Global Educational Research Journal: ISSN-2360-7963, Vol. 3(11): pp 376-382, November, 2015.

Full Length Research Paper

Assessing the Impacts of Evaporation Rate on Dosabligo Dam in the Nabdam District Of Upper East Region – Ghana

***[1]I.O. Danquah, [2]A. J. Abungba, [3]P. Zoungrana.**

[*1]Water Resources Engineer, Goldrain Mountain Company Limited, Koforidua–Ghana.
[2]Water Resources Commission, Bolgatanga – Upper East Region.
[3]Focal Point PRGDT, Permanent Inter-States Committee for Drought Control in the Sahel CILSS, Ougadougou–Burkina Faso.

*Corresponding Author's E-mail: danqdiok1982@yahoo.com,
[2]joachimayiiwe@yahoo.com, [3]philippe.zoungrana@cilss.bf

Accepted 30th November, 2015

The rate of evaporation increases with surface area of reservoirs implying high rate on large dams. Measurement of evaporation rate in these resources is very difficult and various techniques have been suggested, employed and tested by modern scientist and engineers for its determination. Climate change variability in the upper east region is a great contributing factor towards evaporation from water bodies. The most simple, inexpensive and reliable evaporation rate determination is the use of the evaporation pan. The best technique used for this research work is based on functionality, availability of site, data collection process and size of dam. Onedam within the Nabdam district is sampled and an evaporation pan installed at the dam site for assessment, data collection and analysis. This brief paper sorts to describe one simple main principle used in estimating evaporation from the Dosabligo dam. In this work, emphasis is placed on the simple technique professionals can employ to determine evaporation rate in water bodies and resources using the evaporation pan. Evaporation rate is calculated from the evaporation pan using the energy budget equation having the benefit of simplicity of usage. High evaporation rate decreases the quantity of water in the dam affecting water availability for irrigation, domestic use, livestock rearing, aquatic habitation and reduction in the aesthetic of the resources.

Keywords: Climate change (CC), Evaporation, Dams, Reservoirs, Energy budget equation, UER, WVB.

INTRODUCTION

Several methods for determining the rate of evaporation from water bodies have being employed and this include the empirical methods (Kohler et al., 1955), water budget methods (Shuttleworth, 1988), energy budget methods (Anderson, 1954), mass-transfer methods (Harbeck, 1962); and combination methods (Penman, 1948). Both the direct and indirect methods of measurement have being identified as accurate and reliable way of determining evaporation for the long term (Malik et. Al., 2013). Sun as the primary source of light during the day is the energy required for evaporation of water to occur on these small dams. In this study, the rates of evaporation from water surfaces are calculated by the water budget equation and computational fluid dynamics within three small dams in the Pitanga, Dosabligo and Nangodi communities of the Nabdam district within the Upper East Region. The evaporation pan is used in this study because measurements can be assumed to be proportional to evaporation from an open water surface such as the three dams (Malika et. Al., 2013). The amount of evaporation is a function of temperature, humidity, wind and other ambient conditions. A great impact of high droughts identified as negative effect of climate change is the increased evaporation constituting a major constituent of water balance in dams in Upper East Region. For many complex studies such as

