Utilization of Surface Water as a Source for Groundwater Artificial Recharge at Wadi Za'tari Catchment Area, Jordan

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ABSTRACT

This study aims towards utilizing the surface water of Wadi Za'tari at the western part of Dhuleil basin for the artificial recharge of groundwater. The importance of this study is that the basin is suffering from groundwater depletion and increasing salinity. The increasing demand for water to cover the agricultural and municipal needs will accelerate this problem in the near future. The fractured limestones and basalts would help the water to infiltrate naturally; the available materials in the field would help to construct low cost recharge dam. To avoid the sedimentation problems and increase the recharge rates, it is recommended to construct the recharge dam on many phases. The Soil Conservation Service (SCS) method was used to calculate the flood volumes. The results showed that the runoff and evaporation coefficients are 2.81 and 94.84 percent, respectively. This means that most of the surface water evaporates into the atmosphere. The peak discharge of the hydrographs for the years 10, 25, 50 and 100 years is 2394, 5996, 10213 and 13582 m^3/s, respectively. The elevation area-capacity curves show that the reservoir is capable to accommodate about 5.4 MCM for an area of about 1.63 km^2 and 10 m depth. However, if the water depth increases to 15 m, the reservoir can accommodate about 18.8 MCM for an area of about 3.75 km^2. The development of groundwater quality after mixing with floods is assured. The average electrical conductivity (EC) of floods is 240 μS/cm, while it reaches 4310 μS/cm for groundwater. The development of groundwater quality is assured as soon as mixing ratio with floods is increased.

Keywords: Wadi, surface water, artificial recharge, groundwater, curve number, drainage.

1. INTRODUCTION

Wadi Za'tari catchment area is located at the western part of Dhuleil basin between the coordinates 260-295 East and 175-205 North and covers an area of about 403 km^2. The topography of the wadi ranges from 600 m above the mean sea level (amsl) in the south to more than 1350 m in the east and northeast. The wadi shows triangular shape, while the drainage is dendrite type system (Fig. 1). The cyclones which cross Mediterranean sea bring cold air masses from Europe and form the major precipitation in Jordan. These cyclones are responsible for thunderstorm rainfalls, which characterized by irregularity in intensity and duration. The convective is oriented along the major axis of eastern Mediterranean and extends eastward into Iraq and is triggered by temperature contrasts between the relatively warm sea and cold land surfaces to the north. This makes unstable columns depend upon the laps rates and moisture flux convinces in the lower layers (Brenner, 1990). The annual average rainfall ranges from 130 mm in the eastern part to more than 300 mm in the northern and northeastern part, with an average rainfall of about 160 mm in the central part of the basin.

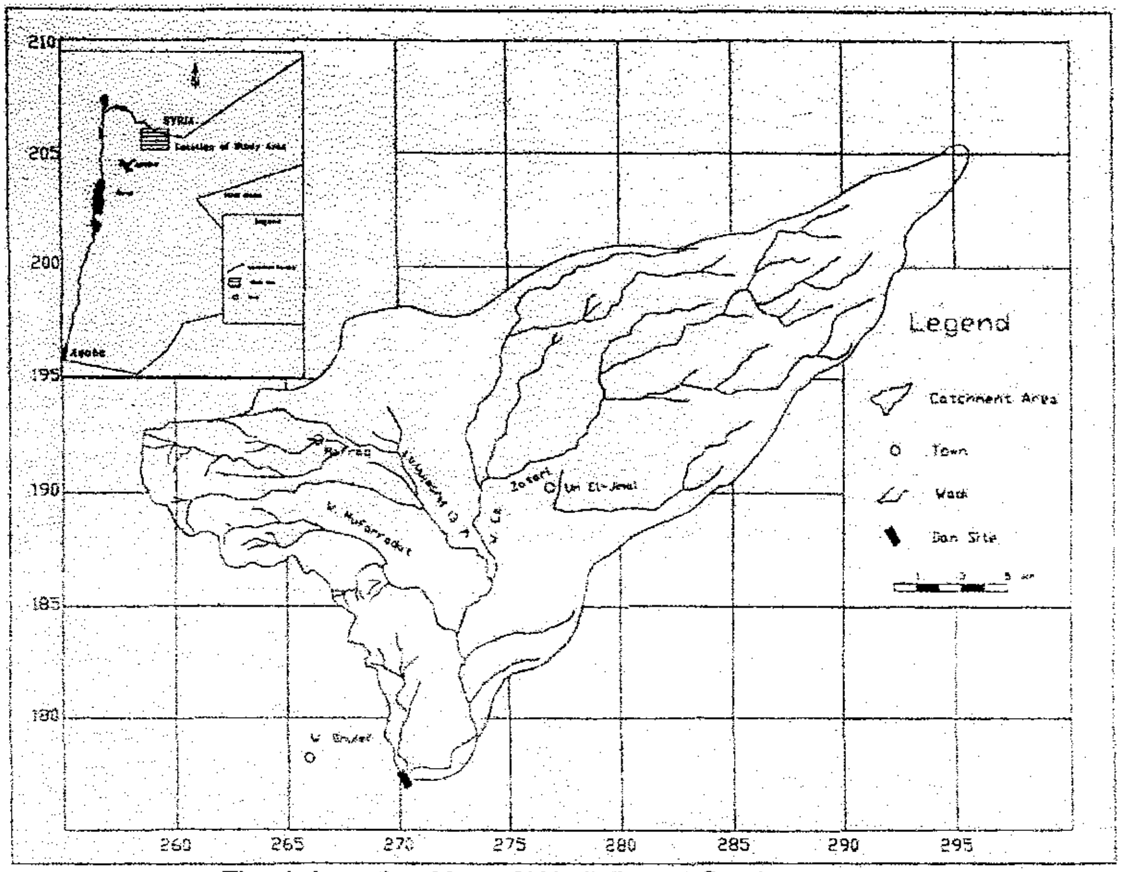

Fig. 1. Location Map of Wadi Za'tari Catchment Area.

