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WATER BALANCE APPROACH FOR ASSESSMENT OF DIFFERENT WATER SUPPLY CONDITIONS IN DAHUK DAM

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Abstract: The authority of Dahuk city decided to give the priority of the Dahuk Dam uses to tourism purpose since it was noticed that Dahuk Dam was not fulfilling the water requirement of its service area. Therefore, water balance calculation at the dam, its catchment and surrounding catchment area were necessary to evaluate and identify the problems. However, water balance needs long and sufficient hydrologic data. Since many data was not available at those regions, generating hydrologic data over a long period and filling the missing data were necessary. Then 24 scenarios with different water supply conditions were simulated. It was found that the dam was unable to support water demand for irrigation together with domestic and tourism due to water level requirement. Then, by supplying water from Khabour River and cancelling the irrigation project, the water level of the reservoir was enhanced, as shown on Scenario-10. In addition, it was identified that Khabour water contribution should be priority of the program to survive the reservoir's goals in case of integrated water resource management at the Dam.

Keywords: *Water demand; water balance; reservoir management; dahuk dam*

1.0 Introduction

The Dam is located approximately 450 km far from Baghdad in Kurdistan Region - Iraq. The lower Dahuk River is regulated by Dahuk Dam 2 km in the north of Dahuk city. It was constructed mainly to supply water to irrigate 4600 Ha of the agriculture area. The dam and catchment's Characteristics are provided in Table 1.

The Lake of Dahuk Dam is one of the main sources of drinking since 1993. The problem of Dahuk Dam's Reservoir (DDR) is the impossibility of getting the needed amount of water to cover the need of Dahuk city, and continue to maintain aesthetic area for touristic purposes; due to the decrease in rainfall, and the constant expansion in the area of the city. Therefore, another solution by using water balance analysis should be considered.

Table 1: Dahuk Dam and Reservoir characteristics (GDID)

Characteristic	Volume
Full supply level	615.75 masl
Wall height	619.73 masl
Full supply storage capacity	52 MCM
Surface area at full supply	2.560 Million km^2
Crest length	740 m
Reservoir catchment area	135 km^2
Spillway type	Bell-Mouth
Spillway capacity	81 m^3/ sec
Life storage	47.51 MCM
Dead storage	4.39 MCM

Note: MCM is million cubic meter
masl is Meters above sea level

The climate of this location is similar to the climate of Mediterranean and partly the climate of Iranian region (Anderson *et al*., 2008). Mainly rainstorms occur from 15-October to 15-May while other times of the year are dry, the amplitude varies between winter and summer temperatures while they are high. The annual mean temperature is 19.5 C (Shawkat, 2007). However, most of hydrologic data at periods 1986-2001 was lost due to civil war. An additional note is the quality of water, soil degradation problems of its natural resources and its effects on living conditions of the settled villages in the area will not be considered in research.

To achieve this alternative solution for solving the water management, the following objectives are targeted:

- To generate sufficient hydrologic data for the Dahuk Dam.
- To identify the exemplary water balance for water supply scheme in the Dahuk Dam.
- To select adequate program for the integrated water resource management at the Dahuk dam system.

2.0 The Water Balance Concept

Increase population, Climate change, and degradation of water due to agricultural and industrial pollution have seriously added to water scarcity (Shiklomanov & Rodda, 2003; Hassan and Harun, 2012). The Commission's World on Dams endorsed this point of view, specifically in relation with dams. In its final report, the Commission emphasized the need for decision-making process on dams to be linked with larger questions pertaining the sustainability of water and energy development (WCD, 2000). To keep reservoirs function properly, integrated managements are necessary such as managing the demands, minimising the losses, and finding another source. For these purposes, recalculations of water balance inside and around the area are required. Water balance may also be used for evaluating the current and future status of the dam since the climate pattern is taken into consideration (Wurbs, 1987).

3.0 Research methodology

The research is carried out in different major steps. The descriptions are shown in Fig.1.

