The Hashemite Kingdom of Jordan
Ministry of Water and Irrigation
Water Authority

Effect of 1991/92 Rainfall on The Groundwater Recharge of Yarmouk and Wadi Al Arab Basins

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FOREWORD

The winter of 1991/92 was one of the coldest seasons during the last 50 years. The total amount of precipitation over the country was calculated to be around 13400 MCM, which exceeds the average year (8500 MCM) by 57%. Looking at the rainfall record of Jordan between the years 1937-1992, the maximum and minimum water years were 1966/67 and 1959/60. The total amount of precipitation were 17797 and 3915 MCM, respectively.

In this study, the authors try to evaluate the effect of an abnormal year on the groundwater recharge of different basins. The available hydrological and meterological data, as well as the observation wells were processed and interpretated in order to have some figures regarding the effect of such an abnormal year on the groundwater.

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PART I

YARMOUK BASIN

1. Yarmouk Basin

1.1 Introduction

The Yarmouk basin is located at the northwestern part of Jordan, where 3/4 of the basin is inside the Syrian territory. The Jordanian part of the Yarmouk Basin is located between the coordinates 210-280 E and 190-240 N (according to Palestine Grids), and covers an area of about 1514 Km^2. The Yarmouk basin is divided into two subbasins, namely: Maqarin and Adasiya. The former represents 86% of the basin catchment in Jordan, where the later represents 14 % of the basin area (see Fig. 1).

1.2 Hydrology

The "Water Budget" approach is used to calculate the infiltration in the Yarmouk Basin for the water year 1991/92. The only observed parameter of the water budget equation in the study area is the rainfall, the other parameters either be calculated or estimated.

Runoff was calculated according to the runoff coefficients of the basin (GTZ, 1977). Evaporation is calculated according to Wundt (1937), and Turc (1954) formulas. Finally, the infiltration rates are calculated according to the basic water budget equation.

1.2.1 Rainfall

The rainfall in the study area occurs mostly in winter months, October to April or early May, while the summer months are completely dry.

There are more than 17 rainfall gauging Stations in and around the Yarmouk basin, out of which 14 Stations were selected for the determination of the average rainfall in the basin. Table (1), represents the monthly and annual rainfall of the rainfall Stations located in the Yarmouk Basin.