The Dhuleil basin has been subjected to groundwater exploitation through six wells in the mid sixties to more than 100 wells recently. The upper aquifer complex, which is the most important aquifer in the area, is composed of three members: Basalt, Amman (B_2) and Wadi Es-Sir (A_7). The basalt is highly porous and scoriaceous reservoir (Bender, 1974). The Amman formation underlies the basalt directly and considered as a good aquifer in the study area. The Wadi Es-Sir formation consists of limestone, marl and chert and it is productive when it has fissures (Rimawi, 1985). The aquifer balance is disturbed with a major decline in the water level accompanied by deterioration in groundwater quality, due to the groundwater overpumping and the intensive irrigated agriculture (Water Authority, 1989). The groundwater flow direction is from northeast to west (Salameh, 1993).

In early sixties, the type of groundwater in the study area was classified to be suitable for all purposes such as domestic, agriculture and industry (Salameh, 1996). But due to the overexploitation of the groundwater and the intensive irrigated agricultural activities, groundwater quality became poor and deteriorated for many purposes. The average groundwater electrical conductivity (EC) increased from about 570 μS/cm in 1971 to more than 4300 μS/cm resecntly . The problem is accelerated due to low recharge amounts comparative with discharge from the aquifers.

In average, the groundwater salinity has become unsuitable for both domestic and/or irrigation, in some areas. Besides, chloride concentration and hardness of water reached limits, which exceeded Jordan standards for domestic water quality. This was due to groundwater overpumping from the main aquifer (Basalt and B_2/A_7) to meet the agricultural demand.

2. Objectives

The main objectives of this study were to investigate the feasibility of the collection and utilization of surface water for the artificial recharge of groundwater for the Upper Aquifer System in Wadi Za'tari Catchment Area. The surface water is considered the most important source for the development of the area; especially when the flood volumes are very high and remains several months before evaporation. This technique will help in avoiding the salt water problems that Dhuleil basin is suffering. To achieve these issues, the following approaches were used:

1. Collect and analyse the rainfall data.
2. Estimate the water budget of the catchment area.
3. Determine the dam sites by studying the topographic and aerial photo maps.
4. Determine the water volume stored by making engineering hydrology survey.
5. Predict of flood volumes by using flow duration curves according to different return periods.
6. Study the subsurface geology to assure that the recharge to the groundwater will increase.

3. Hydrogeology

The groundwater movement is controlled by the hydraulic gradient. The hydrogeological system consists of two main aquifers in Dhuleil basin. The upper aquifer is composed of three members:

1. Basalt: This aquifer represents the main aquifer in Dhuleil, even to the northeast of the study area. The basalt is a potential aquifer where water bearing zone comprises of highly porous and scoriaceous reservoir.
2. Amman Aquifer System (B_2): It underlies the basalt aquifer directly, and classified as a good aquifer. It is composed of limestone, chalk, chert and phosphorite.
3. Wadi Es-Sir Aquifer System (A_7): This aquifer consists of limestone, dolomitic limestone, marl and chert. Also, it could be classified as a good aquifer.

The hydraulic connection between the three aquifers (Basalts, Amman and Wadi Es-Sir) classifies them as one hydraulic unit. Most of the wells penetrated this aquifer, due to the low cost of drilling and good water quality, before the agricultural expansion in the early sixties.

The lower aquifer is composed of poorly consolidated multicolored sandstones of Lower Cretaceous age intercalated with thin beds of shales and clays. It is separated from the upper aquifer by low permeable marls and limestones. Fig. 2 shows the hydrogeological cross section through the study area.

Groundwater flows from the high pressure head at Jebel El-Arab area to the low pressure at the well field area. The depth to water table varies from 20 m in the west to 106 m in the northeast. The elevation of water table ranges from 505 m to 545 m above the mean sea level (amsl) at the southwest. The recharge sources are the direct infiltration of rainfall, infiltration of floodwaters, return flow from irrigation water and the groundwater flow into the basin from Jebel El-Arab area.

Groundwater quality at Dhuleil basin has deteriorated within one decade of intensive use for irrigation purposes. Chemical analysis showed extremely high concentration trends of salts exceeding the acceptable limits for the various purposes according to the water quality standards. The overpumping of groundwater resources, return flow of irrigation and infiltration of wastewater into groundwater are the main sources for the salination problem. Grounis the only available water source for domestic and agricultural activities in the area; therefore, it is abstracted heavily to meet the need for expansion in the agricultural lands. The drawdown in the groundwater observation wells reached about 30 m (Al-Mahamid, 1998).

4. Soils

The soil in the study area is divided into four types, according to the agricultural land use (Mac Donald, 1965):

(a) Nomadic grazing by sheep, goats, camels and occasionally cattle.

(b) Grazing combined with some shifting to cultivation by nomads.
(c) Rainfed farming (dry farming) with winter cereals such as wheat and barely.
(d) Irrigated farming composed of slowly permeable layers affecting internal drainage and limiting the effective soil depth.

