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ENVIRONMENTAL STUDY ON COLLECTING OF RAINWATER HARVESTING AND DETENTION POND DESIGNING TO REDUCE THE LOADS ONTO SANITARY NETWORKS

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Abstract: Rainwaters harvesting has been the vital source of water resource for drinkable and non-drinkable purposes in the ancient eras. As the water transportation systems stayed not used for water supply for these times. At present, the water distribution systems have upgraded, but the request to fresh water is increasing due to the inhabitants growing, and development. The water shortages and presented water supply for drinking are limited, which insisted the specialists working in the water division to search for solutions could be applied to the water deficiency that many countries in the world are facing. Optimization of water habit and the management of water resource will be able to aid to passing water shortage. This work contain the first designing and accumulation of rainwater from the rooftop in Baghdad City. Moreover, designing a detention pond using hydrology studio software programme to store the collected water.

Keywords: *rainwater, collection, hydrology studio, Baghdad.*

1. Introduction

Rainwater harvesting (RWH) method is a process that focus on supporting the maintainable environment improvement. Some of the environment assistances of RWH system are decrease the runoff surface, and provide the accessibility of clean water [1]. There is a great importance for hard working to improve original alternatives for freshwater producing. Beside with the reprocess of wastewater, rainwater collecting might be a smart alternate, even in particularly dry regions. The evaluation of rainwater collecting in the very dry climate of the Negev desert found that a considerable magnitude of rainwater, 2.4 cubic meters / year from a 125 square meters could be collected. Equally, runoff from minor catchments in Niger has been demonstrated to be a significant source of water [2]. In southeastern of Syria a 60-km^2 section, which gets 100 mm/year of rainfall, more than 70 % of the area is suitable for micro-catchment systems [3]. Most of the middle-eastern nations, including Iraq, are considered by arid to be a semi-arid climatic environments and have inadequate water incomes. The fresh water in these countries coming from rivers and groundwater resources that's also dependent on the rain [4, 5]. It is therefore essential to study the prospective for harvesting rainfall in Iraq as a different, renewable source of water. World's inhabitants have been continuously growing and so has the water request. Yet, sources of potable water resources are restricted and assessed to be 2% from the total existing water. Worldwide water claim has enlarged six folds between 1990 and 1995 but the population was merely doubled and the claim of the agricultural is just about 70% of the whole demand [6]. Rainwater was the main source of water supply for drinkable and non-

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drinkable usages in the old ethos since the water systems supplies were not established yet. Uses of the composed water of rainwater harvested was directly and without any treatment [7]. A study also established that lots of river and basins in the world are under the danger of submit the resident water quality values [8]. The optimum division and balanced consumptions of water sources can actually reducing the cost and a sustainable water supply improvement [11,15]. Rainwater harvesting (RWH) might be an alternate resource of water not only for the

Volume of water that can create during the rainstorms, equally because it fulfils the local popular water quality values in terms of the determined contaminant intensities) [12, 13, and 16].

In this research, a RWH system will be erected using different components and a software program will be used for designing of a detention pond as a promising solution to water shortage in Iraq due to drying season and reducing of river water discharge released from the riparian countries.

2. Constituents of a Rainfall Harvesting System:

2.1. Catchment roof

The catchment area in this study is the roof of electrical laboratory at Electrical Eng. Dep. at the college of Engineering/ Mustansiriyah University. The surface area of the roof is (200 m^2) its rectangular shape of (20 m× 10 m). The area calculated by multiplying the length by width. The roof is made of galvanic materials.

2.2. Gutters

The gutters convey the water from catchment area to the pipes and then to a storage tank. The length of gutter is 20 m and the diameter is calculated based on that each 1m^2 of roof area required 1 cm^2 of gutter in this way the diameter of the semi-circular gutter is determined by:

$$Gutter\ surface\ area\ = A = \frac{\pi}{4}D^2 \quad .... \quad (1)$$

Area of catchment roof = 200 m^2

This require 200 cm^2 cross sectional area of gutter, 200 cm^2 = $\frac{\pi}{4}D^2$ this means that D= 16 cm. The gutters supported in away so that they don’t bend or fall off when it’s full. The gutter is made of galvanic of 5 m length pieces and fixed to the right end of the roof with hinges and brackets to support them.

2.3 Pipe mesh

Fine mesh screen with opening 1.5 mm used in the top of the pipe, (inflow), between the gutters and the drainage pipe fig.(1,D).

2.4 Drain pipes

PVC drain pipes are used to convey the rain water from the gutter to the storage tank. PVC pipes used because of they easy to install, easier to replace and can persist in different weather. PVC pipes don’t affected by rust and corrosion and thus could keep the transported RW quality. To be in safe side a commercial diameter of 4 inches (102 mm) is used. Table (1) shows design guide calculations conditions for drainpipes.

