, $Frere_1$, $Frere_2$, Sadek, and McIlory) were applied for estimating the monthly evaporation rate at the meteorological three raft stations for the years 2000 and 2050. Of these seven equations, two methods are depending on Bulk aerodynamic ($Bulk_1$ and $Bulk_2$) using data of temperature, humidity and wind speed. The other five methods (Doorenbos, $Frere_1$, $Frere_2$, Sadek, and McIlory) are based on combination equations, from which four equations are depending on Penman equation and the fifth equation which is the last depends on combination using McIlory equation. These five methods were applied using the above parameters as will as radiation and aerodynamic terms. Intensive calculations were conducted where the obtained results are presented in figures 2 to 7.

Figure 2 shows that the maximum value of the monthly evaporation rate of Aswan raft station at the year 2000 was 9.88mm at June and July by using McIlory method, while the minimum value was 3.3mm at January by using McIlory method. In the same time Figure 3 shows that the maximum value of the monthly evaporation rate of Aswan raft station at the year 2050 was 10mm at June and July by using McIlory method, and the minimum value was 3.4mm at January by using McIlory method. Figure 4 shows that the maximum value of the monthly evaporation rate of Allaquy raft station at the year 2000 was 8.3mm at June and July by using $Frere_1$, $Frere_2$, and Doorenbos methods, in the same time the minimum value was 3.0mm at February by using $Bulk_2$ method. For Allaquy raft station, Figure 5 shows that the maximum value of the monthly evaporation rate at the year 2050 was 8.8mm at June by using $Frere_1$ and $Frere_2$ methods, while the minimum value was 2.9mm at February by using $Bulk_2$ method. For Abu-Simble raft station, figure 6 shows that the maximum value of the monthly evaporation rate of at the year 2000 was 10.2mm at August by using $Bulk_1$ method, while the minimum value was 3.4mm at January by using McIlory method. While figure 7 shows that the maximum value of the monthly evaporation rate of Abu-Simble raft station at the year 2050 was 9.6mm at August by using $Bulk_1$ method, and at June using McIlory method, and the minimum value was 3.5mm at December by using McIlory method.