The excessive use of the chemical fertilizers in the soil, which added to improve its fertility and to increase crop yield, contributes to the deterioration of the groundwater quality. Therefore, a major increase in cations and anions was occurred. Most of the wells shifted from fresh water to brackish water.

5. Flood and Recharge Evaluations

This study is carried out to estimate the flows and frequency floods at Wadi Za'tari Catchment Area in Dhuleil basin, and determine the surface water potential by suggesting feasible engineering solution. For lack of flood observations, the frequency floods were determined using storm rainfall of 10, 25, 50 and 100 year return periods in the Soil Conservation Surface Method (Wanielista, 1990).

The available daily rainfall data of the rainfall stations at Mafraq, Um el-Jimal and Wadi Dhuleil were used in this study to determine the storms runoff during the period 1975 to1999. Thiessen Polygon method was applied to estimate the areal rainfall, this method assumes that the point rainfall at the station is representing the areal rainfall in its polygon (Fig. 3).

The SCS Method was used while it takes into consideration the antecedent moisture conditions, initial abstraction of rainfall and land use, the general formulas of this method are:

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)} \qquad \text{...1}$$

where Q is the accumulated depth of runoff (inches), P is the accumulated depth of storm rainfall (inches), Ia is the depth of the initial abstraction (inches) and S is the depth of potential abstraction (inches) (Ia=0.2S).
Substituting Ia = 0.25 formula (1) is rewritten as follow:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{...2}$$

The relation between the Curve Number (CN) and S was established as:

$$S = \frac{1000}{CN} - 10 \qquad \text{...3}$$

The soil is silty loamy and it is grassed open surface, then the CN of 60 was selected, the runoff calculations are shown in Table 1. From the table, it can be also seen that the evaporation is very high (17 MCM) and the utilization of surface water is very important for the sustainability of groundwater system in Dhuleil basin by increasing the recharge amounts.

The characteristics of the wadi such as, catchment area (A), hydraulic length (L), centroid length (Lc) and the elevation difference between the highest point of the main stream and the outlet (H) are calculated from the topographic maps. The Curve Number (CN) is calculated from topographic maps, geologic map and land use (Table 2). The calculation of the synthetic unit hydrograph (UH) and the derivation of the flood hydrographs of 10, 25, 50 and 100 years return period for subcatchment calculated using method as follows:

$$La = Ct(\frac{L \times Lc}{\sqrt{S}}) \quad \ldots 4$$

$$Slope = \frac{\Delta H\,(Foot)}{L(mile)} \quad \ldots 5$$

$$Dr = \frac{La}{5.5} \quad \ldots 6$$

$$La' = La + \frac{Dr' - Dr}{4} \quad \ldots 7$$

$$Tp = \frac{Dr}{2} + La' \quad \ldots 8$$

$$Qp = \frac{484}{Tp} \times A \quad \ldots 9$$

Table 2. Unit Hydrograph Parameters for Wadi Za'tari Catchment Area.

L (km)	Lc (km)	ΔH (m)	Ct	La (hours)	Dr (hours)	Tp (hours)	Qp (hours)	A (km^2)	CN
44	28	750	0.95	4.2	0.76	4.76	450.8	403	60

The T/Tp and Q/Qp values of the generalized dimensionless UH of the SCS are used to derive the synthetic UH of Wadi Za'tari. Fig. 4 shows the unit hydrograph of Wadi Za'tari catchment area.

The intensity duration frequency curves (IDF) (ref.) were used to calculate the effective rainfall (runoff). The IDF curves for the years 10, 25, 50 and 100 years return period rainfalls for duration of 24 hours were obtained hourly for the wadi from the stations Mafraq, Um el-Jimal and W. Dhuleil.

The incremental runoff values were applied to the unit hydrograph with the lag time and the individual hydrographs are obtained for each incremental runoff. The addition of these hydrographs give the total storm hydrograph, the results of the flood hydrographs for the years 10, 25, 50 and 100 are shown in Fig. 5. Using Stormwater Management Design Aid Computer Package (SMADA, 1977), the calculated runoff data were analyzed using six probability distributions. These six distributions; normal, two parameter log normal, three parameter log normal, Pearson type 3, log Pearson type three and Gumbel type 1 external. Among the six distributions, two parameter log normal shows the best fitness of actual data to distribution as shown in Fig. 6.

6. Maximum Volume of Reservoirs

Flood frequency, volumes and peak flows are important factors for establishing the reservoir design. The elevation area-capacity curves were derived by calculating the difference between three closed contours in the reservoir from topographic maps (Raghunath, 1990). Then, areas between every two consecutive contours were calculated by using a planimeter. The volume of the water in the reservoir was calculated by:

$$V_1 = \left(\frac{1}{3}\right) A_1 * C_{i1} \qquad \text{......10}$$

where V_1 is the volume between the dam and the first contour in million cubic meter (MCM), A_1 is the area between the dam and the first contour in km^2 and C_{i1} is the elevation difference between the dam and the first contour in m.
and

$$V_2 = \left(\frac{A_1 + A_2}{2}\right) * C_{i2} + V_1 \qquad \text{......11}$$

where V_2 is the total volume in the reservoir in MCM, A_2 is the area between the second two contours in km^2 and C_{i2} is the elevation difference between the second two contours in m. The calculations of the accumulated flood volume at Wadi Za'tari resevoir are presented in Table 3. The results show that the Wadi Za'tari reservoir can accommodate about 5.4 MCM on an area of 1.63 km^2 and increased to 18.85 MCM when the area increases to 3.75 km^2 (Fig. 7).