Table 1. Design guide roof gutters & downpipes [12].

Roof area (m^2)	Gutter width (mm)	Min. diameter of downpipe (mm)
17	60	40
25	70	50
46	90	63
66	100	63
128	125	75
208	150	90

2.5 First flush

Diverter (WDDP20, Tank Shop Company, Australia) was used to flush the rainwater before it entering the tank. The specifications of. The whole system is shown in Figure (1, F).

2.6 Storage tank

Storing tank is the greatest costly portion of the rainwater harvesting system and might be positioned over or under the earth [11]. Storing reservoirs are fixed to for well ahead usage of water. The dimension of rainfall reservoir is verbalized by precipitation source, water response, and extent of dry incantation, the roof outward part, and aesthetic aspect, personal favorite, and financial plan [12]. The budget of rain fall reservoirs hinge on dimension, setting up. There are lots of categories of precipitation storing basins in diverse topographical regions. Stoneware reservoirs, huge pots, metallic and plastic containers. a 1500 liter tank used in the present work. The storage tank volume that needed to use to collect the falling rain from the equation below [15].

$$RWH\ potential = P.A.RC \quad .... \quad (2)$$

Where:

$RWH\ potential$ = Maximum Rate of Runoff ($l/year$), RC = Runoff Coefficient, P = total Rainfall Intensity (mm/hr.), A = roof top catchment area (m^2).

Vt-1= 0 from the previous month, *Runoff* = 3784 liters for January.

Demand = 4200 liters from table 3.

$V_T = Vt\text{-}1 + (Runoff - Demand)$

$V_T = 0 + (3784 - 4200) = -415$ liters for January

Vt_{-1}= 0 from the previous month, *Runoff* = 3784 liters for January.

Demand = 4200 liters, from table 3.

$V_T = Vt_{-1} + (Runoff - Demand)$

$V_T = 444 + (5676 - 4200) = 1920$ liters for March. And that is the greatest volume of water to be harvested**, Tables** (2, 3) show the procedures to calculate storage tank.

Table 2. Monthly catchment calculation.

Month	Monthly Rainfall (mm)	Runoff (liter)	V_t (liter)
Jan	22	3784	-416
Feb	27	4644	444
March	33	5676	1920
April	20	3440	1160
May	17	2924	-116
June	…..	…….	……..
July	…..	…..	…..
Aug	…..	…..	…..
Sept	…..	…..	…..
Oct	…..	…..	…..
Nov	14	2408	-1792
Dec	21	3612	-588

Negative sign (-) show the deficiency in storage

Table 3. Tank size calculations.

Average monthly flushing (demand)	(Assumes 5 individuals, 7 liter flushes per day/person 4 times/day) = 4200 liters
Annual rainfall for Baghdad city	150 mm
Monthly average (mm)	Jan 22, Feb 27, Mar 33, Apr 20, May 13, Nov 14 & Dec 21.
Catchment area	200 m^2
R C	86%
Rational Formula	Runoff (liters) = 0.87 × Rainfall × Roof Area e.g. Jan runoff = 0.87 ×26 × 200 = 3828 liters
Tank size to be used	2000 litter bigger than bigger V_t water (1920) litter.

2.7 Rainfall amount calculation

A typical rain gage is simply consist of a cone connected to container or a flask that the fall down rain drops dropped into the vessel or container over the funnel during the rain storms. The apparent area of the funnel is ten times the surface area of lower opening of the cone or the funnel. The intensity of the rainfall might be measured easily once the rain storm end by take the reading from the graduated container or pouring the collected water from the vessel into a graduated cylinder and reed the result. The reading representing the rain fall after multiplying by the surface area of the roof in the rain coefficient, (C), estimation equation. Runoff coefficient for every catchment is the proportion between the volumes of water run off a surface to the volume of rainfall that falls on the surface.

$$C = \frac{runoff}{rainfall} \qquad (3)$$

Where the runoff: is the water collected in the tank, the rainfall: is the Surface area of the rooftop multiplying by the death of water from rain gauge [13]. The rain gage placed near the roof of collection on a approximately the same height away from any obstacles or the rain shadow area to be able of giving a best and correct readings fit to the reading of the Iraqi station meteorology and weather. The estimation of the rainfall that is calculated from the rain gage is very important and essential in obtaining the storage tank volume that needed to use to collect the falling rain from Eq. (1).

The surface area of the Electrical laboratory roof is (200 m^2) its rectangular shape of (20 m× 10 m) the area is calculated by multiplying the length by width. The rainfall coefficient (C) could be calculated form equation (3). Table (4) show the runoff collected, rainfall intensity measurement and coefficient of discharge (C):

Take sample 1 as an example:

C = $\frac{0.843\ m^3}{4.9\ mm \times 10^{-3} \times 200\ m^2}$, C = 0.86. The average (C) is equal to (0.865).