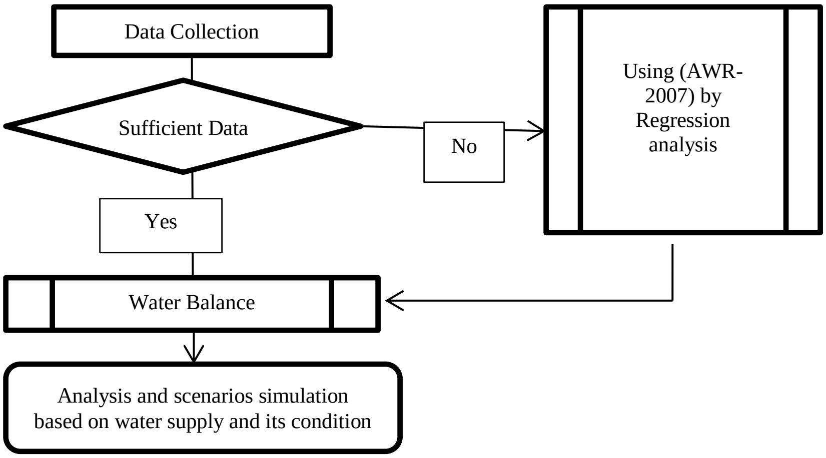


Figure 1: Flow chart of research

3.1 Data Collection

Rainfalls are the only main way that drives water in to the Dam reservoir. The precipitation was estimated by gauge of precipitation. As far as the DDR is concerned, longer era records of temperature and precipitation does not exist (<30 years), but the data collection relevant to hydro-climatically can be elected for a near term. Unfortunately, data are available only for periods from (2001-2012) from General Directorate for Irrigation and Dam (GDID), therefore rainfall data from the Aphrodite's Water Resources (AWR-2007) was employed to generate data from 1986 to 2000, after confirming the reasonability AWR-2007 data at 2001-2007 periods.

3.2 Evaluation of Water Balance in the Dahuk Dam

Precision method for calculating water balance that developed by researcher (Ji *et al*., 2007) will be considered for the evaluation, and then the water balance in the dam is calculated by the following simple formula (Eq.1).

$$\Delta S = \Delta Oi + \Delta Ii \quad (1)$$

Where,

ΔIi : discharge inflow in i period

$\Delta \mathrm{S}$: water reservoir volume in i period

ΔOi : outflow from the dam in i period

3.3 Identify the River Flow from nearby Watershed

According to the hydrological system, the best area to get additional water for DDR is Khabour River's catchment area (KRC). Where KRC at north of Dahuk Dam Catchments (DDC), some of its parts have high elevation of area and larger percentage and tends for significant and huge precipitation, maintains its soil moisture and going to lasting flows. Hydrologic data of KRC depend to two main resources, GDID and AWR-2007.

To fill the missing rainfall data, six stations were recorded data of monthly precipitation from year 2001 to 2012 and controlled by GDID. The stations are: Dahuk Dam, Zakho Batufa, Kani Mase, Duski, Bamarni and Sarsink station (Figure 2) and from 1986-2000 can be added by depending on AWR-2007. According to AWR-2007, there are five points for precipitation measurement around DDC areas.