Table 3. Accumulated flood volume of Wadi Za'tari Reservoir.

Elevation (m)	Depth (m)	Cumulative Area (km^2)	Cumulative Volume (MCM)
565	0	0	0
575	10	1.63	5.4 [(1)]

$$(1): V_1 = \frac{1}{3}(1.63)(575-565) = 5.4 MCM$$

$$(2): V2 = \frac{(1.63+3.75)}{2}(580-565) + 5.4 = 18.85 MCM$$

Table 1. Calculation of Direct Runoff and Infiltration Using Storm by Storm Analyses Technique for Wadi Za'tari Catchment Area.

Water	Storm	Rainfall Stations			Weighted Aver.	Weighted Aver.	Weighted Aver.	Total Annual	Total Annual	Total Annual	Total Annual	Runoff	Evaporation	Infiltration
Year	Date	Mafraq	Um Jimal	Dhuleil	Rainfall (mm)	Rainfall (MCM)	Runoff (mm)	Runoff (mm)	Runoff (MCM)	Evapor. (MCM)	Infilt. (MCM)	Coeff.(%)	Coeff.(%)	Coeff.(%)
75/76	11-13/3/76	51.30	40.00	30.90	42.32	17.06	0.402	0.402	0.162	16.442	0.452	0.950	96.400	2.650
76/77	-	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	100.000	0.000
77/78	12-16/12/77	31.50	39.60	30.30	36.67	14.78	0.046	0.046	0.019	14.556	0.203	0.125	98.500	1.375
78/79	-	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	100.000	0.000
79/80	28-30/11/79	66.00	46.70	64.30	52.52		1.850							
	23/2-2/3/80	41.40	36.60	42.80	38.39	36.64	0.118	1.968	0.793	32.758	3.091	5.126	89.400	5.474
80/81	10-13/12/80	43.60	37.50	43.40	39.62		0.189							
	25-31/12/80	50.30	42.10	40.50	44.19	33.78	0.592	0.781	0.315	31.179	2.286	1.788	92.300	5.932
81/82	-	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	100.000	0.000
82/83	16-22/2/83	39.10	37.90	38.90	38.30	15.44	0.113	0.113	0.046	15.143	0.248	0.295	98.100	1.605
83/84	12-23/3/84	41.60	49.20	58.80	47.92	19.31	1.076	1.076	0.434	18.383	0.493	2.246	95.200	2.554
84/85	24-26/2/85	38.60	39.50	69.80	41.68	16.80	0.344	0.344	0.139	16.126	0.533	0.825	96.000	3.175
85/86	-	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	100.000	0.000
86/87	11/06/86	77.80	61.50	51.50	65.10	26.24	4.863	4.863	1.960	23.087	1.188	7.470	88.000	4.530
87/88	3-6/1/88	36.60	38.60	31.00	37.45		0.074							
	11-16/1/88	41.10	36.00	36.10	37.39	46.05	0.071	0.322	0.130	44.484	1.436	0.861	96.800	2.539
	1-2/2/88	42.50	38.00	40.60	39.42		0.176							
88/89	24-28/12/88	110.40	68.00	55.10	78.42	31.60	9.278	9.278	3.739	26.008	1.854	11.832	82.300	5.868
89/90	1-4/1/90	35.10	38.90	37.90	37.79	15.23	0.089	0.089	0.036	14.896	0.299	0.235	97.800	1.965
90/91	22-23/3/91	38.70	42.60	38.60	41.23	16.61	0.306	0.306	0.123	16.033	0.456	0.742	96.500	2.758
91/92	30/12/-2/1/91	36.60	41.40	40.00	39.99		0.214							
		100.30	50.70	32.90	62.67	79.73	4.185	20.694	8.340	48.954	22.436	33.022	61.400	5.578
		139.10	79.50	74.30	95.18		16.295							
92/93	12-18/12/92	33.20	42.20	32.90	39.03		0.152							
	7-11/1/93	33.60	36.20	35.80	35.47	30.02	0.015	0.167	0.067	28.669	1.284	0.471	95.500	4.029
93/94	-	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	100.000	0.000
94/95	3-7/11/94	45.50	34.00	38.60	37.47	15.10	0.075	0.075	0.030	14.800	0.272	0.200	98.000	1.800
95/96	1-7/1/96	34.80	36.20	33.50	35.61	14.35	0.018	0.018	0.007	14.206	0.136	0.051	99.000	0.949
96/97	20-25/2/97	39.80	38.50	30.70	38.23	15.41	0.109	0.109	0.044	14.943	0.418	1.000	97.000	2.000
97/98	18-19/12/97	37.30	32.50	36.30	34.10									
	17-20/3/98	40.30	37.00	38.10	37.98	15.31	0.097	0.098	0.039	15.030	0.236	0.258	98.200	1.542
98/99	-	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	100.000	0.000
Average					36.69	19.14	1.314	1.698	0.684	16.904	1.555	2.81	94.84	2.35