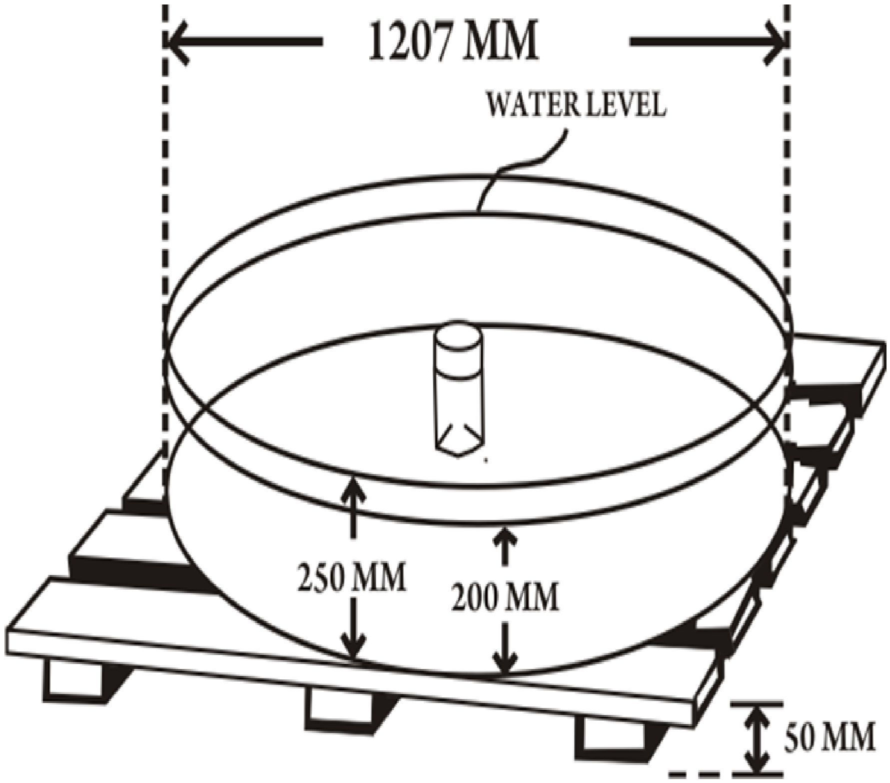

Figure 1: Dimensions for Class A Evaporation pan

determining the impacts of potential climate change or variability on small dams evaporation, it is necessary to combine the energy balance and mass transfer procedures (Croley, 1989; Hostetler and Bartlein, 1990).

STUDY AREA

This study on evaporation rate on dams as a result of changes in the climate is undertaken on one small dam in the Nabdam district within the White Volta Basin (WVB). This research work is done in Dosabligo community of the Upper East Region of Ghana. The community covers a total land area of km2 with a total population of 1082. The community lies between longitude latitude 11˚94ˈ14.60ˈˈN and longitude 0˚73ˈ53.96ˈW at an elevation of 258m above sea level. The Dosabligo dam is shared by the people of Dosabligo community of the Nabdam district and Sakpoore community of the Bongo district. The landscape is flat, low lying with gentle slopes at various areas. The Nabdam district is a newly carved district out of the Talensi district. The Upper East Region (UER) is bounded by Burkina Faso to the north, Togo to the East, Northern Region to the south and Upper West Region to the west. The region occupies a total land area of 8842km2 and is the smallest administrative region in Ghana. It's covered with grass and small plants with trees at a distance of 2m apart. The main activities within this community is farming and rearing of livestock's. Small dams within these communities are serving varied purposes: for domestic use, irrigation, livestock's rearing and construction purposes. There are a number of dams within the district and region but the Dosabligo dam was selected based on accessibility, location and availability of evaporation pan. The resource is of utmost importance during the long drought from October to May where animals are allowed to move freely in search of water. Farming and livestock rearing is the main means by which the population supports livelihoods in this community. Farming for each season starts in May where farmers begin preparing their lands to meet the first rains.

MEASUREMENT METHODOLOGY

Evaporation from small dams can be calculated using various weather parameters obtained from a weather station or directly from an evaporation pan. Two types of pans are commonly used throughout the world: the class "A" pan and the sunken pan. For this study, the class A evaporation pan (Figure 1) is used as a standardized pan with a diameter of 1207mm and a depth of 250m (Craig, 2004). It is elevated 150mm off the ground on a wooden support. The operating water level is 200mm deep; therefore, the water level in the pan is kept 20% from the rime. It contains water surface up to the original

Figure 2: Installed Class A Evaporation pan at Dam Site

Figure 3: Dosabligo Dam

ground surface. The rate of evaporation on the Dosabligo dam depends on the (Frank, 1992);

- Vapor pressures at the water surfaces and their air above
- The evaporation pan environment
- Wind speed
- Exchange of heat between evaporation pan and ground surfaces
- Atmospheric pressure
- Surface area of the Dosabligo dam
- Solar radiation
- Water quality
- Air and water temperature

A universally simple 'pan factor' Kpan is introduced and where Epan is the measured evaporation for the pan (Martinez et. Al., 2006), dam evaporation estimates are obtained by multiplying the pan data by an appropriate coefficient, Kp as follows:

$$E = E * K_{pan} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [1]$$

Where E is evaporation rate from dam or reservoir in unit of depth (mm), Epan is the amount of evaporation from the class "A" pan in unit of depth (mm) and Kp is the pan coefficient. The pan coefficient, Kpan depends on (the kind of pan used, the pan environment and the climate: the humidity and wind speed). For the Class "A" evaporation pan, the Kpan varies between 0.35 and 0.85. Average Kpan = 0.7.