Table 4. Rainfall collection frequencies and the coefficient of drops rain.

NO.	date	runoff m^3	rainfall mm	c
Sample 1	9/2/2019	0.843	4.9	0.86
Sample 2	18/2/2019	0.81	4.6	0.88
Sample 3	4/3/2019	4.199	24.7	0.85
Sample 4	26/3/2019	0.662	3.8	0.87
Sample 5	31/3/2019	0.5882	3.4	0.865
Sample 6	1/4/2019	0.999	13.6	0.86
Sample 7	29/4/2019	2.3392	5.7	0.87

The components of RW harvesting system are shown in Fig. (1).

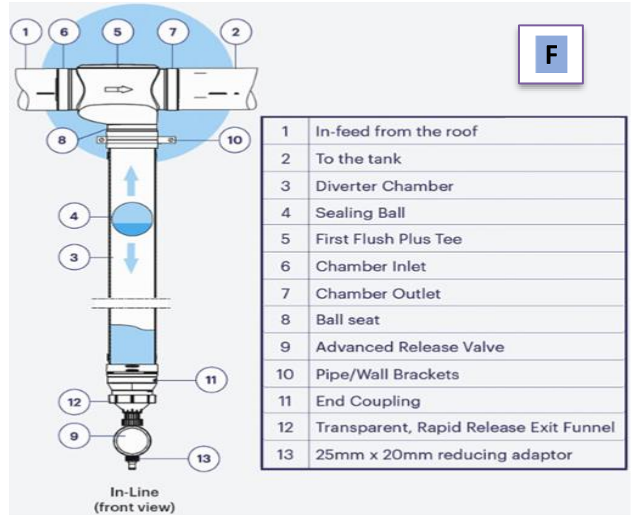

Figure 1. (A) Gutters. (B) Downspouts.(C) Storage tanks (D) Pipe mesh. (E) Downspouts and gutter. (F) First flush. (G) Rain gauge.

2.8 Detention and Retention ponds

Water storm storage facilities are often denoted to as either detention or retention facilities. Detention facilities are designed to reduce the peak flow and only delay runoff for short period of time its proposed solution to control the flooding after the rain storms. These facilities are considered to completely drain after the design storm has passed. Retention facilities are aimed to contain a long-lasting pool of water. A detention basin is an artificial flow control structure that is used to contain flood water for a limited period of a time the objective of a detention facility is to regulate the runoff from a given rainfall event and to control discharge rates to reduce the impact on downstream storm water [12].

2.9 Detention pond designing Using hydrology studio programmer

This is created on molding a pre- and post-development assignment on a ten-acre site; pre- and post- hydrographs of runoff were produced using the fitting runoff factors (C) and Times of Concentration (Tc). Below are the inputs and the subsequent basin model and steps used in designing of detention pond:

Table 5. Selecting the pre and post development hydrographs with coefficient and the area of the Pond

	Area (ac)	**10.00**
Pre-developed	Runoff Coefficient (C)	0.30
	Tc (min)	30
Post-developed	Runoff Coefficient (C)	0.85
	Tc (min)	12

Step 1. Create Pre-developed Hydrograph:

The typical Rational is constantly applied for the pre-developed since the entire needed peak Qs to utilize in the post- hydrograph. The addition icon of rational method via click on the knob **Rational Method** on the upper toolbar. Then, input the information of table 5 and click **"Compute"**. Fig. (2) Shows the inputs in rational method.

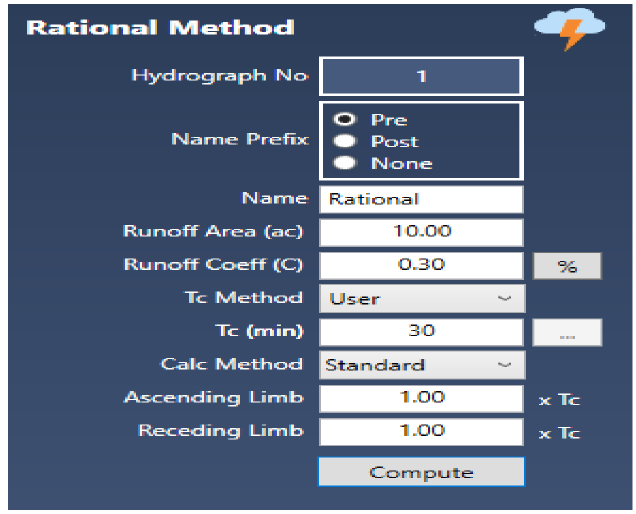

Figure 2. Pre-hydrograph estimation using rational method built-in the software.