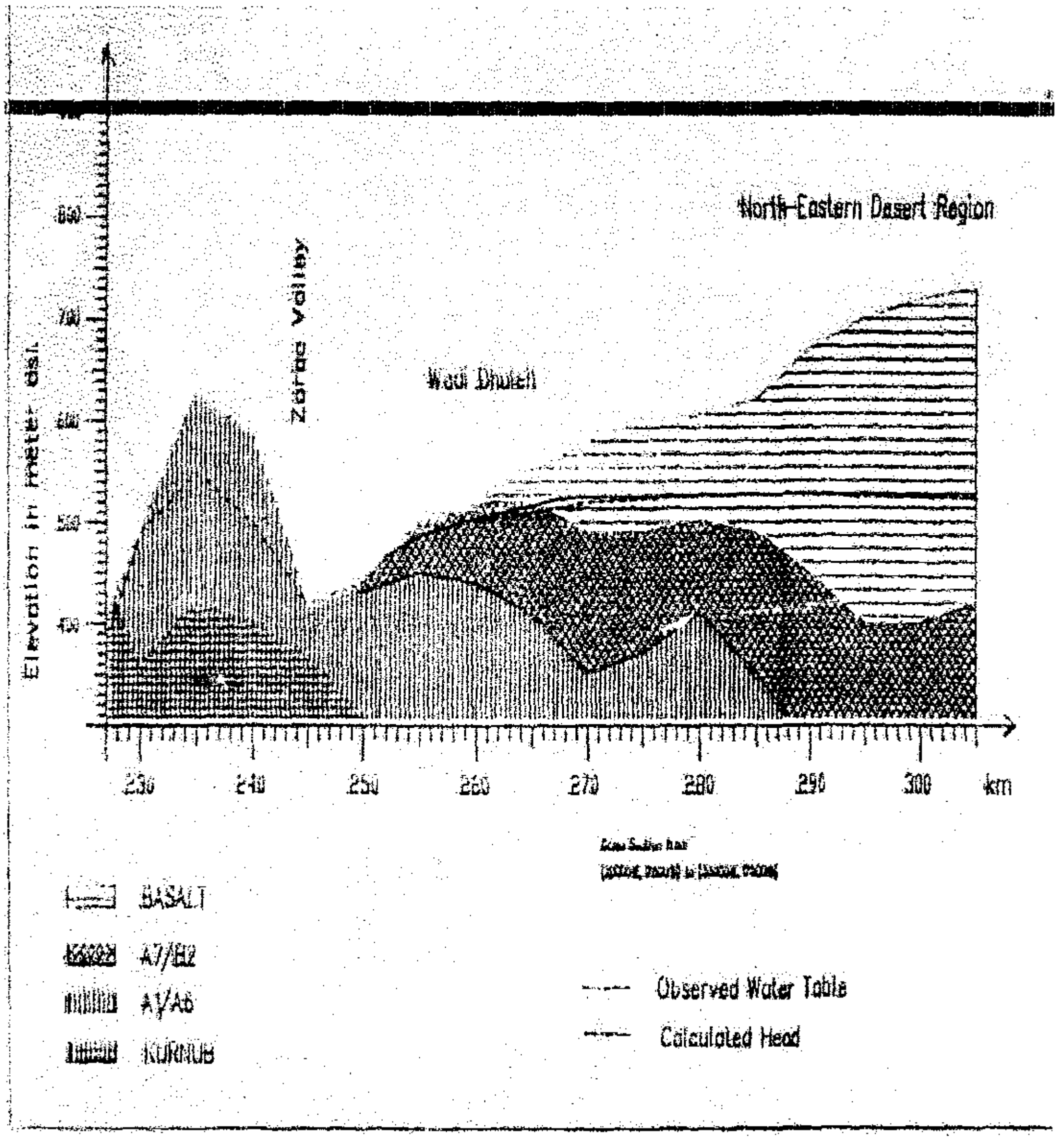

Fig. 2. Hydrogeological Cross-Section along Wadi Dhuleil Area.