In order to obtain accurate evaporation rate from the dam, the pan coefficient (Kp) for the class "A" pan was selected from tables (FAO irrigation and Drainage Paper No. 24) because of the siting environment and different levels of mean relative humidity and wind speeds (Figure 2 and 3).

The standardized evaporation pan is mounted on a 50mm high wooden support, 2m away from the dam and filled with water from the Dosabligo dam to about 80% of the pan capacity. The installed set up is protected from birds and animals with fencing material. The initial depth of water in the pan is recorded. The air, water in dam and pan temperatures are recorded with a thermometer and the time also logged. A 24 hour period of evaporation is allowed to occur. A full measuring cylinder is filled with water from the dam and used to fill the evaporation pan till it reaches the 80% mark of the pan capacity after every evaporation rate. The quantity added is recorded as the Epan (mm). Kpan is then selected from the tables based on land area characteristics around the mounted evaporation pan.

COMPUTATION PROCEDURE

A number of methods exist for estimating evaporation from open water resources such as small dams. These include energy budget method, eddy correlations method, mass-transfer method, the water budget method, the penman method, and the pan method (Dingman, 1994; Brustsaert, 1982). Most of these methods require huge amounts of meteorological data such as temperature, solar radiation, humidity, wind speed in estimating evaporation rate for dams. This is a disadvantage to most of these methods during evaporation computation.

In this work of evaporation from small dams, evaporation rate is estimated from the pan using the energy budget equation and computational fluid dynamics and is thoroughly explained below.

The energy budget method

The basic method for estimating evaporation rate from the three small dams in the study area is recognized as the energy budget method and has the equation;

$$R_n = L_V E + H + G \quad [2]$$

Where Rn is the net radiation on the surface of the dam. Part of this energy is used to vaporize water and gives rise to a latent flux LVE, where E is the evaporation speed per unit area LV is the latent heat of dam water vaporization (2.4×106J/Kg). The remaining energy is dissipated as sensible heat flux H which heats the air and as a heat flux G stored in the dam water. Since we can neglect the storage term compared to the other terms, we let G≅0 (Saïghi, 2002; Eichinger et. al., 2003).

The evaporation rate therefore becomes:

$$E = \frac{R_n - H}{L_V} \quad [3]$$

With

$$H = h_c (T_s - T_a) \quad [4]$$

And

$$R_n = (1-\alpha)R_g + \varepsilon\sigma (T_a - 6)^4 - \varepsilon\sigma T_s^4 \quad [5]$$

Where hc is the coefficient of convective heat transfer in turbulent boundary layer on flat plate (Sartori, 2006).

$$h_c = 5.907\, V^{0.8} L_C^{-0.2} \quad [6]$$

R_g in eqn. [5] is the global radiation which corresponds to the sum of the direct and diffuse solar radiation of short wavelength. It is written as:

$$R_g = 0.271\; I_o \lambda_1 \, Sinh + 0.706\, I_o A_1 \, Sinh \exp\left(\frac{-A_1}{Sinh}\right) \quad [7]$$

A very important input parameter is the temperature at the surface T_s. It is calculated from the resolution of the energy budget equation at the surface eqn. [2]. Eqn. [5], Stefan equation is used to calculate the latent heat flux based on the Fick low (Lewis, 1995; Bowen, 1926; Mosner et. al, 2003). Thus we obtain;

$$L_V E = \frac{L_V K_E M_W}{R T_a}\left[P_{VS}(T_S) - P_V(T_a)\right] \quad [8]$$

Where $K_E$is the convective mass transfer coefficient calculated from the Lewis hypothesis.

$$K_E = \frac{h_c}{\rho C_P} \quad [9]$$

Pvs is the saturated vapor pressure calculated from Clapeyron- Clausius formula:

$$P_{VS}(T) = exp\left(25.5058 - \frac{5204.9}{T}\right) \quad [10]$$

And

$$P_V(T_a) = H_r\, P_{VS}(T_a) \quad [11]$$

Replacing eqn. [4], [5] and [8] in eqn. [2], the energy budget is finally written as:

$$(1-\alpha)R_g + \varepsilon\sigma(T_a - 6)^4 - \varepsilon\sigma T_s^4 - h_o(T_s - T_a) = \frac{L_V K_E M_W}{R T_a}\left[P_{VS}(T_S) - P_V(T_a)\right] \quad [12]$$

The determination of eqn. [12] allows us to evaluate the surface temperature T_s at every moment of the day according to the hourly data of the following parameters: the net radiation R_n per unit area, the air temperature T_a, the relative humidity H_r and the wind speed V. The determination of this eqn. is carried out with contrast method. The value of the surface temperature T_s evaluated at every moment gives us access to the water flux evaporated at the surface.