The peak Qs are 7.080, 9.990 and 14.97 cfs meant for the 2, 10 and 100-year periods correspondingly. Those are the Aimed Qs used to construct the post-developed hydrograph in the following step. At this point is the result 100-yr hydrograph revealed on the Graphs tab however all the actually wanted are the ultimate Qs as in Fig. 3 below.

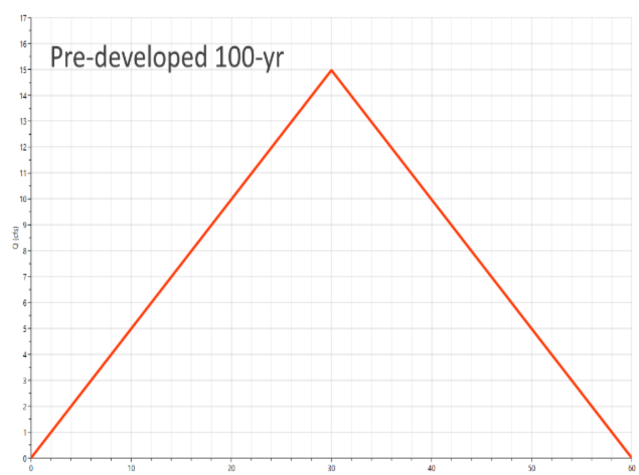

Figure 3. Pre- development 100-yr.

Step 2. Create Post-developed Hydrograph: Echoing Step 1 added another icon of rational method by click on the Rational Method switch on the top strip toolbar and adding the succeeding data. The improved method was elected to design method and input a Qs Peak from Step 1 for the Q target. Note that "Storm Duration Factors" kept unfilled, (SDF), the programme calculates these empty space once the designer click “Compute”. Fig 4 show the information of post-hydrograph.

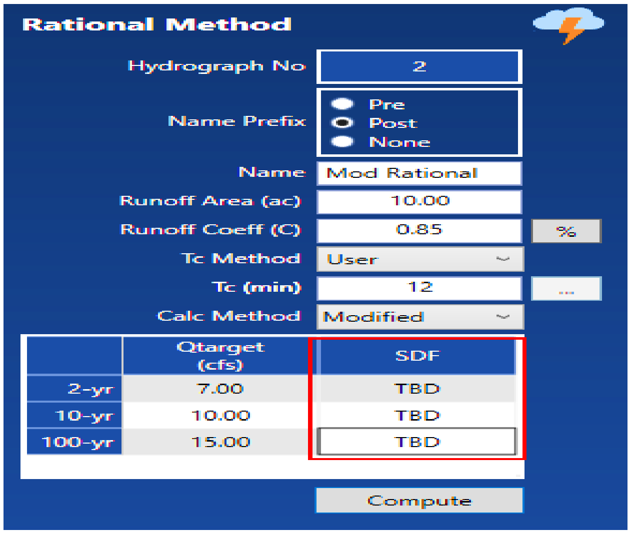

Figure 4. Post-hydrograph estimation using rational method built-in the software.

The notion from the using Modified Rational is for encountering an overall duration that is blue-shadowed section that are shown in Figs. (5, 6).
The light blue highlighting in Fig. 6 is the value above the required storage, while Table (6) shows volume estimation using rational method.

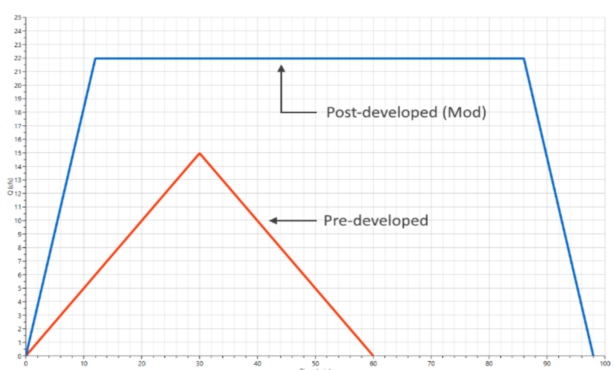

Figure 5. Pre and post hydrographs**.**

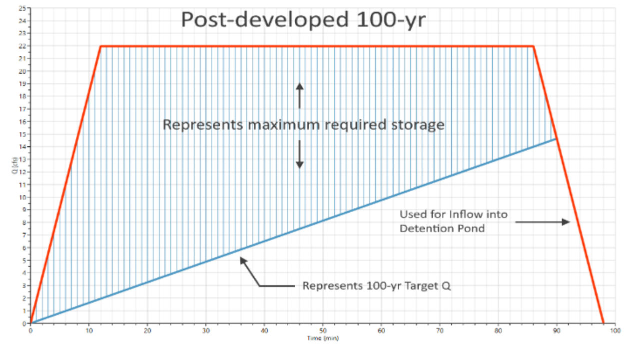

Figure 6. Pre and post hydrographs and the estimation of maximum required storage.