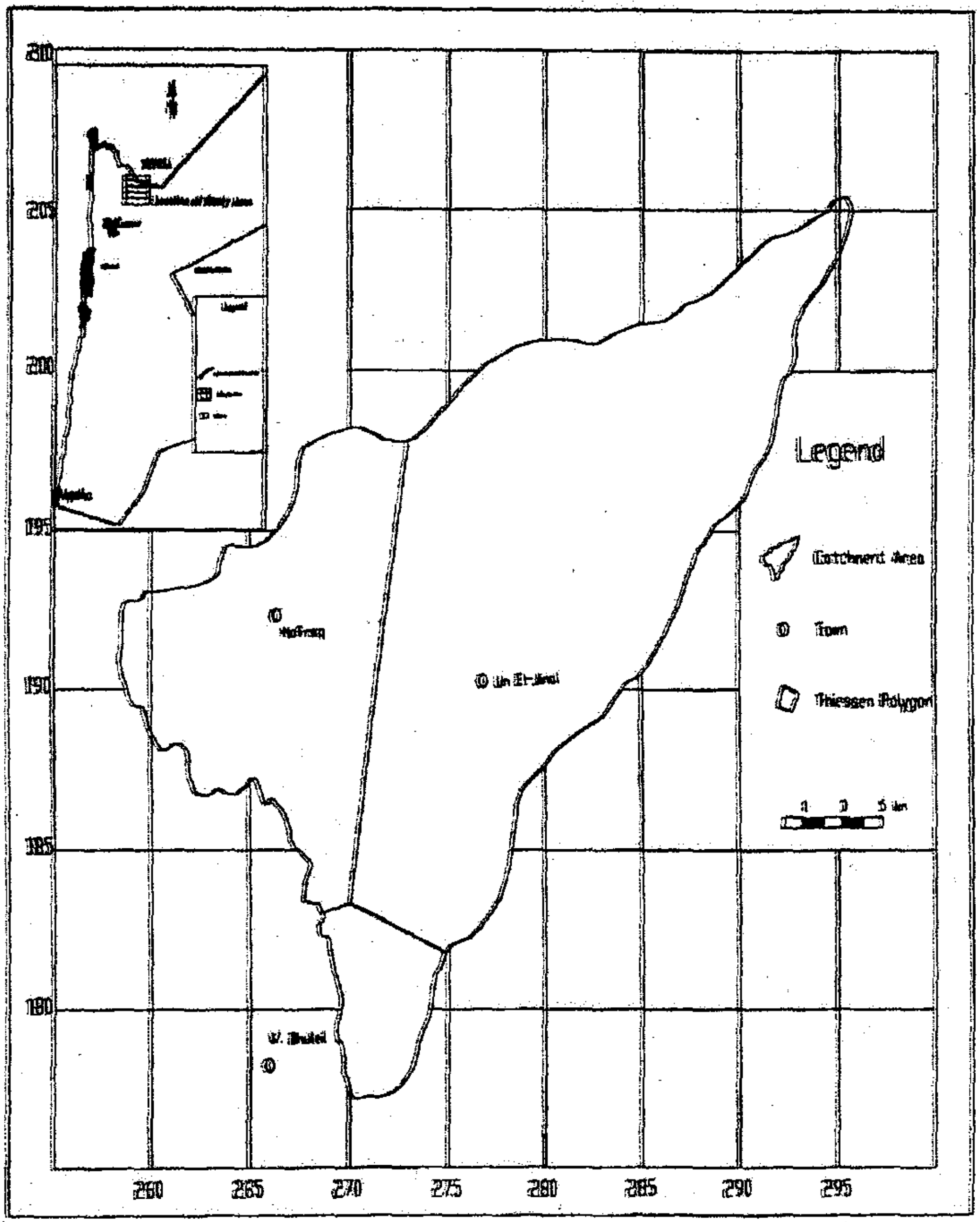

Fig. 3. Thiessen Polygons for the Study Area.

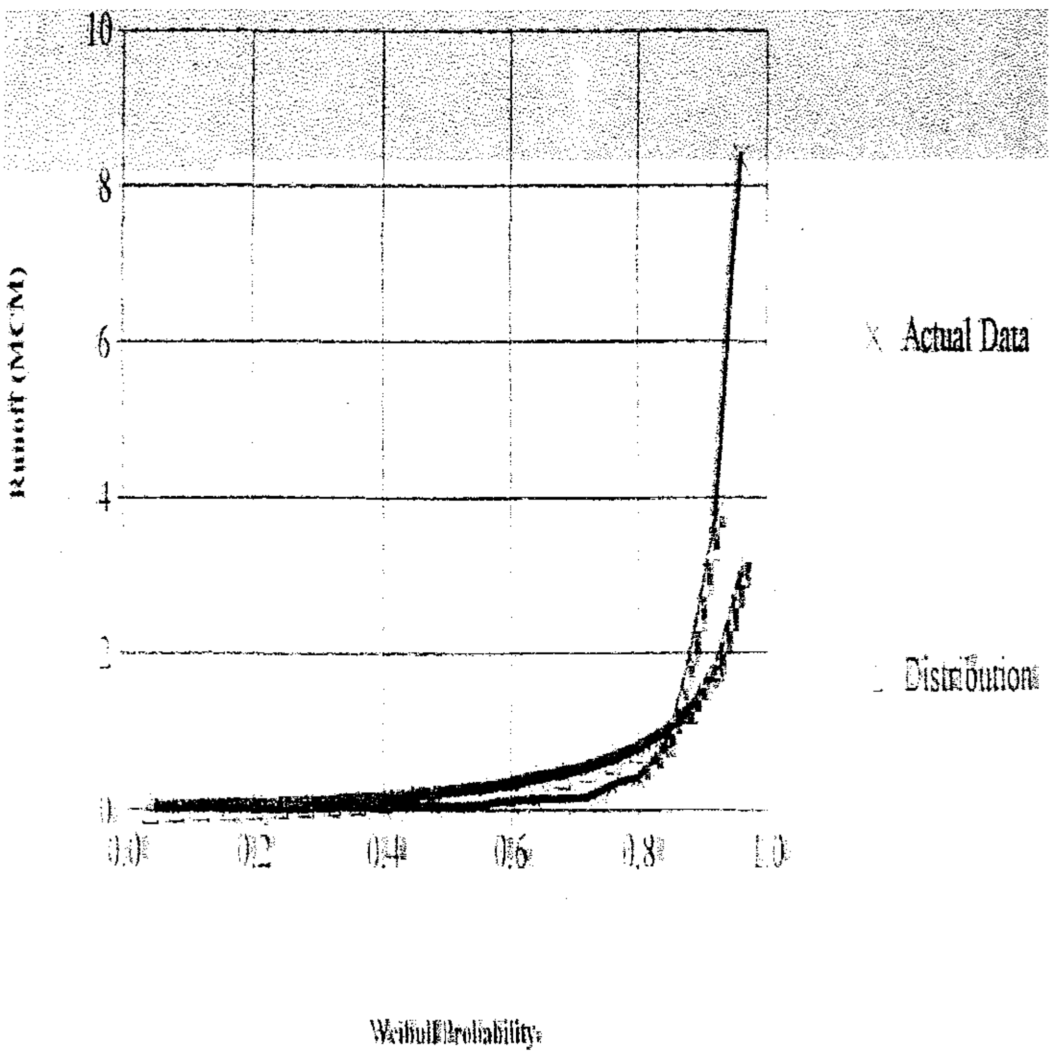

Fig. 6. Two Parameter Log Normal Distribution for the Runoff Data of Wadi Za'tari Catchment Area.