RESULTS AND ANALYSIS

Evaporation rate over the Dam resources

The long drought in the Upper East Region starts from October ending in May with various rate of evapotran-

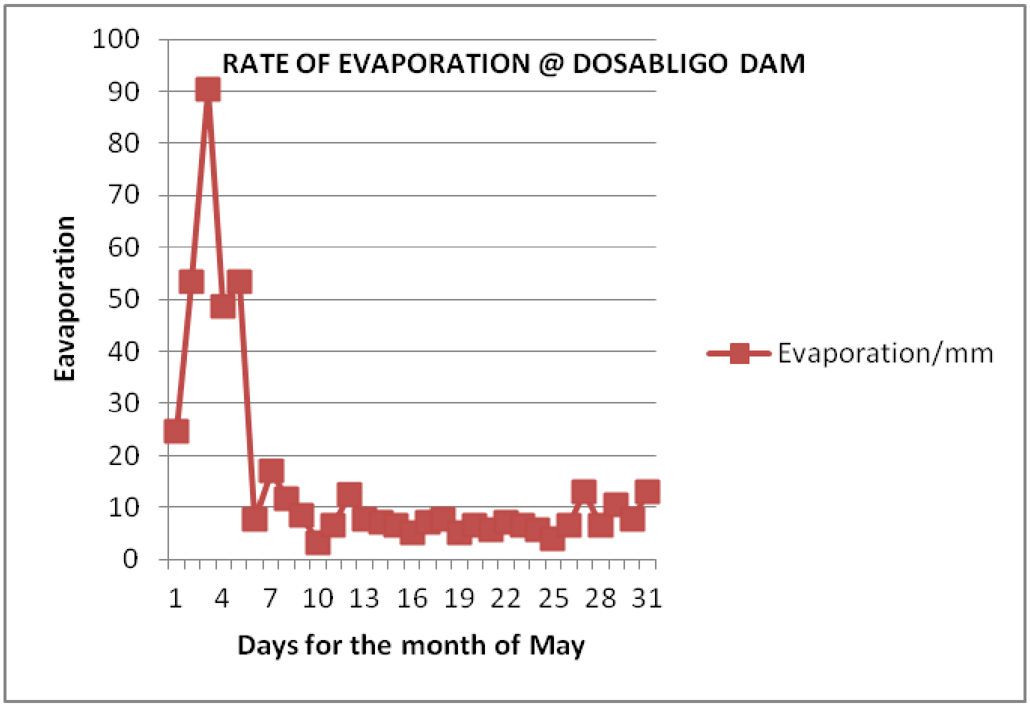

Figure 4: Rate of evaporation at Dosabligo in May

spiration. The Dosabligo dam was selected as the study area because of proximity and data collection materials and process. Data collection was in May as it's the last month of the drought period and into the rainy season. Using the evaporation pan, temperatures, water evaporation from pan and precipitation are recorded within the one month period. The highest rate of evaporation of 90.4mm was recorded on the 3rd of May with 160m^3 of water evaporating into the atmosphere. This was due to warm air within the environ of the evaporation pan which measured air temperature of 32˚C. This is the highest air temperature recorded during the study. The rate of evaporation dropped gradually from 53.3mm to 7.8mm. Cloud formation and the resultant precipitation formed is a great factor towards the rate of evaporation as precipitation of 23mm recorded the least evaporation rate of 3.3mm. Climate change variability factors such as wind contributed greatly to the evaporation rate as the study area is bare steady area with gentle slopes. Four precipitations were observed during the study of which evaporation rate recordings yielded low values. It's observed that evaporation rate is high on large surface areas with a great contributing factor from flora coverage's. The Dosabligo dam observes a total filling capacity of 90% during high peak periods such as in August. This has great impact on the dam as seepages is high. Runoff generation from all water divide areas into the dam has recorded high level of siltation reducing the total capacity of the dam. Siltation has blocked the canal hence making it difficult for water to flow downstream to support irrigation. The evaporation pan was simply used to estimate the maximum volume of water evaporating from the dam each day. Estimation is only for evaporation as water redrawn from the dam also serves other purposes such as animal watering, fishing and washing (figure 4).