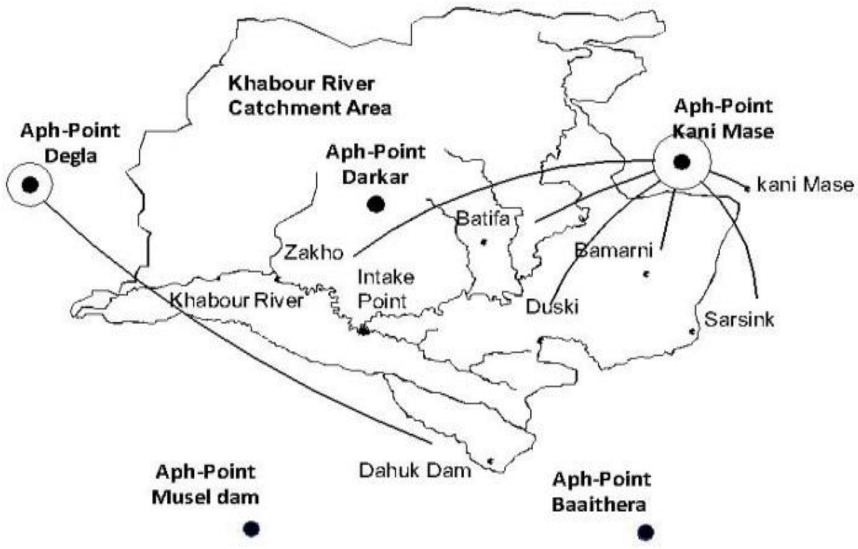


Figure 2: Location of precipitation points according AWR-2007 and GDID

The monthly discharge in Khabour River for long period will create by converting rainfall information in KRC to river discharge by using multiple regression analysis involving seasonal condition, monthly temperature, and irrigation scheme since the discharge data of KRC are only at period 1986–1989 (Saleh, 2010), as shown in Table 2.

Table 2: Monthly discharge at stream flow-gaging station IRQ_T2, Khabour River at Zakho, water years 1986–1989 (Saleh, 2010).

Water year	Monthly Discharge (MCM)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1986	25.7	54.4	65	67.4	66.4	36.8	17	14.5	15.2	18.4	16	17.6
1987	32.4	49.4	122.1	193.8	255.7	147.7	36.4	17.8	15.8	16.3	25.8	33.5
1988	145.1	112.4	246	323.1	337.6	171.5	72.3	32.7	23.6	18	28.1	125.5
1989	23.5	20.6	32.8	53.7	59.1	26.6	32.2	23.4	10.3	21.6	19.7	27.7

3.4 Scenarios Setting and Analysis Method

The essential goal of this analysis is to get as much surface water as possible into the reservoir not less than 614 masl, and to supply water for drinking. There are four parameters in each scenario, having different case in each phase, as listed below:

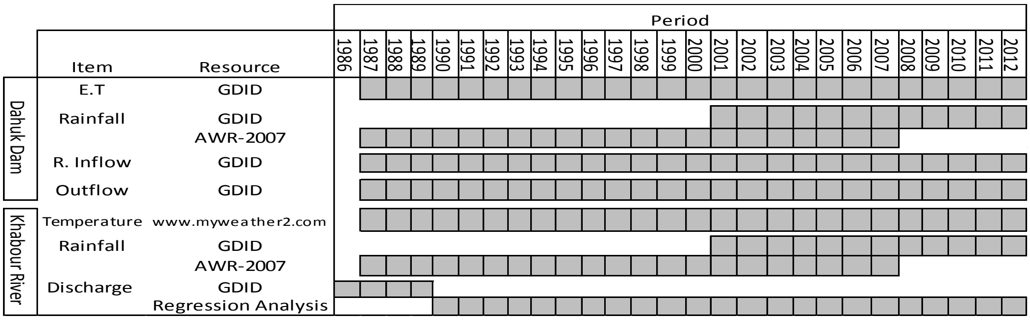
- For irrigation; the land area is considered be 78.75 hectare (GDID) which requires 40 cm of irrigation water during 150 days of irrigation and using pipe to transport the water to the land,
- For drinking purposes; water needs to be supplied to (100000-300000) people (GDID), the amount of water consumed by each person in the Middle East is 280 L/day (UN-Water Annual Report 2012).
- For infiltration; this depends on three situations, first, if there is no infiltration due to the water in the reservoir being directly opposite to the ground water, the second case uses 0.25 mm/day (for clay soil), and the third case uses 0.5 mm/days in worst case.
- Supply water from Khabour River, about 30% of its low flow.

4.0 Results and Discussion

4.1 Data Generation

Data collection don according to Table 3. When the data of rainfall for two catchments are prepared from 1986 to 2012 and will be consider for calculating the discharge from watershed and reservoir.