Fig.1 Drainage and well Location map of

Yarmouk Basin & Wadi Arab Catchment

◎ Observation Well

∘ Well

☐ Yarmouk Basin

▒ Wadi Arab

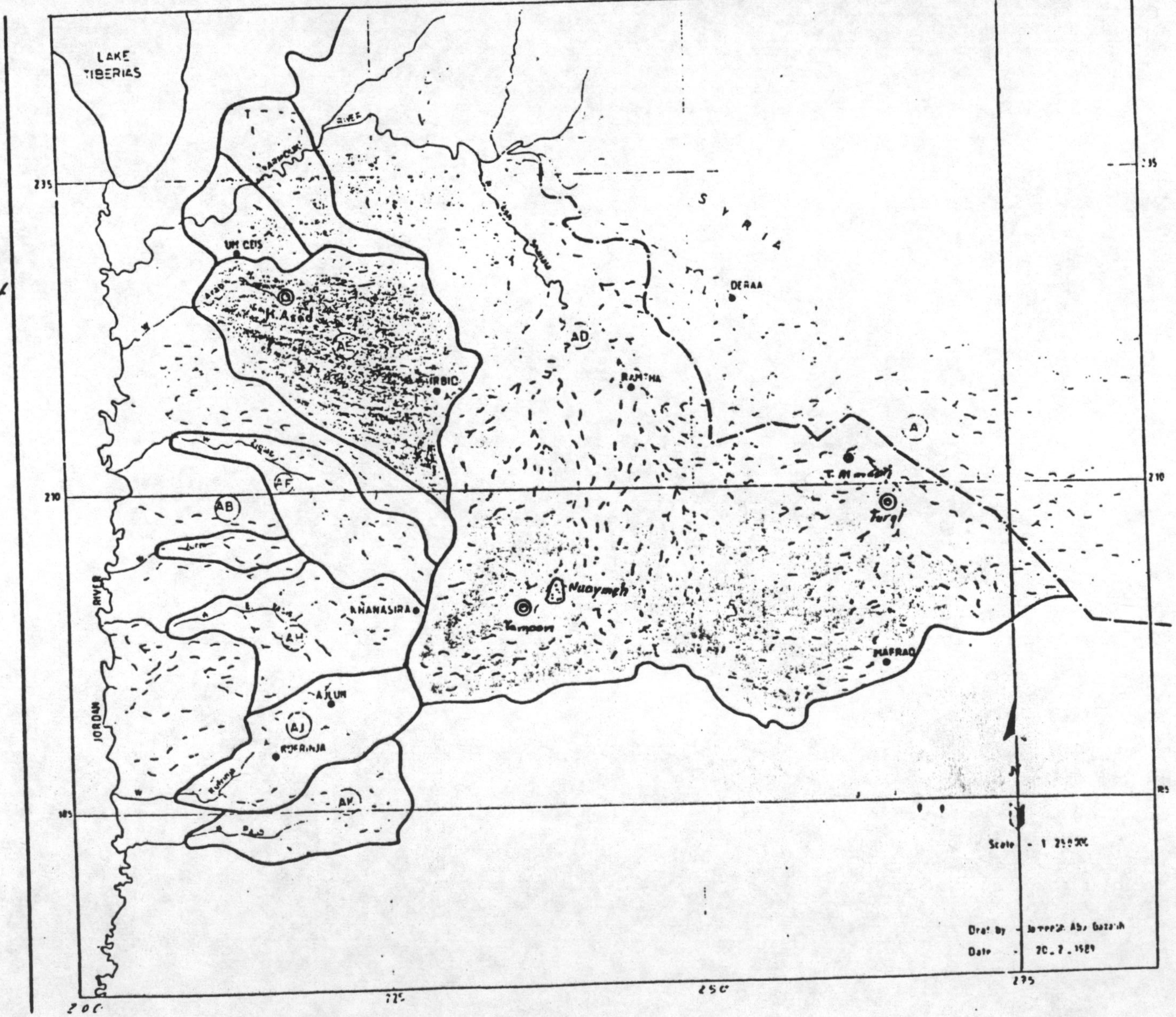

Table (1) Monthly and Annual Rainfall (mm) Precipitated over the Stations Located in the Yarmouk Basin During (1991/1992)

Station Name	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual
Mafraq	13	8.5	50.5	27.2	69.1	13.9	-	4.7	186.8
Jabir - Sirhan	4.9	35.0	110.5	40.5	70.0	8.0	-	1.1	270.0
Hosha	3.3	13.9	94.0	50.2	69.1	11.5	-	1.0	243.0
Rihab	5.5	24.0	132.3	114.5	161.3	16.2	-	-	453.8
Ramtha	2.7	35.2	118.5	124.9	173.1	14.8	0.2	3.1	472.5
Hawara	-	47.2	156.6	162.0	258.5	33.8	2.5	5.2	665.8
Husn	-	39.4	230.0	96.2	294.5	35.5	-	6.2	494.8
Qafqafa	-	53.2	120.7	120.6	196.2	152	-	11.0	516.9
Ibbin	32.0	76.0	350.0	263.8	397.1	44.1	-	7.0	1170.0
Turra	-	38.8	133.0	126.3	186.1	17.0	3.4	5.4	509.7
Irbid	-	62.3	233.3	244.6	346.0	41.2	4.4	12.1	943.9
Kharja	-	75.0	193.9	176.6	305.5	30.2	8.6	3.8	793.6
Samar	1.9	102.2	220.7	201.5	329.0	29.9	8.2	10.2	903.6
Um - Qeis	-	106.3	220.0	187.5	302.0	17.8	7.0	8.4	849.0

The intensity of the rainfall Stations in the study area is sufficient for the evaluation of regional rainfall distribution and the determination of annual averages.

The Thiessen Polygons Technique, Figure (2) was applied to estimate the areal rainfall occurred in the study area. The Thiessen method attempts to allow for nonuniform distribution of gauges by providing a weighting factor for each gauge.