Temperature effect

Medium of transmission of light rays has a great effect on temperature as less dense medium gives higher temperatures than dense medium. A maximum temperature of 32˚C and 26˚C was recorded for the air temperature throughout the study. A temperature of 32˚C generated the highest evaporation rate of 90.3mm during the investigation resulting in the highest quantity of water leaving the dam. Wind is a great contributor when it comes to evaporation from water surfaces and climate change. Transpiration from trees increases the rate of cloud formation in areas like the southern part of Ghana. Dosabligo in the Upper East Region is an area with less vegetation and therefore decreased rate of evapotranspiration. Temperatures obtained for the air, reservoir and water in the pan falls within a specific range. Air temperatures were high followed by water in the reservoir and lastly, water in the evaporation pan. Heat transfers during the sunny days accounted for the high temperature of the water in the reservoirs. Heat loss is slow due to the total volume of dam water compared

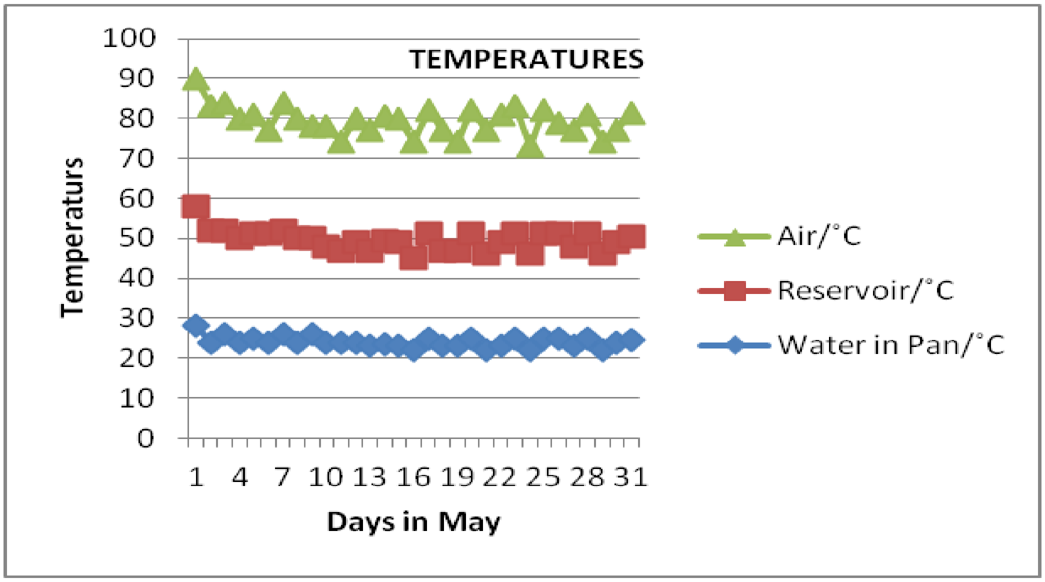

Figure 5: Air and Dam water Temperatures

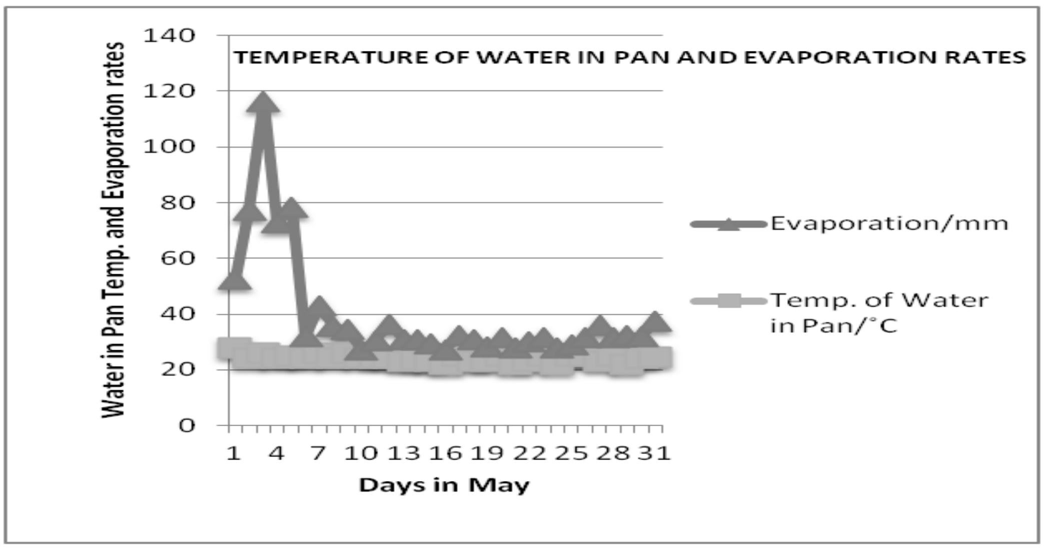

Figure 6: Temperature effect on evaporation

to the water in the evaporation pan. Sediment concentration also contributed to the rate of heat loss hence recording higher temperatures than the water in the evaporation pan. The lowest temperature of 22˚C for the evaporation pan obtained generated an average evaporation rate of 5.8mm. Evaporation rate decrease depends on precipitation recordings in the previous day (Figure 5).