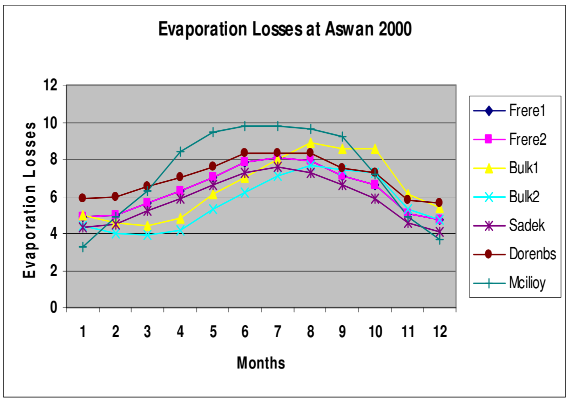

Fig 2 Average Monthly Evaporation Rates for Aswan Raft at 2000

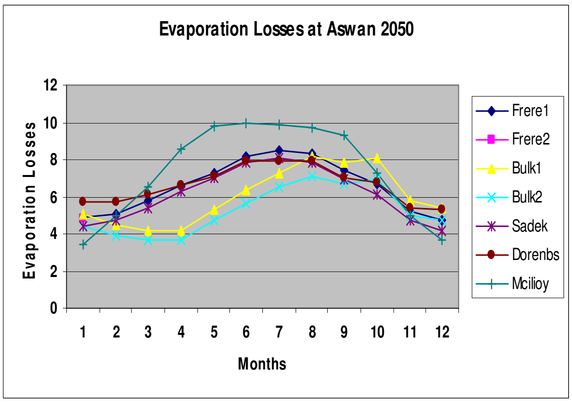

Fig 3 Average Monthly Evaporation Rates for Aswan Raft at 2050

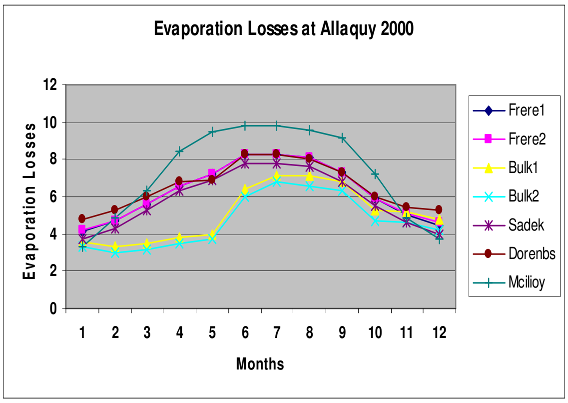

Fig 4 Average Monthly Evaporation Rates for Allaquy Raft at 2000

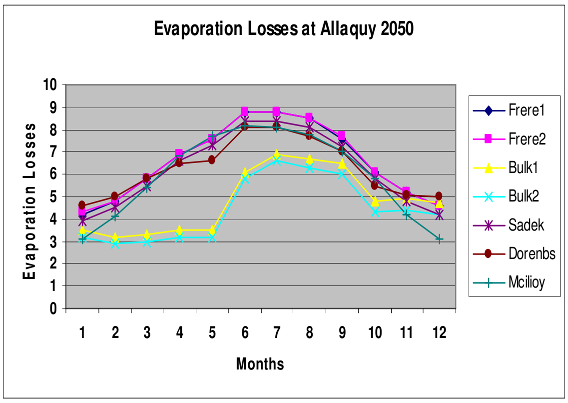

Fig 5 Average Monthly Evaporation Rates Allaquy Raft at 2050

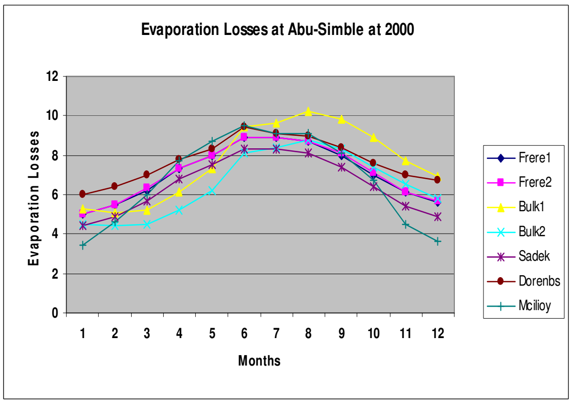

Fig 6 Average Monthly Evaporation Rates for Abu-Simble Raft at 2000

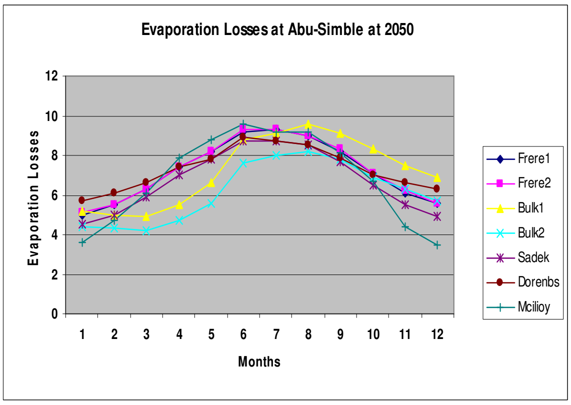

Fig 7 Average Monthly Evaporation Rates for Abu-Simble Raft at 2050

Table 2 The Average Annual Evaporation Rate for the three Raft Stations for the years 2000 and 2050

	Aswan 2000	Aswan 2050	Allaquy 2000	Allaquy 2050	Abu-Simble 2000	Abu-Simble 2050
$Bulk_1$	6.5	6.0	5.1	4.8	7.6	7.2
$Bulk_2$	5.6	5.3	4.7	4.4	6.2	6.1
Dor.	7.0	6.6	5.8	6.2	7.7	7.3
$Fre._1$	6.3	6.5	6.3	6.6	7.1	7.3
$Fre._2$	6.4	6.6	6.3	6.6	7.1	7.3
Sad.	5.8	6.1	5.9	6.2	6.5	6.7
Mcl.	7.0	7.3	5.8	5.9	6.8	6.8
Mean	6.37	6.34	5.70	5.81	7.00	6.96

Table 2 shows the average annual evaporation rate for the three raft stations using the seven equations for the years 2000 and 2050. It is clear from table 2 that the annual mean evaporation rates for Aswan meteorological station at year 2000 and 2050 for the seven equations were 6.37mm and 6.34mm respectively. For Allaquy station, the mean evaporation rate for year 2000 and 2050 were 5.70mm and 5.81mm respectively. For the third meteorological station Abu Simble, the mean evaporation rate for year 2000 and 2050 were 7.0mm and 6.96mm, respectively.