Table 3: Construction of data collection



4.2 Reservoir Storage and Water Level

The relationship between the reservoir storage in the Dahuk Dam and the level of the water is given through the level-storage capacity curve. The maximum water storage of the dam was 52.5 MCM and about 615.75 masl, as the spillway elevation giving an inundated area of 2.55 km^2. By using the polynomial regressions between the water elevation in Dahuk Dam and the volume, the formula relationship as the best possible relation was determined, as presented on Eq.2.

$$y = 25655.22959\, x^2 - 29422802\, x + 8437782777 \quad (2)$$

Where,
y is dependent variable (Volume)
x is independent variable (Elevation).

4.3 Rainfall in DDC area

Approximate rainfall data of AWR-2007 in Dahuk Dam station was Point Degla the coefficient of determination (R^2) is equal to 71.25% and the linear relation is (y = 1.284x). The result of annual rainfall is presented in Figure 4. Seasonal pattern and of dry seasons sequence, between years 1998 to 2011 can be shown in Figure 3, which has a huge effect of inflow amount in reservoir and capacity of outflow.

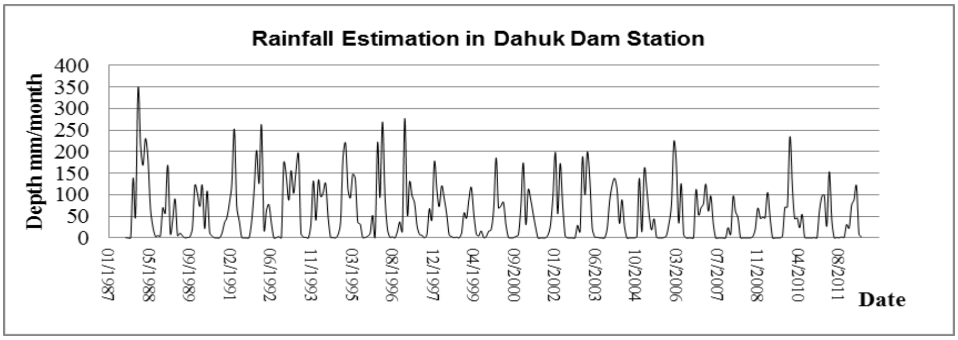


Figure 3: Amount of Rainfall in Dahuk Dam Station from1987 to 2012

4.4 Annual Inflow

The maximum inflow was recorded in 31/12/1991 equal to 9.818 MCM per month and the minimum was 0.0162 MCM per month in 30/09/1998. The highest point of inflow in the record was from 1991 to 1992. The sequence of dry seasons, between years 1998 to 2011 is one of the strongest periods for DDR as dry seasons of these years were recorded the second lowest after those were between 2007 to 2010. The inflow data for each year in the Dahuk Dam are shown in Figure 4.

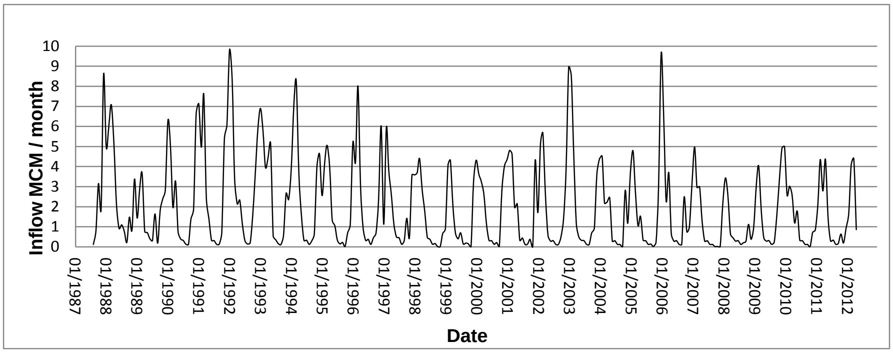


Figure 4: Annual Inflow to Dahuk Dam Reservoir

4.5 Outflows from the Reservoir

The outflows from the reservoir are consist of withdraw, evaporation, and flow from the spilway (overflow). The water volume outflow from DDR was calculated depending on discharge volume which was reading by a mechanical meter. From periods 1987 to 2012, outflow volume ranged from a maximum of 35.26 MCM/Year in 31/12/1993 to a minimum of 10.62 MCM/year in 31/12/2010, as shown in Figure 5. The amount of evaporation from the reservoir was equal to 61.12 MCM, which was about 10.44 % of the total outflows. Then evaporation was accounted as a significant water loss volumes from the reservoir. While, overflows occur only from 05/04/1994 to 31/05/1994 and from 27/03/1995 to 12/04/, or just in 42 days during 25 years (Fig. 6)