Table 6. Volume estimation using rational method built-in the software

	Rational - Quick Results		
Ret Pd (Yrs)	Qpk (cfs)	Tpk (hrs)	Volume (cuft)
2	7.080	0.50	12,744
10	9.990	0.50	17,982
100	14.97	0.50	26,946

Quick Results

Step 3: Project a Detention Pond:

Establishment of the pre-and post- hydrographs are completed, now design a pond with discharge amounts that equal the Pre-developed Qs. Once more, the pre-developed peak Qs are 7.080, 9.990 and 14.97 cfs meant for the 2, 10 and 100-year periods correspondingly as in table 6 above , Hydrology Studio uses a three-step procedure for easy detention pond design. Clicking on the “Pond” key on the upper of toolbar that released the Pond Frame. Here the data inputs the subsequent as showing in table 7:

Table 7. storage estimation of the pond.

Post-dev Hyd = 2 - Mod Rational - Post Mod Rational

Pre-dev Hyd = 1 - Rational - Pre Rational

	Vol Post (cuft)	Qp Post (cfs)	Q target (cfs)	Req Stor (cuft)
1-yr				
2-yr	50,125	11.23	7.08	31,858
3-yr				
5-yr				
10-yr	70,513	15.80	9.99	44,739
25-yr				
50-yr				
100-yr	113,889	21.97	14.97	69,877

Clear | Estimate Storage

Choice Hydrograph 2 to "Post-dev. Hyd" and Hydrograph 1 to "Pre-dev. Hyd" as revealed above in the pop-up list (The Q target will be full in mechanically). At that moment click "Estimate Storage". The soft-ware delivered an evaluation on pond size ought to be… 69,877 cuft. Then utilize this digit to figure out the pond table 7 affirms that.

Step 4. Generate a Detention Pond:

Tick **"Create Pond >"** to progress to subsequent stage in the planning. Via a typical Trapezoidal pond. It essential to be (8ft) in depth; 1 ft. as free-board; and has 2:1 slopes at the side. All the desired to done was catch a dimension of the lowermost bottom (L x W) that providing a whole capacity of at smallest possible 69,877 cuft of 7 ft deep. After a little attempts of a Bottom Dimensions, (L x W), (80 x 80) D. pond reached.as in Fig.7 dimensions of the pond, and trapezoidal detention pond diagram Fig. 8.below.

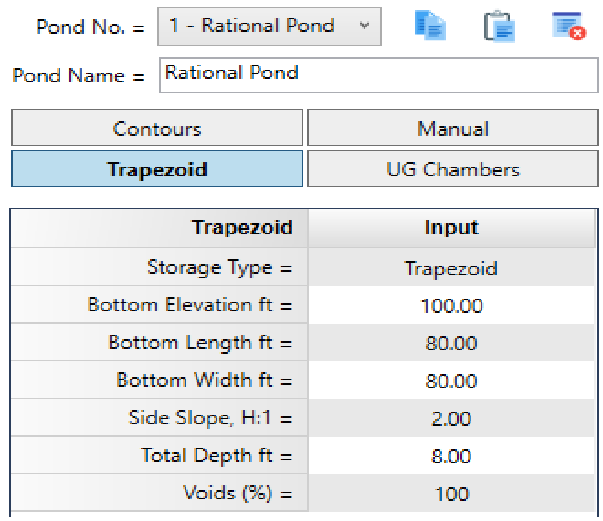

Figure 7. Trapezoidal detentions pond dimension entering.

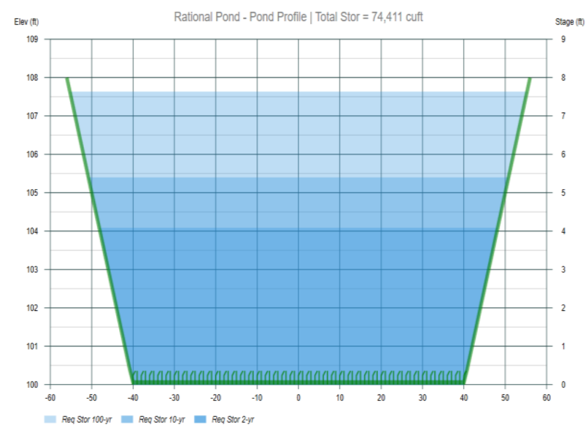

Figure 8. Trapezoidal detention pond diagram pond creation.