The distribution of the annual rainfall over the Yarmouk basin shows a drop from east to west. The annual rainfall of the water year (1991/1992) in the basin ranged between 186.8 mm at Mafraq and 1170 mm at the southern borders of the basin (Ibbin), as listed in Table 1.

1.2.2 Runoff

The volume of runoff is calculated using the runoff coefficients estimated in the Water Master Plan of Jordan (GTZ, 1977). The runoff coefficients of a wet condition were selected for Maqarin and Adasiya areas. A runoff coefficient of 18 percent were chosen for Adasiya and 7.5 percent for Maqarin area.

The annual volume of runoff was calculated to be about 48.04 MCM at Maqarin site, and 32.86 MCM at Adasiya Site. The Maqarin subbasin of the Yarmouk Basin covers an area of about 1302 Km^2 or 86 percent of the basin, and Adasiya subbasin covers an area of about 212 Km^2 or 14 percent.

1.2.3 Evaporation

The rates of evapotranspiration were calculated using the empirical evaporation formulas of Wundt and Turc. These formulas depend on certain factors to approximate evaporation. The main factors are the soil moisture, which depends on the amount of rainfall and the temperature which plays a major role in providing energy for evapotranspiration. Therefore, the moisture and temperature are considered in the calculation of actual evapotranspiration. Figure (3) illustrates the Thiessen Polygons of the evaporation stations lies in the Yarmouk Basin, and Table (2), gives the mean monthly temperature monitored from the evaporation station located in the study area.

