Anbar Journal Of Engineering Science©Vol .7,No.3 (2018) 260 – 266

Unviersty of Anbar

Anbar Journal Of Engineering Science©

journal homepage: http:// http://www.uoanbar.edu.iq/Evaluate/

Experimental Investigation about the Parameters that Effect on Evaporation from Sub-storage Reservoir

Isam M. Abdulhameed [a*], Ammar Hatem Kamel[b], Sura Ibraheem[c]

[a] **Upper Euphrates Basin Center, University of Anbar, IraqProfessor in Water Resources Engineering**
[b] **Water Resources Engineering, University of Anbar, Iraq Assistant Professor in Water Resources Engineering**
[c] **Civil Engineering Department, University of Anbar, IraqMsc. in Water Resources Engineering**

PAPER INFO

Paper history:
Received … … …
Received in revised form … … …
Accepted … … …

Keywords:
Evaporation, Sub-surface Reservoirs, Physical Model. Small Dams

ABSTRACT

Management of water resources become one of the most important subjects in the human's life. The water sustains life on earth, therefore; more care for water management is necessary. In the last years, studies show water use will be more in the world as result of rapid increase in population, industrialization, and urbanization etc. The evaporation losses from dam's reservoirs and lagoon form very huge losses in water resources. The annual evaporation depth losses in Iraqi Western Desert is about (2.25 -3) meter, this depth store the highest percentage of the small dams. Sub-surface storage reduces evaporation losses and maintains water quality by minimizing salt concentration. In present study, three tanks are used to simulate the subsurface reservoirs to study the effectiveness of underground storage on reducing the evaporation loss. Each tank have squares cross section tanks of (80) cm length and (40) cm depth and filled up to (34) cm with different graded soil (labeled as A, B with coarse soil, and D with fine soil) to simulate the storage below the ground. While the forth tank filled with water (labeled as C) to represent the reservoir of direct evaporation for comparison study. The present study considers three parameters that can controlled the evaporation from subsurface reservoirs: (a) temperature variation, (b) water table variation, and (c) material properties such as porosity. The field study continues for four months, it was started at Jun.11, 2016 and ended at Dec. 15, 2016 in the Erbil city at north of Iraq. The results showed evaporation losses are reduced by using subsurface storage reservoir with gravel in comparison with free surface evaporation. The evaporation losses are reduced about 46 % , 39% , 64% when the water table below gravel surface range from 5 to 10 cm , while at 20 cm depth of the water table the evaporation reduction is about (85 % to 86% 95%) from A, B and D tanks with porosity 0.65 ,0.67 and o.35 for A ,B and D tanks, respectively..

1. Introduction

Water scarcity demands the maximum use of every drop of rainfall. The annual rainfall in western Iraq is about 115mm. However, high percent of this amount is lost due to evaporation. Therefore, water management projects to collect and use the maximum amount of water have a considerable attention of Iraqi government. Water harvesting is one of the ancient technics to increase water supply especially in arid and semiarid countries like Iraq. The Iraqi Ministry of Water Resources adopted water harvesting to supply water in desert region western Iraq, which includes building earth dams and water ponds in valleys and big catchment area all over the region like, Horan, Ghdaf, and Tubel.

Collecting rainfall in large storage reservoir of dams can be very expensive and may lead to high water losses due to evaporation. This is particularly important in arid and semi-arid regions where the amount of evaporation greatly exceeds the amount of rainfall. One solution to the evaporation problem is to use closed storage tanks. Covered tanks can practically eliminate water evaporation but the cost is extremely high. The other solution is to store collected rainfall directly in the soil for crop production. The use of sand dam is a new technic to increase soil water storage and agricultural production in arid region and it uses the soil profile as a storage media. The sand dam can eliminate the need for storage tanks and reduce water evaporation at minimal cost. A sand dam is a block on the riverbed of a seasonal sandy riverbed. During the high flow, a seasonal river flow downstream is loaded with earth materials (sand and silt). The sediments will settle upstream of the dam and gradually the reservoir will fill up with sand, which is used to store water from the rainy season. A single flash flood may fully recharge a sand reservoir. Upon full saturation of the reservoir, the remaining flash floods will pass over the dam. Sand dams differ from surface dams by storing water with saturated the voids between the sand particles in riverbeds. Water will be available by wells or pumps on the river bank close to the dam or by using scoop holes in the sand reservoir.