Table 3 The Average Annual Evaporation Rate for the Three Raft Stations

	2000	2050	Change %
Aswan	6.37	6.34	-0.47
Allaquy	5.70	5.81	1.90
Abu-Smile	7.00	6.96	-0.57
Mean Lake	6.36	6.37	0.29

Table 3 shows the average annual evaporation rate for the three raft stations and the evaporation rate of the whole AHDR for the years 2000 and 2050. It's clear from the table that the average evaporation rate from AHDR which estimated by using the seven equations were 6.37mm and 6.34mm for the years 2000 and 2050 respectively with change percent of -0.47. At Allaquy the values were 5.70mm and 5.81mm for the years 2000 and 2050 respectively with change percent of 1.9, while at Abu-Simble the average evaporation rate for the years 2000 and 2050 were 7.00mm and 6.96mm respectively with change percent of -0.57. By assuming that the mean values of evaporation rate of the three raft meteorological stations is representing the evaporation rate of the whole lake, it was found that the average values for these three stations were 6.36mm and 6.37mm for the years 2000 and 2050 respectively with change percent of 0.29. It is clear that, although the temperature is expected to increase in year 2050 than that of year 2000, however, the average change percent in the evaporation rate for the lake will be 0.29 which prove that the mean evaporation losses of the lake will be increased by 0.29% compared with that for year 2000. This negligible change can be explained due to the effect of temperature increase, followed by increase humidity and decrease wind speed which have negative effect on evaporation. However it was found that there is a considerable change in evaporation between 2000 and 2050 in some months (winter and summer). In general it was proved that the mean annual values of evaporation will not have much change during the study period (2000-2050).

It is known that the lake-to-pan coefficients vary according to size and type of pan, type of installation, and climate condition. For class "A" pan, this coefficient varies between 0.60 in warm and arid areas, and 0.80 in humid areas. Mean annual evaporation from class "A" pan at Aswan Shore Station for the period ending by the 2000 was found 13.92 mm/cm^2, rate of climate change for class "A" pan 0.0416 mm/cm^2/year, and have annual evaporation for class "A" pan for the period ending by 2050 was 11.84 mm/cm^2. Total change in annual class "A" evaporation was

-2.08 mm/cm^2/50 years with -14.94% from the reference year evaporation. It is clear that the measure of evaporation values obtained by Class "A" pan is quite higher than the average values obtained by the seven equations. This change is due to the selection of the lake-to-pan coefficient.

CONCLUSIONS

It was assumed that the three raft stations (Aswan, Allaquy, and Abu-Simble) are representing the whole AHDR. Since the first is at distance 2.0 km, the second at distance of 120 km while the third at distance of 280km upstream AHD respectively. The distributions of the three stations are almost covering 90% from whole lake area.

The Meteorological data of the three Raft Stations, Aswan, Allaquy, and Abu-Simble are collected and considered in this study where results were analyzed in order to evaluate the evaporation losses from AHDR at year 2050. The evaporation losses from the lake were calculated twice for each station. The first one was for year 2000 representing the present condition, while the second one was for 2050, representing the expected future values of evaporation.

Table 2 showed that the mean value of evaporation for Aswan Station in 2000 were 6.37mm and 6.34mm respectively in 2050 which equal to 6.4mm. However, the mean change percent for the results of the seven equations was -0.47%. For Allaquy Station it was found that the mean value of evaporation for the seven equations in 2000 and 2050 were 5.70mm and 5.81mm respectively, while the mean change percent between 2000 and 2050 was 1.9%. For Abu-Simble Station the mean evaporation value for the seven equations was 7.00mm for year 2000 and 6.96mm for 2050, and the mean change percent was -0.57%. These data showed that by applying the seven equations for the three meteorological stations, the differences in evaporation values and the change percent were quite negligible.