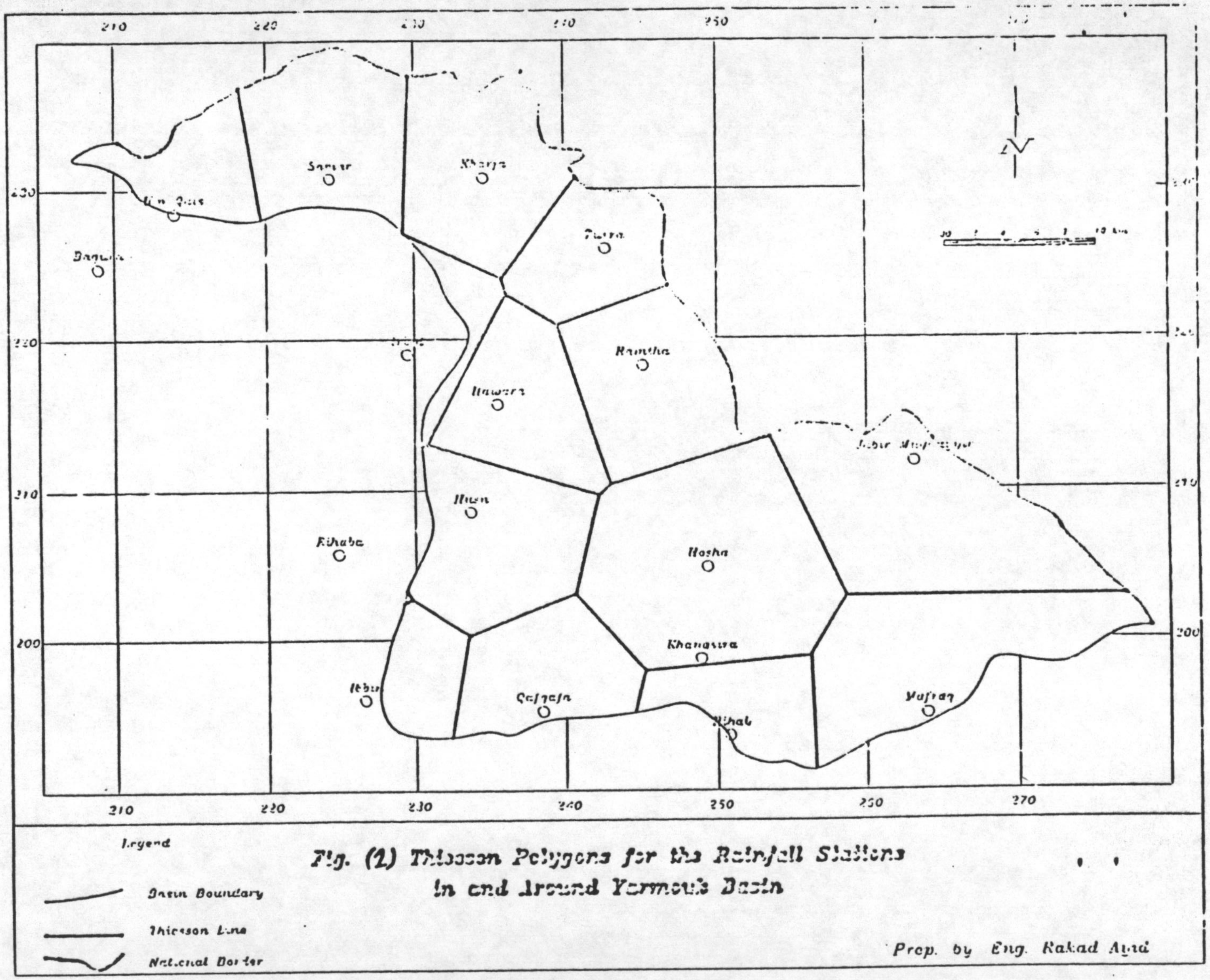

Fig. (1) Thiessen Polygons for the Rainfall Stations in and Around Yarmouk Basin

Prep. by Eng. Rakad Ayid

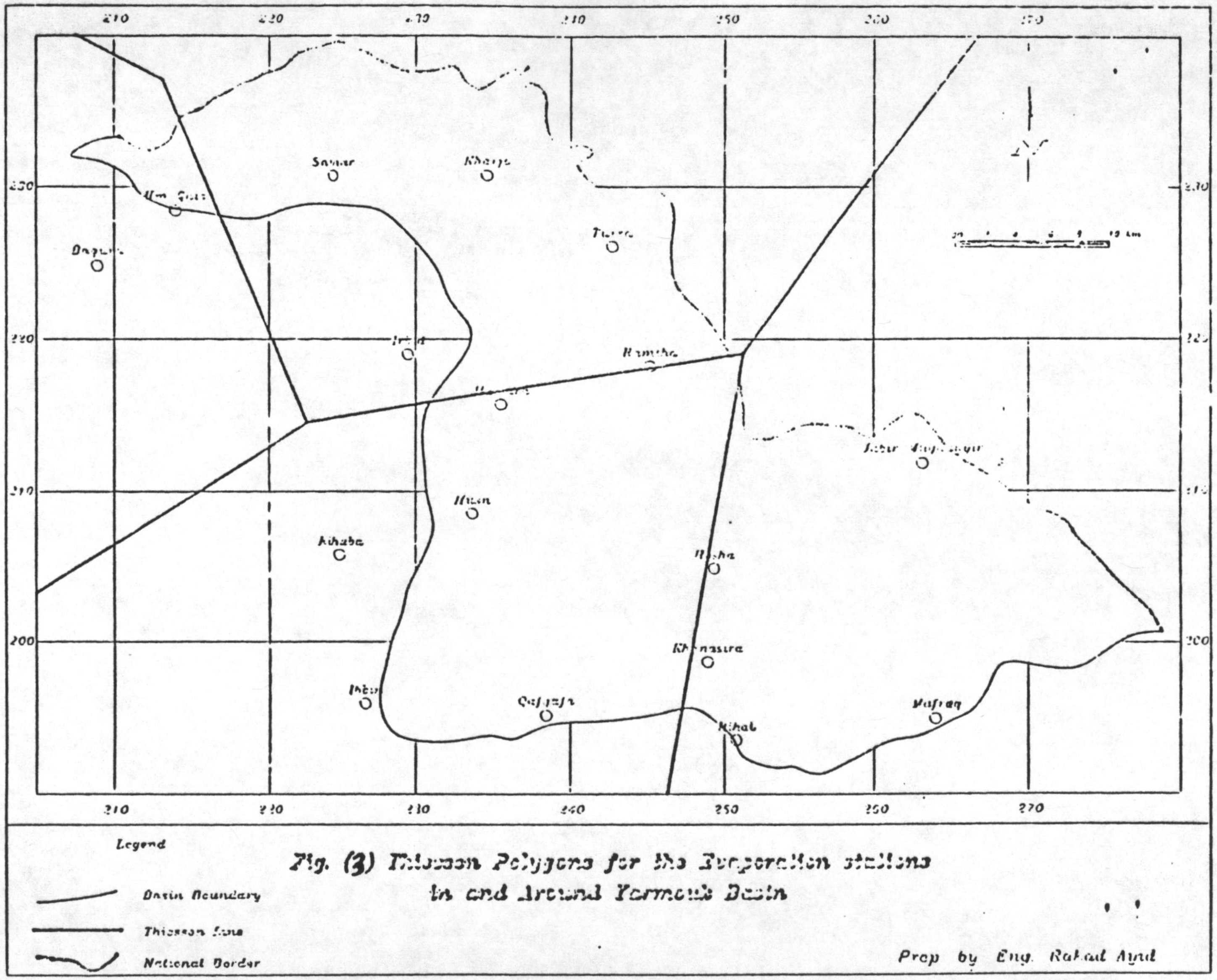

Fig. (3) Thiessen Polygons for the Evaporation stations in and Around Yarmouk Basin

Prep by Eng. Rahat Ayul

Table (2)Mean Monthly Temperature for the Stations in Yarmouk Basin (1991/1992)

Station Name	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Mafraq	20.3	14.5	6.8	4.6	5.3	8.4	13.4
Ras Muncif	18.2	13	4.4	5.1	6.3	9.4	13.9
Samar	23.1	17.6	8.7	6.1	7.5	10.8	16.5
Baqura	26.3	20.1	12.8	10.7	10.8	12.3	18.8

1.2.3.1 Wundt Formula

$$E = \frac{P}{\left(0.59 + \frac{P}{f(t)}\right)^3}$$

where:

E = *is the annual potential evaporation (mm).*

P = *is the annual precipitation (mm).*

t = *is the annual temperature for the season where water or soil moisture are still available.*

$f(t)$ = *Temperature function, which is equal to;*

$$= 1400 + 170\,t + 5.5\,t^2 + 0.15\,t^3$$

Where;

t = *is the average temperature and usually in the range of -5 and 20.*

By using this formula, the annual evaporation rates were computed for the Maqarin and Adasiya subbasins. The average temperature was found to be about 9.2 C at Maqarin, and 11.8 C at Adasiya area. Table (3) gives the calculated evaporation by Wundt and Turc formulas. The