Research study the water consumption of communities that use sand-storage dams to reduce evaporation and supply water is rare [1,2] studied the hydro-geological processes around sand-storage dams and how dams are influenced by these processes. They have discussed relevant specific elements within the general hydrology of sand-storage techniques and not necessarily restricted to sand-storage dams. Van Haveren [5] describes general hydrological characteristics of sand-storage dams. Whiting and Pomeranets [6]) discuss water storage in river banks and ways it influences base flows. Work of Mansell and Hussey [4] presents results from surface and subsurface flow analysis for ephemeral rivers in Zimbabwe. They conclude the sand properties of the aquifer were largely controlling flows and storage in these rivers. Mechanism of evaporation from sand volumes has been studied by Yamanakaet al. [3,7] develop a physical model to study the sand dam in Kitui District, Kenya. The model showed the sand storage dams in Kitui capture maximally 3.8% from the total runoff generated in the wet seasons. When climate change is considered and the number of dams is increased, the percentage can reach to 60%.

In present study, sand dam is Modeled using three squares cross section tanks (80*80 cm, and 40cm in depth). Three tanks were filled up to (34) cm with earth fill materials have different graduals to simulate the storage below the ground, while the forth tank filled with water to represent the traditional reservoir dam. The effects of sand dams to decrease the evaporation of storage water under climate change are studied in present study. The methodology includes measuring evaporation from storage water below the soil surface, and comparing it with free water surface evaporation using a sand dam model. The relation between soil types (by size) and evaporation amount to determine ideal material type and areas of construction of sub-surface storage also is considered in present study.

1. **Physical Model (Evaporation Tank):-**

The modeling of sand small dams' reservoir was developed using model contains four squares cross section tanks (80*80cm) and (40cm depth). Three tanks are filled with different types of earth fill materials and labeled (A, B, and D) while the fourth one is filled with water and labeled C. The evaporation losses from gravel are measured by using tape fixed at end piece of a float. The tape inters the piezometer in the center of the gravels tanks. When the float reaches the water surface the tape reading will record the level of water. This reading has been taking daily and evaporation is determined from the difference between two readings. The evaporation from gravel conclusion is compared with free surface evaporation and saved water by using these types of dams can be estimated.

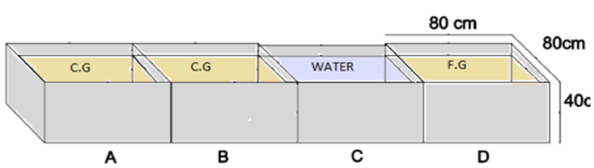

Figure (1-a) Tanks.

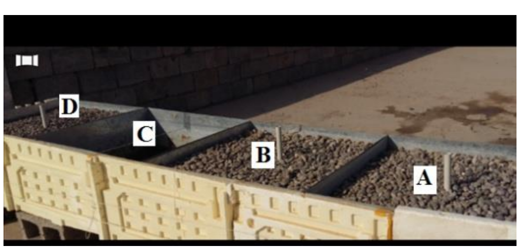

Figure (1-b) Tanks.