Step 5. Add Outlet Structures:

The requisite is to form a multi-phase exit configuration that look like Fig. 9:

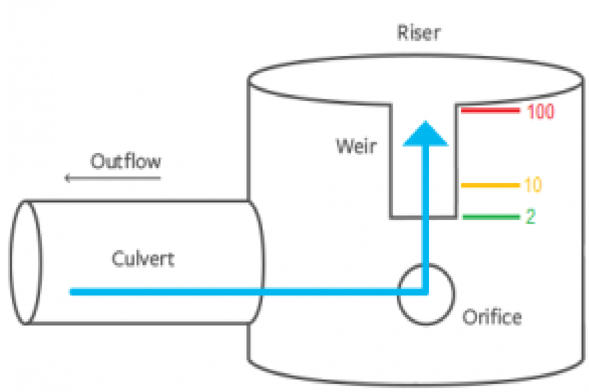

Figure 9. The outlet structures.

The Culvert required to be 50 ft. long of 0.50% gradient. The objective was to custom a 4′ x 4′ container Riser that seized a grouping of openings and weirs to fulfil target Q necessities. There is no necessary to make the Riser's upper to be utilized as weir. Also, be certain to choice the 100-yr row in the **Trial Route** table. The objective now stands to insert exit devices, one-after-one, until it's fulfilled the discharge amount supplies.

5.1 The Culvert Addition:

Head add a Culvert utilize the original scheme restrictions stated above. Just for getting anything on the monitor, choice a 12 in round culvert. At that moment click **"Add/Update"**, and then **"Trial Route"**. **Fig 10** and, Table 8 show the **culvert** adding trial route estimation.

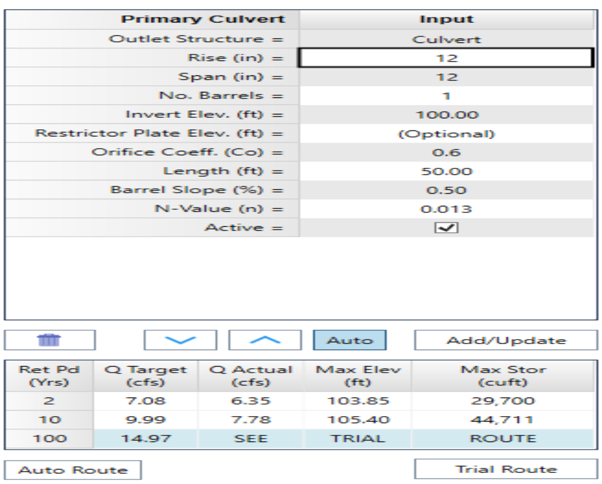

Figure 10. culvert dimensions adding.

Table 8. Culvert adding trial route estimation.

Ret Pd (Yrs)	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2	7.08	8.68	103.06	22,758
10	9.99	11.08	104.36	34,430
100	14.97	14.34	106.62	57,981

Auto Route Trial Route

As displayed above, the 100-year result unsuccessful. If clicked is be done on the **Trial Route** that will perform accurately when and where it's unsuccessful. Clearly there is required to rise the Culvert dimension increasing from 12 to a 15-in. At that moment clicking on "**Add/Update**" and **"Trial Route"** once more Table 7. The routing be successful however the Q real fell just little of the Target and it left slight free-board than the required. Settle 18-inch. Its Q Actual will surpass the target, Culvert have to be sufficient big to permit the 100-yr return period. Using further configurations to regulate the 100-yr occasion. (This is a classic consequence). If target Q can't reach the wanted Q (infrequently occurs), take subsequent size up.

5.2 Additional of the Riser:

Riser use a as container for the further configuration, so add it following. The data are equally like the follow: Set the top height so it will not contribute to outflow. The pond diagram seen like below with Culvert and Riser only Fig. 11 and Fig. 12 present the riser dimensions to be added.

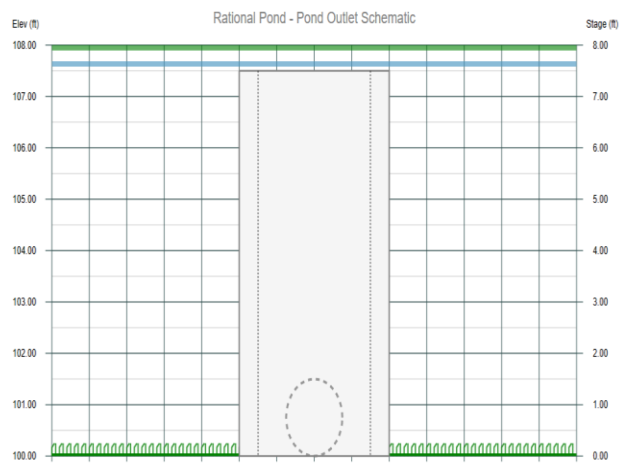

Figure 11. outlet scheme of the pond with Culvert and Riser only

Riser Structure	Input
Outlet Structure =	Riser
Riser Shape =	Box
Crest Elevation (ft) =	107.50
Crest Length (ft) =	12.00
Weir Coeff. (Cw) =	3.3
Flows through Culvert =	☑
Active =	☑

Figure 12. The Riser dimensions adding.