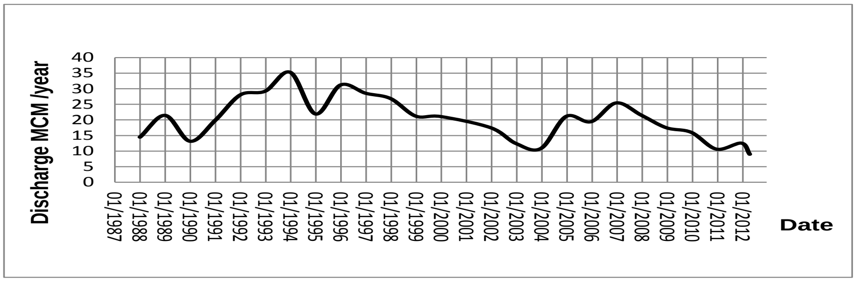


Figure 5: Annual Withdrawals from Dahuk Dam Reservoir

4.6 Analysis of Water Balance

Starting from July 1987 through May 2012 the monthly values added to each over these 298 months, water gains and losses were computed as shown in Table 4 and Depending on the size of life storage (47.51×10^6 m^3) the ratio of final residual storage is 43.34%.

Table 4: The Refined Reservoir Water Balance of The Dahuk Dam

Source	Volume (MCM)
inflow from stream	601.24
inflow from spring water	4.81
Total Inflows	606.05
Evaporation	61.12
Discharge	524.34
Total Discharge(outflow)	585.46
Residual Storage	20.59

4.7 Tourism's Surface Water Level and Reservoir Operations

Only in periods between 1991 to 1995 and 2002 to 2004, the reservoir achieved elevation more than 614 masl (Figure 6).

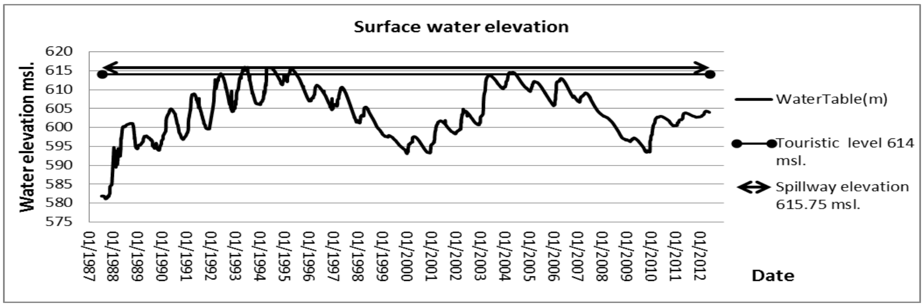


Figure 6: Times of the reservoir surface elevation that exceeded level of touristic

4.8 Precipitation in Khabour Catchment Area

Based on Thiessen polygon network to calculate station weights, shown in Table 5, the areal average precipitation in KRC computed by multiplied the individual weights with the station observation as shown in Figure 7 and the result shown in Figure 8.

Table 5: Contributing areas

Contributing Area for each station		
Rainfall Stations	Ratio %	Area km^2
Zahko	25.53	893.640
Batufa	46.11	1613.685
Duski	9.90	346.468
Dahuk Dam	2.46	86.233
Bamarni	11.73	410.548
Sarsink	2.54	88.873
Kani Mase	1.73	60.555