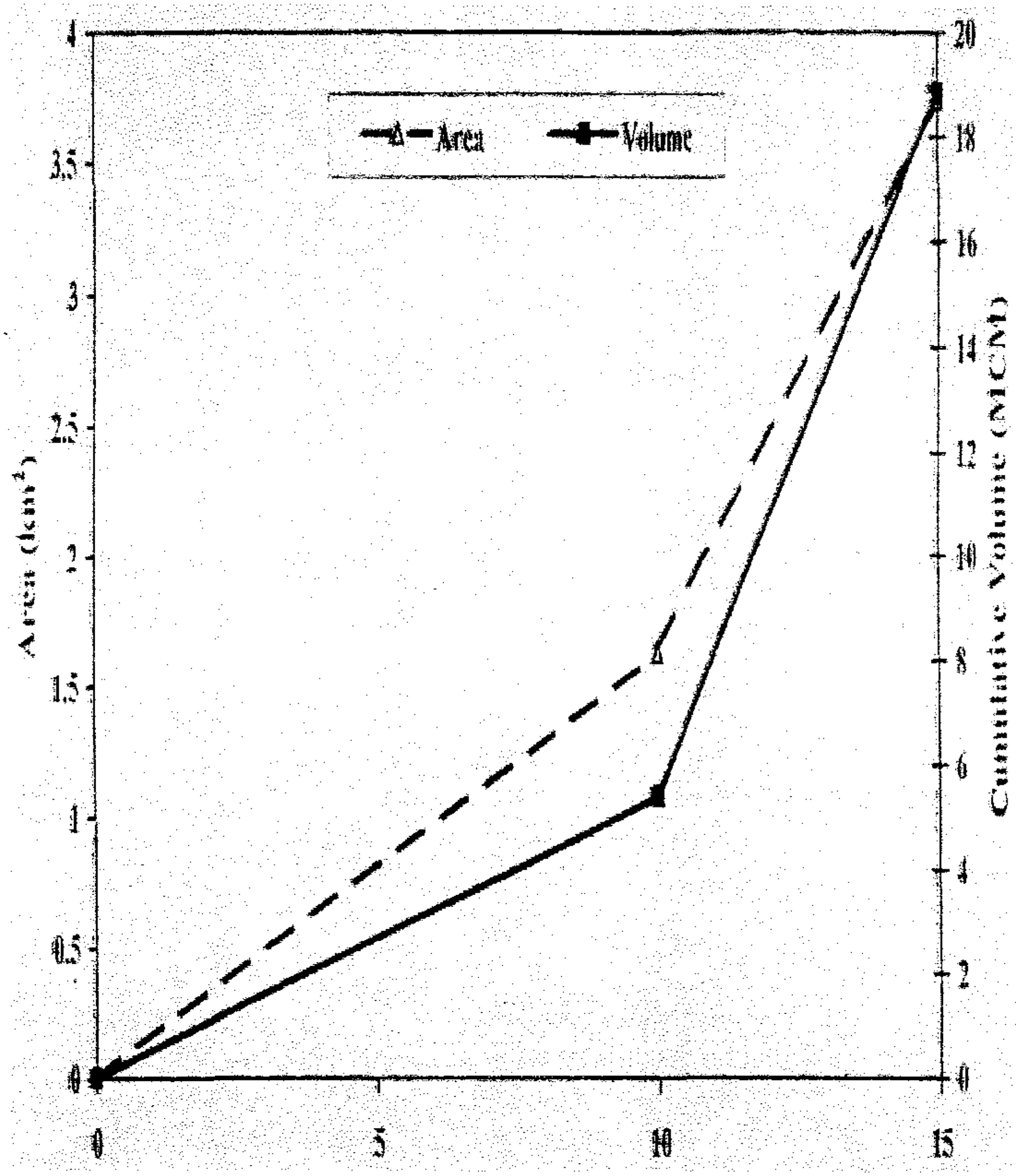

Fig. 7. Elevation Area-Capacity Curve for the Reservoir of Wadi Za'tari Catchment Area.

7. DISCUSSION

The aim of this study is to utilize the surface water at Wadi Za'tari Catchment Area. The thunderstoms that characterized by their irregularity in intensity and duration are responsible for most rainfall in the area. Normally, huge amounts of water are precipitating in short time causing puddles and desert lakes, the water remains several months before it evaporates into atmosphere.

Due to the importance of Dhuleil basin as a source of drinking and agricultural purposes, Wadi Za'tari was chosen for artificial recharge of groundwater using earth dams techniques. The wadi is located at the western part in the direction of groundwater flow. In this process, the surface water will be kept from evaporation, pollution, eroding soils and puddling as a result of thunderstorm rainfalls. The dam will preserve the groundwater quantity and quality.

The important factors in the catchment selection are geological situation, drainage system, rainfall quantities, depth to water, structural and topographic features, slope and length of the channel system, which allow the water to infiltrate naturally. The location of the observation and production wells will use the maximum water quantity. The soil of the wadi is silty loamy and partly residential and the CN of 60 was chosen, which means that the initial abstraction is 33.87 mm.