mean temperature taken into consideration is that between November and April, because soil moisture for evaporation is available only during this period. Between May and October, no water is available in the soil for evaporation.

1.2.3.2 Turc Formula

$$E = \frac{P}{\left(0.9 + \frac{P^2}{f(t)^2}\right)^{0.5}}$$

Table (3) Calculated Evaporation by Wundt and Turc

Sub-basin	Precipitation (mm)	Temperature C	Evaporation (mm)	
			Wundt	Turc
Maqarin	492.1	9.2	381.3	383.3
Adasiya	861.1	11.8	573.8	542.8

Table (4) Calculation Infiltration,Evaporation and Runoff

Site	Evaporation (mcm)		Runoff (MCM)	Precipitation (MCM)	Infiltration		Inf. Rate	
	Wundt	Turc			Wundt	Turc	Wundt	Turc
Maqarin	496.5	499.1	48.1	640.7	96.1	93.5	15	14.6
Adasiya	121.6	115.1	32.9	182.6	28.1	34.6	15.4	18.9

Where;

E = is the annual evaporation (mm)
P = is the annual precipitation (mm)
t = is the temperature function, which is equal to;

$$F(t) = 300 + 25t + 0.05\, t^3$$

The results of the two methods of Wundt and Turc which are listed in Table (3) were found to coincide to a large extent, 381.3 mm by Wundt and 383.3 mm by Turc for Maqarin site, and 573.8 mm by Wundt and 542.8 by Turc for Adasiya site.

1.2.4 Infiltration

Infiltration capacity is defined as the minimum rate at which rainfall can be absorbed by a soil in a given condition.