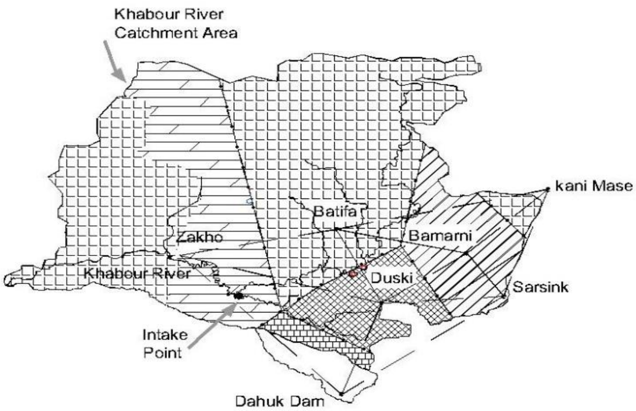


Figure 7: Thiessen polygon network in Khabour Catchment Area

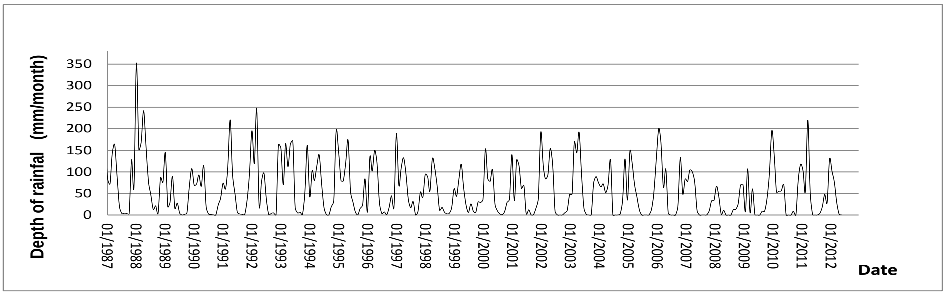


Figure 8**:** Amount of Precipitation in Khabour Catchment Area

4.9 Khabour River Discharge

Through using the multiple regression of non parametrik models to determine the quantity of discharge from year 1991 to 2012 at Zakho station, were result or the formula found in this regression are presented on Eq.3, with the value of R^2 is (0.60) and probability distribution is (3.28×10^{-05}). Outflow for one year for example is shown in Table 6.

$$Y = -0.19X_1 + 23.58X_2 + 36.85X_3 + 1.27X_4 - 14.92X_5 - 40 \quad (3)$$

Where: X_1 = rainfall, X_2 = season (1 - 4), X_3 = snow (0 - 2), X_4 = temperature, and X_5 = irrigation (0 or 1)

Table 6: Sample of result the regression analysis for daily discharge of Khabour River in Zakho station

Date	X1 Rainfall (mm)	X2 Climate	X3 Snow	X4 Tep.	X5 Irrigation	Depth (mm)	Estimation (mm)	Discharge (m3/sec)	Discharge (MCM/day)
31/10/1986	88.3	2	0	30	1	13.6	13.7	18.5	1.60
30/11/1986	192.1	2	0	25	0	11.8	2.6	3.5	0.30
31/12/1986	97.1	3	1	15	0	13.0	68.3	92.2	7.97
31/1/1987	82.1	3	1	5	0	19.0	58.4	78.9	6.82
28/2/1987	161.9	3	1	5	0	40.3	43.3	58.5	5.05
31/3/1987	186.8	3	2	25	0	48.1	100.9	136.2	11.77
30/4/1987	105.0	4	2	30	0	49.9	146.3	197.6	17.07
31/5/1987	22.0	4	2	35	0	49.2	168.4	227.4	19.65
30/6/1987	4.1	1	2	40	1	27.3	92.5	124.9	10.79
31/7/1987	4.6	1	0	45	1	12.6	25.0	33.8	2.92
31/8/1987	4.0	1	0	45	1	10.7	25.1	34.0	2.93
30/9/1987	3.0	1	0	35	1	11.3	12.6	17.0	1.47
31/10/1987	146.2	2	0	30	1	12.1	2.7	3.7	0.32

The discharge in Khabour River-Zakho Station in the periods from 1986 to 2012 is calculated (Figure 9). In general, the maximum flow was 19.9 MCM/day in May 2008 and the minimum flow was 0.3 MCM/day in November 1986. The annual pattern of stream flow shows that the highest point of discharge in the river is always between March to June and the low flow occurs from September to November.