2.1 Tank A: -

This tank is lifted from the ground surface by four blocks for the thermal segregate purpose. The tank Contains coarse gravel which is mixed with different ground fills. The porosity of the soil sample is calculated in the field by adding ten liters of water to the tank (B) and adding the same water volume to the tank C that is filled with water only. The water level is measured in both tanks, then the porosity is estimated using the following equation:- Porosity (n) =

$$\frac{\text{amount of increase of water level in tank C after addition of 10 L water}}{\text{amount of increase of water level in tank B after addition of 10 L water}} \quad \ldots\ldots (1)$$

$$n = \frac{1.56\ cm}{2.4\ cm} = 65\ \%$$

2.2 Tank B (Coarse Gravel):

The tank is filled with gravel in different sizes. The porosity of the gravel is calculated in the field by special calibrations by adding ten liters of water to tank B and tank C. The water level is measured in both tanks, then the porosity is estimated using the following equation:- Porosity(n=

$$\frac{\text{amount of increase of water level in tank C after addition of 10 L water}}{\text{amount of increase of water level in tank B after addition of 10 L water}} \quad \ldots\ldots (2)$$

$$n = \frac{1.56\ cm}{2.32\ cm} = 67\ \%$$

3.1Tank C (Pan Evaporation):-

This tank was used to be filled with water only to measure the direct evaporation which represents the standard evaporation level.

2.4 Tank D (Fine Gravels): -

The tank contains another type of gravel (fine gravel). The porosity of gravel is calculated at the field as described in tank B. Porosity (n) =

$$\frac{\text{amount of increase of water level in tank C after addition of 10 L water}}{\text{amount of increase of water level in tank D after addition of 10 L water}} \quad \ldots (3)$$

$$n = \frac{\mathbf{1.46\ cm}}{\mathbf{4.45\ cm}} = 35\ \%.$$

The results are illustrated in table (1).

Table (1) classification and porosity for tanks materials

1. **EVAPORATION MEASUREMENT :-**

A simple device is used to determine the water table in the storage reservoir (tanks that filled with soil). It

N	Tanks	Classification	Porosity
1	Tank A (C.G)	limited gradation from 5 to 40 mm	65 %
2	Tank B (C.G)	limited gradation from 10 to 40 mm	67%
3	Tank D (F.G)	limited gradation from 5 to 16 mm	35%

represents a simple piezometer fixed in the center of the reservoir and the measuring tape is fixed to cork float. The tap inserts into the piezometer, then the cork will float and water surface (water table) level can be recorded in the piezometer.

4.RESULTS AND DISCUSSION :-

The collected data for the four tanks consider the relation between evaporation and the depth of water table at different temperatures. The collected data through study period were distributed according to the average temperatures. These relations can be illustrated as follows:-

4.1 Evaporation Depth Related to Water Table Depth:-

The daily average evaporation was plotted vs the water table depth at different temperatures. These relations are shown in figure (2, 3, and 4) for coarse gravel. There is an inverse relation between water table depth and the evaporation depth for cores and fine gravelrespectively

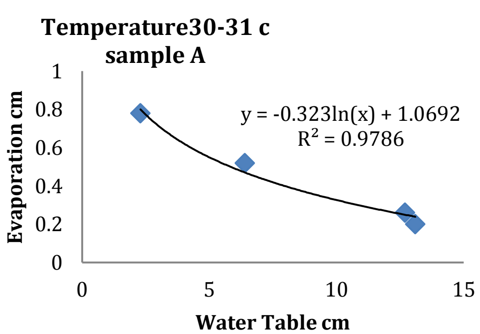

Figure (2) Relation between depth of water table and evaporation at temperature 30-31 for tank A

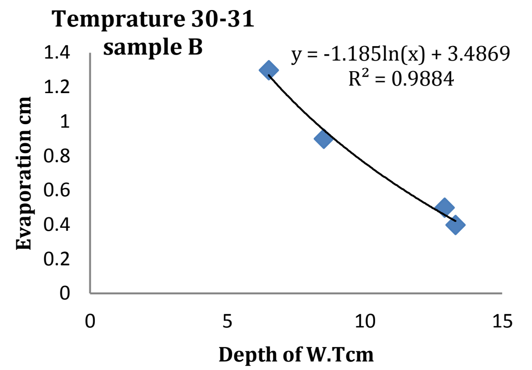

Figure (3) relation between depth of water table and evaporation at temperature 30-31 for tank B