Finally this study have proved with no doubt that the change percent in evaporation for the three stations Aswan, Allaquy, and Abu-Simble were -0.47, 1.9, and -0.57% respectively and the final change percent for whole lake is 0.29% (Table 3).

This mean that the expected climate change and the temperature rise in 2050 will have quite negligible effect on evaporation losses from Lake Nasser, it will be increased by 0.29% due to the expected temperature rise which will increase the humidity and decrease the wind speed. Wind speed is considered one of the main parameters that have direct effect on evaporation rate. At the beginning of this work it was born in mined that the evaporation losses from AHDR will be definitely increased, but after the thoroughly calculations by applying the available reliable published methods and by using the actual data collected from the three raft meteorological stations in the lake. However, the obtained results showed that the evaporation losses from AHDR will be increased by a very negligible change percent of 0.29%. This unexpected result will encourage for more investigations when more metrological data for the raft stations are obtained.

ACKNOWLEDGEMENT

The author would like to thank Prof. Dr. Abd-El-Fattah Motawae Chairman of Water Nile Sector, (MWRI) and Dr. Abd. El-Latif Mehanna for their support for providing the study with the needed data.

REFERENCES

- Chattopadhyary, N. and M. Hulme, 1997: Evaporation and Potential Evapotranspiration in India under Conditions of Recent and Future Climate Change. Agricultural and Forest Meteorology. 87.55-73.
- El-Bakry, M.M., 1993: Hydrometeorological Measurements over the Lake of Aswan High Dam and Evaporation Estimate. Nile 2002 Conference, Aswan, Egypt, February 1-6-1993.
- El-Bakry, M.M., 1994: Net Radiation Over Aswan High Dam Lake. Theor. Apph. Climatol. 49,129-133.
- Dorembos, J., and Pruit, W.O., 1977: Crop Water Requirements. FAO Irrigation and Drainage Paper no. 24, 144P.
- Frere, M. And Popov, G.F., 1986: Early Agrometeorogical Crop Yield Assessment. FAO Plant Production and Protection Papers, Tech. Paper No. 73.
- Hoy, R.D. and Stephens, S.K. (1977): Field Study of Evaporation Analysis of Data from Lakes Eucumbene, Cataract, Manton, and Mundering. Rs. Project 68/s, Tech. Paper No.21, A.W.R.C., Cambena, A.C.T., 195 PP.
- Omar, M.H., and M.M. El-Bakry, 1981: Estimation of Evaporation from the Lake of Aswan High Dam (Lake Nasser) based on measurements over the Lake. Agric. Meteorola., 23, 293-308
- Omar, M.H., and M.M. El-Bakry, 1997: Estimation of Evaporation from Lake Nasser by the Heat Budget Method, and Morton's CRLE Model. Meteorology and Environmental Cases Conference, 2-6 March 1997, Egyptian Meteorological Authority, Cairo, Egypt.
- Penman, H.L., 1948: Natural Evaporation from Open Water, Bare Soil and grass: Proceedings Royal Society, London A 193,120.
- Penman, H.L., 1956: Vegetation and Hydrology. Technical Comm. No. 53, Commonwelth Bureau of Soils.
- Sadek, M.F., M.M, Shahin, and C.J. Stigter (1997): Evaporation from the Reservoir of High Aswan Dam, Egypt: Anew Comparison of Relevant Methods with Limited Data. Theor. Appl. Climatol. 56, pp 57-66.
- Slatyer, R.O., and I.C. McIlroy, 1961: Practical Microclimatology. Melbourne, CSIRO, Australia, pp. 330.
- Webb, E.K., 1965: Aerial Microclimate. Meteorol. Monogr., 6(28): 27-58, July 1965.

- WMO, 1966: Measurements and Estimation of Evaporation and Evapotranspiration. Tech. note 83, Geneva, World Meteorological Organization, 121 pp.
- WMO, 1983: Guide to Hydrological Practices. WMO No. 168, Vol. 2 Chapters 5-7: 59-115, Geneva: World Meteorological Organization.