Infiltration depends upon a number of factors, including physical nature of the soil moisture content, permeability of the soil profile, rainfall intensity and vegetation cover.

Due to the fact there are no direct infiltration measurements in the Yarmouk Basin, a "Water Budget" approach was applied to estimate the annual infiltration to the following equation.

$$I = P - E - R$$

Where ;

P = Is the annual volume of precipitation (MCM)
E = Is the annual volume of evaporation (MCM)
R = Is the annual volume of Runoff (MCM)
I = Is the annual volume of Infiltration (MCM)

Table (4) presents the infiltration amounts and rates according to this approach.

1.2.5 Comparison between Normal and Wet Year.

In an attempt to quantify the amount of infiltration in a normal and a wet year, the calculated infiltration rates by various authors were used. Salem (1984) calculated the infiltration rate to the aquifer, by using water budget equation, to be around 40 MCM/yr. El-Naser (1991) simulated the infiltration rates, by using modelling techniques, to around 31.0 MCM/yr. However, the calculated infiltration rates, by various authors, are equal to 7-9% of the total precipitation amount (441 MCM/yr). The calculated infiltration rates of the wet year (as mentioned before) are equal to 128.1 MCM/yr (according to Turc) and 124.2 (according to Wundt), which represent around 15 to 16% of the total precipitation (823.3 MCM/yr). This means that the infiltration of water in a wet year is equal to 2 times the percent of infiltration of a normal year. In term of quantities, the percentage of infiltration in the wet year (1991/92) corresponds to around 3 to 4 times as taht of the normal year. This seems to be correct, if we consider the exponential relation between precipitation and infiltration.

1.3 Hydrogeology

The B2-A7 aquifer system is the most significant aquifer from grounwater resources point of view in the Yarmouk basin. Due to the overlying aquifers and aquitards the recharge to this aquifer system for most of the basin area, seems to be small. Exclusively, the outcrop area of the aquifer system and the subsurface flow from the surrounding areas (see Fig.4).

The B4 shallow aquifer outcrops at the northern part of Yarmouk Basin and recieves most of the direct infiltration, which makes the direct infiltration to the B2-A7 aquifer system unlikely to occur.

1.3.1 Groundwater Flow System.

The B2-A7 Aquifers system is the main aquifer in the Yarmouk and Wadi Al Arab Basins. Aquifers and aquitards as well as the soil cover make direct recharge as infiltration from the rainfall limited to the outcrops of the aquifer. The B2-A7 crops