Materials to be used in dam construction are easily obtained from surrounded areas. To decrease the effects of silt accumulation, it is recommended to construct the dam on several parts, the first parts act as sedimentation dams and the last as recharge dam.

The storm analyses for the years 75/76-98/99 were conducted using Thiessen Polygons for the stations of Mafraq (27 % of the total rainfall), Um El-Jimal (65 % of the total rainfall) and Wadi Dhuleil (8 % of the total rainfall). The weighted average rainfall is about 19 MCM, the total runoff, evaporation and infiltration are about 0.7, 17 and 1.55 MCM respectively. The coefficients of runoff, evaporation and infiltration are 2.81, 94.84 and 2.35 percent respectively. The maximum total discharge for the years 10, 25, 50 and 100 is 2394, 5996, 10213 and 13582 m^3/s respe, which confirms that most of rainfall in the study area is from thunderstorms type.

The elevation area-capacity curves show that the reservoir of the proposed dam can accommodate about 5.4 MCM if the water depth is 10 m and 18.85 MCM if the water depth is 15 m. These quantities will develop the groundwater quality and decrease the problems of groundwater salinity.

The chemical analyses of surface water from different parts of the basin show that the best water quality is located at the northern part of the catchment area, but the quality is still much better than groundwater. The groundwater quality has deteriorated, due to overpumping of groundwater and the intensive agricultural activities near the recharge sources.

The chemical analyses of surface water and groundwater indicate that the recharge water will positively affect the groundwater quality. The salinity of groundwater will decrease as soon as mixing with surface water is increased (Table 4). This means that the high groundwater quality is assured and no negative environmental impacts are expected to occur.

Table 4. Comparison between Chemical analyses of Surface Water and Groundwater at Wadi Za'tari Catchment Area.

Variable	Surface Water	Groundwater
EC (μS/cm)	240.4±41.9	4310±577
PH	7.5±0.3	7.7±0.5
Ca (mg/l)	22.4±1.5	262±22.4
Mg (mg/l)	5±1.4	182.1±18.9
Na (mg/l)	15.9±9.2	232.3±68.2
K (mg/l)	6±1.9	24.9±6.2
HCO_3 (mg/l)	119.6±24.2	92.5±20.3
Cl (mg/l)	7.4±4.4	1184.9±94.5
SO_4 (mg/l)	7.8±3.3	348.8±57.6
NO_3 (mg/l)	6.3±1.3	98.8±8.5

±: Standard Deviation

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الملخص العربي

استغلال المياه السطحية في التغذية الاصطناعية للمياه الجوفية في حوض وادي الزعتري/ الأردن

عاطف الخرابشة و ركاد طعاني

جامعة البلقاء التطبيقية ووزارة المياه والري – الأردن

تهدف هذه الدراسة استغلال المياه السطحية لتغذية المياه الجوفية في وادي الزعتري في الجزء الغربي من حوض الضليل. وتأتي أهمية هذه الدراسة إلى أن مستويات المياه الجوفية في هبوط مستمر وذلك بسبب إستغلالها في تغطية زيادة الحاجة للاستخدامات المنزلية والزراعية. أما بالنسبة للصخور الحاوية على المياه فهي من النوع الجيري والبازلتي المتشقق وهذا يساعد على رشح المياه طبيعيا كذلك فان مواد بناء السدود متوفرة في الموقع وهذا يقلل تكاليف الإنشاء. وللتغلب على مشاكل انسداد الشقوق بالمواد الطينية فانه ينصح ببناء السد على اكثر من مرحلة حيث تستعمل الأجزاء الأولى لتقليل سرعة المياه وترسيب المواد الطينية في حين يستعمل الجزء الأخير لأغراض التغذية الاصطناعية للمياه الجوفية. أشارت الحسابات التي أجريت بواسطة (Curve Number Method) أن معاملا الفيضانات والتبخر هما (٢,٨١) و (٩٤,٨٤) بالمائة على التوالي. وهذا يعني أن معظم المياه السطحية تتبخر في الجو وان استغلالها ضروري جدا. أما أعلى قيمة للتصريف لسنوات التكرار ١٠ و ٢٥ و ٥٠ و ١٠٠ سنة فهي ٢٣٩٤ و ٥٩٩٦ و ١٠٢١٣ و ١٣٥٨٢ م٣/ثانية على التوالي. كما أشارت الحسابات التي أجريت على استيعاب أرضية بحيرة السد للمياه أنها قادرة على استيعاب (٥,٤) مليون متر مكعب عندما يكون عمق المياه ١٠م ويرتفع هذا الرقم إلى (١٨,٨) مليون متر مكعب عندما يزداد ارتفاع المياه إلى ١٥م وذلك لان مساحة السد تزداد من (١,٦٣) كم^2 إلى (٣,٧٥) كم^2.أما بالنسبة للتحاليل الكيماوية التي أجريت على مياه الفيضانات السطحية والمياه الجوفية فقد أكدت التحسن الذي سيطرأ على نوعية المياه الجوفية بعد خلطها بمياه الفيضانات. ففي حين يبلغ معدل التوصيل الكهربائي ٢٤٠ ميكروسيمنز/سم لمياه الفيضانات فإنه سيصل إلى ٤٣١٠ ميكروسيمنز/سم للمياه الجوفية.