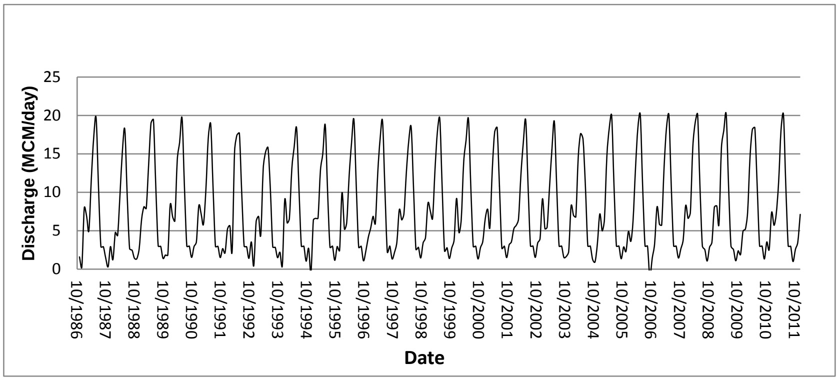


Figure 9: Estimated Discharge in Khabour River –Intake Point

4.10 Scenario Analysis

It will be the best program if it has a minimum time recorded for: level less than 614 masl, level more than 615.75 masl, and period of drinking water fail. After the analysis all 24 scenarios according to vary programs, the result for each one will be presented in Table 7. In Scenario-5 there is no time recorded for water elevation less than 614 masl and minimum time recorded for levels more than 615.75 masl at conditions of no irrigation and water for drinking purposes. But comparing with Scenario-6 that have the same conditions, maximum out flow in Scenario-5 less than maximum out flow at Scenario-6, is effected by inflow size from Khabour River that is not stored in the reservoir.

In Scenario-6, the total quantity of inflow from Khabour River is equal to 91.07 MCM and total outflow is 638.9 MCM. This means that the inflow from Khabour River is only 14.25% from the total outflow, so it not necessary to take water from outer sources and in the case of not exploiting water for irrigation or drinking, the reservoir watershed has the self-efficiency.

While, having the condition to supply water for irrigation and drinking at same time of achieving the priority goal, the Scenario-22 have the minimum recorded time for phase water surface level which is less than 614 masl and more than 615.75 masl, and comparing with Scenario-21 and 20, also the capability in Scenario-22 to supply water for drinking and irrigation is higher than Scenario-21 and it is close to Scenario-20 if the infiltration situation is not considered. However, Scenarois-10 as shown in Figure 10 with the condition to supply drinking water as a second prior point and keeping surface water level at 614 masl. it records minimum time at phase level less than 614 masl and more than 615.75 masl and the failure time to supply water for drinking purpose is only 4 times or the ratio of failure is 1.56% by supporting continuous inflow from Khabour River. After year 2007, water surface was fall dawn because of increasing amount of consumption water. In addition, the amount of water supply from Khabour River should be increased gradually with the increase number of population or amount of consumption water must be fixed in constant level. The Scenario-10 will be considered as a main program for dam balance with availability maximum water supply from Khabour River.