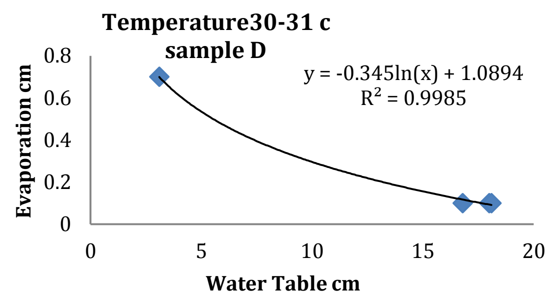

Figure (4) relation between depth of water table and evaporation at temperature 30-31 for tank D

The good correlated relations between evaporation depth and water table depth for the three samples for example at (30-31c) are:-

Y = - 0.323ln(x) + 1.0692 ……………… (4) (Sample A.)

Y = - 0.786ln(x) + 2.309 ……………… (5) (Sample B.)

Y = - 1.413ln(x) + 4.0963 ……………… (6) (Sample D.)

These equations are using to exam evaporation at any water table depth. For example, if water table depth equal to 10 cm, the evaporation from A. tank (from equation 4):-

Y = -0.323*ln(10) + 1.0692 = 0.324 mm/day …….. (7

Evaporation from B. tank (from equation 2)

Y = - 0.786*ln (10) + 2.309 = 0.499 mm/day ……..(8)

Evaporation from D. tank (from equation 3)

Y = - 1.413*ln(10) + 4.0963 = 0.841 mm/day ……..(9)

Multiplying both results in equation 7, 8 and 9 by corresponding porosity, which equal 65% for A, 67% for B, and 35%for D

0.324 * 0.65 = 0.21 mm/day

0.449 * 0.67 = 0.33 mm/day

0.841 * 0.35 = 0.29 mm/day

Figures (5-a) and (5-b) show a very important relation between the ratio of evaporation from sub-surface to evaporation from surface at any water table depth. The depth of water table causes the decrease the evaporation from soil relative to evaporation from surface water or direct evaporation.