Evaporation as temperature dependent

The rate of evaporation is highly dependent on temperature which is very high around 46˚C during certain times of the drought period. A temperature of 32˚C which recorded the highest evaporation rate 90.4mm during the study gave an indication of direct proportionality. Temperature readings during the night were high resulting in higher rate of evaporation from evaporation pan and dam. The bare grassy land area with few trees decreased foliage percentage hence greater surface area between atmosphere and water surfaces. Radiant heat concentration is area dependent and therefore temperature recordings during the study were higher for the reservoir or water in the dam than water in the evaporation pan as depicted in figure 6.

CONCLUSION

Evaporation in the Upper East Region of Ghana is at a higher rate due to the long drought starting from October to May. Humidity concentration and dry air causes the radiant heat from the sun to have a greater impact due to the varied change in the climate resulting in high absorption rate. At a maximum temperature of 32˚C, a maximum volume of 160m^3 of water evaporated at a rate of 90.4mm. Evaporation in the night is very high due to the generation of extra heat from the land surface as a result of radiant heat absorption during the day. The Volume of water left in the dam can only be correlated and justified with the volume and rate of evaporation if seepages and piping through dam walls is corrected. The use of the class A evaporation pan is good for studying and analyzing evaporation rate on dams. Sediment concentration and surface areas are of utmost importance when estimating evaporation rate since temperature readings for the evaporation pan are higher than the temperature of water in the dam.

ACKNOWLEDGEMENT

Thanks be to the Almighty God for this great work as it's a proof of his divine creating power and control over his creation. Thanks to the staff of CILSS' – Burkina Faso for their loving kindness and good will towards me during this period. I am grateful to Malik of Gratis Foundation, Bolgatanga for the good work and making this work a success. Thanks once again to the Danquah family of New Tafo–Akim for another great master piece work to glorify God. God bless you all.

REFERENCES

Craig IP (2004), Literature Review of Methods for Assessing Dam Evaporation. Draft report for the Rural Water Use Efficiency Initiative Evaporation Control Project, NCEA Draft Report, University of Southern Queensland.

Croley TE II. (1989). "Verifiable evaporation modeling on Laurentian Great Lakes." *Water Resources Res.*, 25(5):781-792.

Kohler MA, Nordenson TJ, Fox WE (1958). "Pan and lake evaporation." pp. 38-60, In: Harbeck, G.E. Jr., Kohler, M.A., Koberg G.E., and others. "Water Loss Investigations: Lake Mead Studies." Geological Survey Prof. Paper 298, 112 pp, 1958.

Kohler MA, Nordenson TJ, Fox,WE (1995). Evaporation from Pans and Lakes. U.S. Dept. Com.Weather Bur. Res. Paper 38. 21 pp, 1955.

Johnson M, Saito L, Anderson MA, Weiss P, Andre M, Fontaine DG (2004). "Effects of

Climate and reservoir and dam operations on reservoir thermal structure." *J. Water Resources. Planning and Management*, 130(2):112-122.

Hostetler SW, Bartlein PJ (1990). "Simulation of lake evaporation with application to modeling lake level variations of Harney-Malheur Lake, Oregon." *Water Resources Res.*, 26(10):2603-2612.

Hostetler SW, Bartlein PJ (1990). "Simulation of lake evaporation with application to modeling lake level variations of Harney-Malheur Lake, Oregon." *Water Resources Res.*, 26(10):2603-2612.

Jones Frank E (1992). Evaporation of water with Emphasis on Applications and Measurements, Lewis Publishers, Michigan, USA, 1992.

Malika F, Abdenour B, Saighi M (2013), Evaluation of two methods for estimation of evaporation from Dams in arid and semi-arid areas in Algeria, (IJAIEM), Vol 2.

Penman HL (1948). "Natural evaporation from open water, bare soil and grass." *Proc. Roy. Soc.*

London, A193:120-146.