Table 7: Scenarios Analysis and Simulation Result

Scenarios	Irrigation (m3/day)	Drinking (L/day/Persons)	Infeltration (mm/day)	Khabour inflow (m3/day)	level less than 614 m	level more than 615.75 m	Min level (m)	Max out flow (MCM/month)	Min out flow (MCM/month)	Drinking water No.fail	Irrigation water No.fail
1	0	0	0	0	0	279	615.75	9.80	0.0016	255	0
2	0	0	0	10000	0	279	615.75	10.13	0.3016	255	0
3	0	0	0.25	0	0	270	615.75	9.79	0.0000	255.00	0.00
4	0	0	0.25	10000	0	279	615.75	10.12	0.2850	255	0
5	0	0	0.5	0	0	268	615.73	9.77	0.0000	255	0
6	0	0	0.5	10000	0	279	615.75	10.10	0.2684	255	0
7	0	280	0	0	183	57	579.04	8.36	0.0000	16	0
8	0	280	0	10000	133	76	580.68	8.69	0.0000	4	0
9	0	280	0.25	0	184	57	578.64	8.34	0.0000	17	0
10	0	280	0.25	10000	138	75	578.30	8.67	0.0000	4	0
11	0	280	0.5	0	186	56	577.52	8.32	0.0000	17	0
12	0	280	0.5	10000	140	75	579.98	8.65	0.0000	4	0
13	50000	0	0	0	77	128	612.49	9.80	0.0000	255	0
14	50000	0	0	10000	37	143	613.25	10.13	0.0000	255	0
15	50000	0	0.25	0	79	128	612.45	9.79	0.0000	255	0
16	50000	0	0.25	10000	40	143	613.21	10.12	0.0000	255	0
17	50000	0	0.5	0	82	127	612.40	9.77	0.0000	255	0
18	50000	0	0.5	10000	41	143	613.17	10.10	0.0000	255	0
19	50000	280	0	0	225	42	577.34	7.12	0.0000	47	31
20	50000	280	0	10000	214	48	578.71	7.45	0.0000	26	23
21	50000	280	0.25	0	226	42	575.92	7.11	0.0000	47	32
22	50000	280	0.25	10000	214	47	578.79	7.44	0.0000	26	24
23	50000	280	0.5	0	226	42	576.87	7.09	0.0000	47	33
24	50000	280	0.5	10000	214	47	578.80	7.42	0.0000	28	22

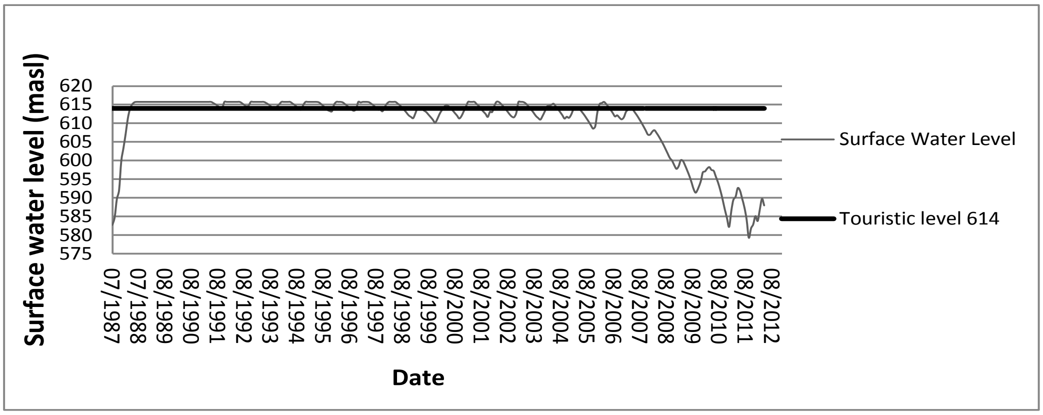


Figure 10: Surface of water in Dahuk Reservoir according to Scenario-10

5.0 Conclusions

The main objective of this research was to assess the sustainability of water resources of Dahuk city as well as the reservoir of Dahuk dam. The evaluation of the offered research is divided into three sections:

- Hydrologic data was generated by depending on the GDID and AWR-2007. Regression analysis was employed to verify and determine the strength of the relationship between GDID and AWR-2007.
- Analysis of water balance in the Dahuk Reservoir shows that there is fluctuation in the water level in the reservoir due to unbalancing of water between inflow and outflow. It was found almost the time the water level is lower than appropriate level. Because of this reason, DDR is not suitable for touristic purposes. In order to solve this issue, Khabour River can be used as the alternative potential source of water to Dahuk Reservoir
- Considering the different cases based on the 24 scenarios used in the study, it has been shown that the Dahuk dam is unable to meet with the needs of water for irrigation and domestic use simultaneously with touristic purpose. However, the Scenario-10 should be considered as adequate and the priority of our program since it has better success condition for domestic use, touristic purpose with minimum supply water from Khabour River.

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