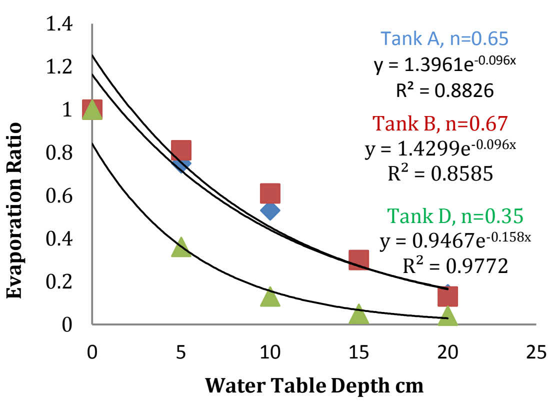

Fig (5 -a) relation depth of water table and evaporation ratio

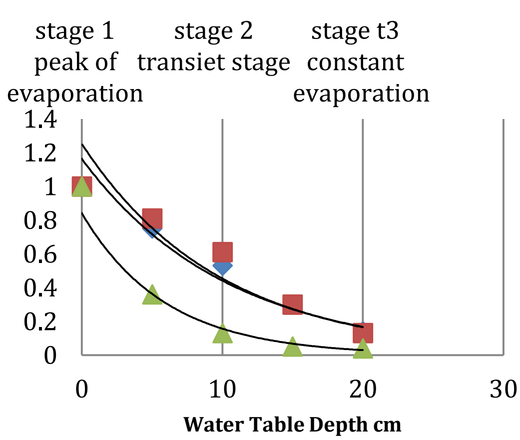

Fig (5-b) relation between depth of water table and evaporation ratio

Figure (5- b) shows that the evaporation included three stages. The first stage began with a relatively high evaporation rate when the soil is saturated and water level equal to soil surface level. The evaporation zone begins from soil surface and extended to sub surface until 5 cm water table depth that represents the peak evaporation stage. The second stage began at (5-10) cm water table depth. The evaporation in this stage is very highly effected by climatic factors or is controlled by the atmospheric evaporative demand. It is close to the evaporation from free surface, with the progressive drying. In this stage, the surface moisture is depleted and the width of the drying layer increased with falling rate of evaporation. The second stage represents a transient stage, when the water table increased causes the width of evaporation zone become more and completely moved into the subsurface. In this stage the evaporation rate is decreased compared with first stage when the soil properties are most effected role in it. The evaporation zone divides the soil into two parts, first with only vapor flow occurring in the profile above the evaporation zone. Then water content reached its critical values and the near-surface profile is approximately air-dry. The second is liquid water flows that mainly occurring in the profile below the evaporation zone. Stage three occurs at 15 cm water table depth and more which can notice a very low and constant rate of evaporation with time.

The relation between evaporation from subsurface and water table depth affected by materials porosity. The rate of evaporation increases with more material porosity as in tank B, While it decreases with material that has the low porosity as in case D tank.
The diference of the evaporation rate between tank B (porosity o.67), and tank A another coarse material (porosity 0.65), h(B-A) referes that high diference occur at the peak evaporation zone (W.T=5 cm). While it is unsensible to the water table depth in the transision stage and constant stage . The h(B-D) is the diference between the evaporation from tank B and tank D with finest material and porosity 0.35. The experemintal shows (table2) that as the water table increased the evaporation decreased. the results show the evaporation rate from the coarse material is more and faster than evaporation rate from fine material

No.	$\triangle h_{(B-A)}$	$\triangle h_{(B-D)}$

△ h_1(W.T= 5cm)	0.06	0.45
△ h_2(W.T=15cm)	0	0.25
△ h_3 (W.T=20cm)	0.01	0.09

4-2:- Evaporation Depth Related to the Temperature

The daily average soil surface evaporation was plotted against the temperature at different water table depth. These relations can be shown in figures 6, 7 and 8 for coarse and fine gravel respectively. The effect of temperatures on the fine soil (low porosity) more than their effect on coarse soil (high porosity) as a total rate of evaporation. Increasing temperatures cause increase evaporation rate for coarse soil but absolutely less than evaporation rate from direct surface water. The evaporation rate for fine soil is constant (less than direct surface) with increasing in temperatures which means there is no effect of temperatures on evaporation rate. For coarse soil the spaces for water to move are large than the spaces in fine soil which lead to increase the energy for water molecules to leave the surface water and increase the evaporation rate.

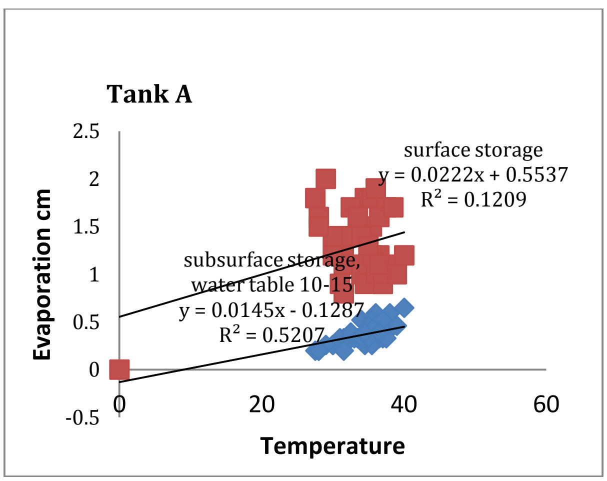

Figure (6) relation between temperature and evaporation for sample (A) at water table depth (10-15) cm and B=0

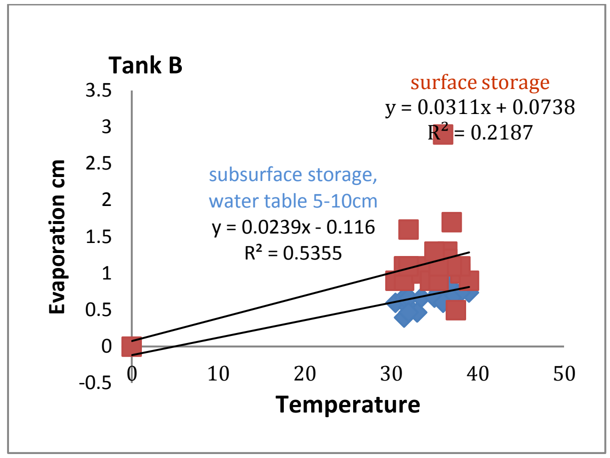

Figure (7) relation between temperature and evaporation for sample (A) at water table depth (5-10) cm and B=0