5.3 Added the Orifice (2-Yr):

Following construction to add the orifice, which matches to the 2-year occasion. Orifice 1is used. Identical to the Culvert, the initial guesstimate at a 12-inch as follows in Fig. 13, besides Fig. 14 shows outlet scheme of the pond with Culvert and Riser and 2-yr orifice.

Orifice 1	Input
Outlet Structure =	Orifice 1
Rise (in) =	12.00
Span (in) =	12.00
No. Barrels =	1
Invert Elev. (ft) =	100.01
Orifice Coeff. (Co) =	0.6
Flows through Culvert =	☑
Active =	☑

Figure 13. The Orifice of 2-yr addition the initial guesstimate at a 12-inch dimensions.

Now click **"Add/Update"** and **"Trial Route"**. The routing be successful then the 2-year **Q** $_{act}$ drop little of Target **Q**. basically made adjustments of the size whereas carrying out **Trial Routes** up until it met objective Q of 2-year. 14 inches the approach size.

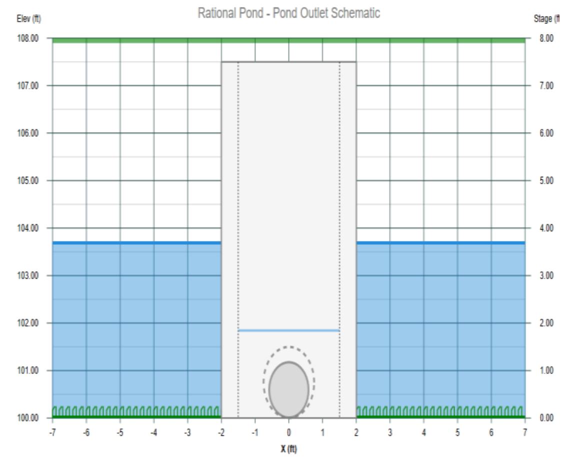

Figure 14. Outlet scheme of the pond with Culvert and Riser and 2-yr orifice.

The configuration (front view) seen identical this as below. The determined 2-year water height of 103.69 as in table 9 underneath.

Table 9. Orifice 2-yr adding trial route estimation.

Ret Pd (Yrs)	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2	7.08	7.00	103.69	28,232
10	9.99	9.98	105.00	40,686
100	14.97	13.31	107.23	65,063

Auto Route   Trial Route

5.4 Adding the Orifice (10-Yr):

Using the same procedure of orifice 2-yr to add a 10-yr orifice as in figure 15 and table 10 below.

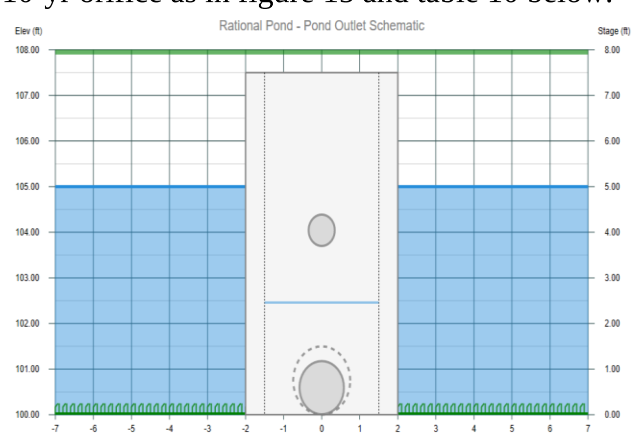

Figure 15. Outlet scheme of the pond with Culvert and Riser and 2-yr orifice and 10-yr orifice.

Table 10. The Orifice of 10-yrs addition the initial guesstimate at a 12-inch.

Ret Pd (Yrs)	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2	7.08	7.00	103.69	28,232
10	9.99	9.98	105.00	40,686
100	14.97	13.31	107.23	65,063

Auto Route Trial Route

5.5 Addition the Orifice (100-yr):

Last orifice, Orifice 3, to satisfy the 100-year. Recurring what had been prepared for the preceding orifice Fig. 16 shows that.

Orifice 3	Input
Outlet Structure =	Orifice 3
Rise (in) =	12.00
Span (in) =	12.00
No. Barrels =	1
Invert Elev. (ft) =	105.00
Orifice Coeff. (Co) =	0.6
Flows through Culvert =	☑
Active =	☑

Figure 16. The Orifice of 100-yrs addition the initial guesstimate at a 12-inch dimensions.

After that click **"Add/Update** "and **"Trial Route"**. The routing succeeded and Q $_{\textbf{Actual}}$ surpassed the Q $_{\textbf{Tar}}$. Of 15 cfs. Basically adjust the size down while carrying out **Trial Routes** until it come across 100-year target. That size is 9.25 in. the last configuration and the routing consequences as the following table 10. Fig 17 outlet scheme of the pond with Culvert and Riser and 2-yrs, 10-yrs, and 100-yrs orifices. Also table 11 the Orifice of 100-yr addition the estimate at a 12-inch.

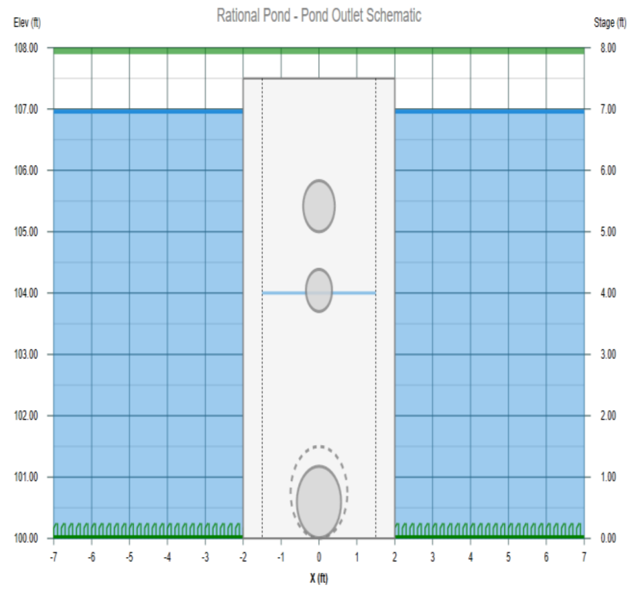

Figure 17. outlet scheme of the pond with Culvert and Riser and 2-yrs, 10-yrs, and 100-yrs orifices.

Table 11. the Orifice of 100-yr addition the estimate at a 12-inch

Ret Pd (Yrs)	Q Target (cfs)	Q Actual (cfs)	Max Elev (ft)	Max Stor (cuft)
2	7.08	7.00	103.69	28,232
10	9.99	9.98	105.00	40,686
100	14.97	14.94	106.99	62,229

3. Results and discussion

The mean annual rainfall for Baghdad city according to meteorology of Baghdad (150) mm.Rain storms that fall on Iraq in general and that fall on Baghdad in particular are varying in intensity and quantity. Rainfall records have shown that quantity of rain falls in one day is more than the mean monthly or sometime annual rainfall. It has been perceived that some of stations with a few yearly rainfall sums record precipitation was higher than that recorded by stations. Where the annual rainfall amounts more than recorded by these stations this related with the repetition of the air depressions that cause this type of rain Rainfall as their frequency, duration and depth variations in the atmosphere between year and year the total 25000 liters harvested annually. That is great reduction of the rainfall water to help collection system and big decrease in the city inundation. A recorded of the Amara City station (southern Iraq) in 1993/3/1 where 114 mm fell in one day. It was about twice the total rainfall in the same station for the year 1985 (60.1mm). A rainstorm of 67 mm (about 45% of the mean annual rainfall) in 24 hours recorded in the City of Baghdad 2012/12/25. The intensity of rainfall was (67mm) in one day .The presence of an intense rainstorm with high amount of rain in short tome causes occasional flooding. beside that and according to the confirmation from Baghdad mayoralty that in the past in the plain design of Baghdad it had been considered that 40% of the area for construction and buildings (impermeable area), the rest of the area were characterized as a green land and parks (permeable area). There were no problem if there is a heavy rain storms since there is no massive accumulation of rain water in the street most of it permeate inside of the ground and the residual goes to sewer system. Following the year (2003) and due to the absence of regulations, chaos, and the randomness in the construction of building and distribution of land as well as unlicensed rezoning and uncontrolled urbanization. Most of the rural and agricultural areas have been urbanized illegally and become non-permeable to the water.

4. Research Conclusions and Recommendations

The present research data showed that is the drowning in the city of Baghdad according to the indicators and standards of the Secretariat of Baghdad. As a result, there is infrequent heavy rainfall that exceeds monthly and annual rates a great amount of water will be soon accumulated after the rainstorms ends causing a serious problem to deal with and the collection system of the city cannot covenant with the rainfalls exceeded 17 mm/hr. so that a harvesting of these storm and store it in a pond will be an appropriate and economically suitable solution.

The intense rainstorm with in short period causes occasional flooding. beside that and according to the confirmation from Baghdad mayoralty that in the past in the plain design of Baghdad it had been considered that 40% of the area for construction and buildings (impermeable area), the rest of the area were characterized as a green land and parks (permeable area). There were no problem if there is a heavy rain storms since there is no massive accumulation of rain water in the street most of it permeate inside of the ground and the residual goes to sewer system. Following the year (2003) and due to the absence of regulations, chaos, and the randomness in the

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Conflict of interest

There are not conflicts to declare.

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