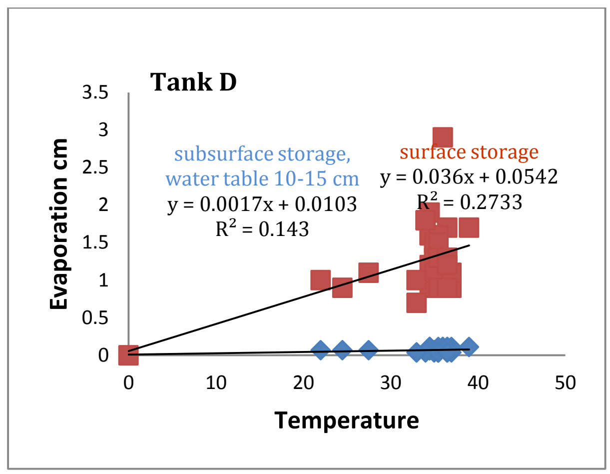

Figure (8) relation between temperature and evaporation for sample (D) at water table depth (10-15) cm and B=0, (F.G)

3. Conclusion

1. Water table depth is the most important parameter that has the effect on evaporation rate from bare soil.
2. Evaporation from coarse soil is more affected by depth of water table, and average temperature than fine soil.
3. For the sub-surface storage reservoir, evaporation decrease in fine soil with rate more than coarse soil and makes it optimal choice for water harvesting.

4. There is an exponential relation between depth of water table and evaporation ratio which is proposed in this study. Evaporation ratio is defined as a (ratio of subsurface evaporation depth to surface evaporation depth).
5. The evaporation ratio at depth of water table 10 cm is 0.53 when using gravel sample (A) with 65% porosity, 0.61 when using gravel sample (B) with 66% porosity, and 0.13 when using gravel sample (D) with 35% porosity are at 20 cm depth. The evaporation ratio is 0.15, 0.14 and 0.05 when using A, B and D sample respectively

References

[1] E. H. Hofkes and J. T. Visscher, “Artificial Groundwater Recharge for Water Supply of Medium-Size Communities in Developing Countries,” International Reference Center for Community Water Supply and Sanitation, Hague,1986

[2] Hoogmoed, Merel. 2007 Analyses of impacts of a sand storage dam on groundwater flow and storage - Groundwater flow modeling in Kitui District, Kenya, Kitui District, Kenya Master thesis Hydrogeology code 450122, 27 ECTS.

[3] J. Aerts, R. Lasage, G.C.M " Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya" ScienceDirect, Physics and Chemistry of the Earth 33 (2008) 67-73.

[4] Mansell, M.G., Hussey, S.W., 2005, An investigation of flows and losses within the alluvial sands of ephemeral river in Zimbabwe, J. Hydrology, 314, 192- 203

[5] Van Haveren, B. P. (2004). Dependable water supplies from valley alluvium in arid regions, Environmental Monitoring and Assessment, 99, 259-266.

[6] Whiting. J., and M. Pomeranets (1997), A numerical study of bank storage and its contribution to streamflow, J. Hydrol., 202(1– 4), 121–136, doi:10.1016/S0022-1694(97)00064-4

[7] Yamanaka, T., Yonetani, T., 1999. Dynamics of the evaporation zone in dry sandy soils, Journal of Hydrology 217, 135{148 amanaka, T., Takeda, A., Shimada, J., 1998. Evaporation beneath the soil surface: some observational evidences and numerical experiments. Hydro-logical Processes 12, 21932203