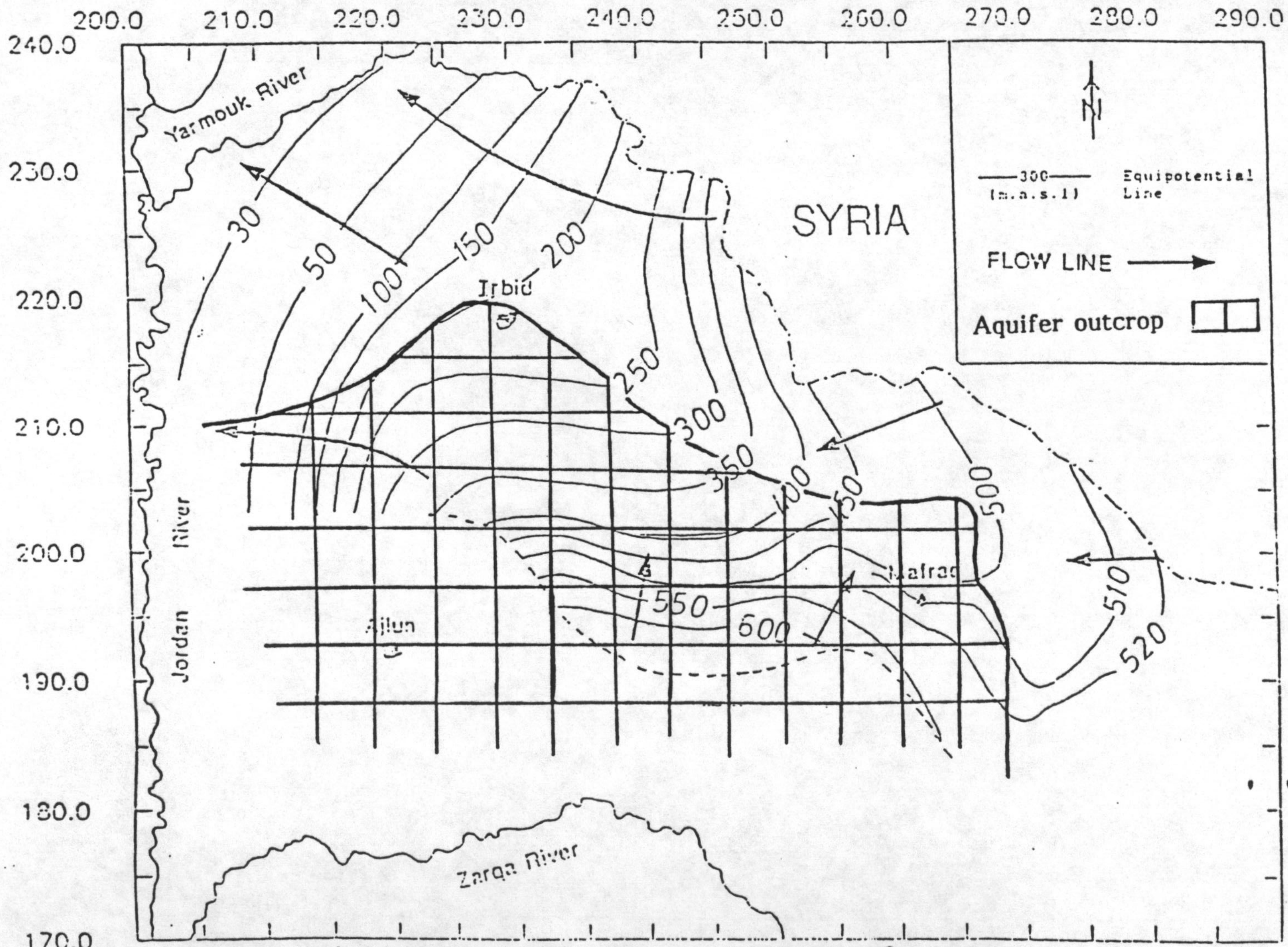

Fig.(4): Groundwater Flow System & Aquifer Outcrop of the B_2/A_7

out in the eastern and southern Border of the Basin, where direct recharge occurs. However, the groundwater flow map (El-Naser, 1991; Fig. 4) indicates that a groundwater divide exists at the Ajlun mound where the groundwater flows into two main directions from Ajlun region in the South groundwater flows north-westwards to Wadi Al Arab and Mukheiba and north-eastward to Ramtha and Maqarin/Wadi Shallala area. On the otherhand, the groundwater comming from the north-eastern desert (Jabal Al Arab) appears to convert as under flow in Ramtha and from there it flows north-westward and westward to Mukheiba, Wadi Al Arab and Yarmouk river where most of the discharge occurs.

1.3.2 Groundwater Recharge

The available observation wells have been used to quantify the amount of received recharge by the aquifer systems (B2-A7). The hydrograph of the Toraqi/Somaya-2 observation well (Fig.5) which assumed to represent the eastern side of the basin, did not show any unusual increases in the water table. This seems to be quite correct for many reasons:

(1) The amount of precipitation at that part of the aquifer is not sufficient to cause significant amount of direct recharge to the aquifer.

(2) The overlying aquitards allow very small amount of water to flow vertically to the aquifer, because of their low permeability.

(3) The most siginficant recharge to this area is the subsurface flow from the northeastern desert (Jabel Al Arab). Due to the remotness of the recharge area, the underground water will take time to reach the aquifer. The Lag time of recharge was calculated by various authors and methods to be in the range of 100 to 150 years. On the otherhand, the Isotopic radio active C-14 analyses of groundwater in Taleb-Al Masri well indicates that the water is old (3.3 PMC).

The analyses and interpretations mentioned above have proved that the eastern part of the basin did not recieve any valuable amount of recharge. Therefore, no any additional development in the aquifer is recommended. The second observation well,

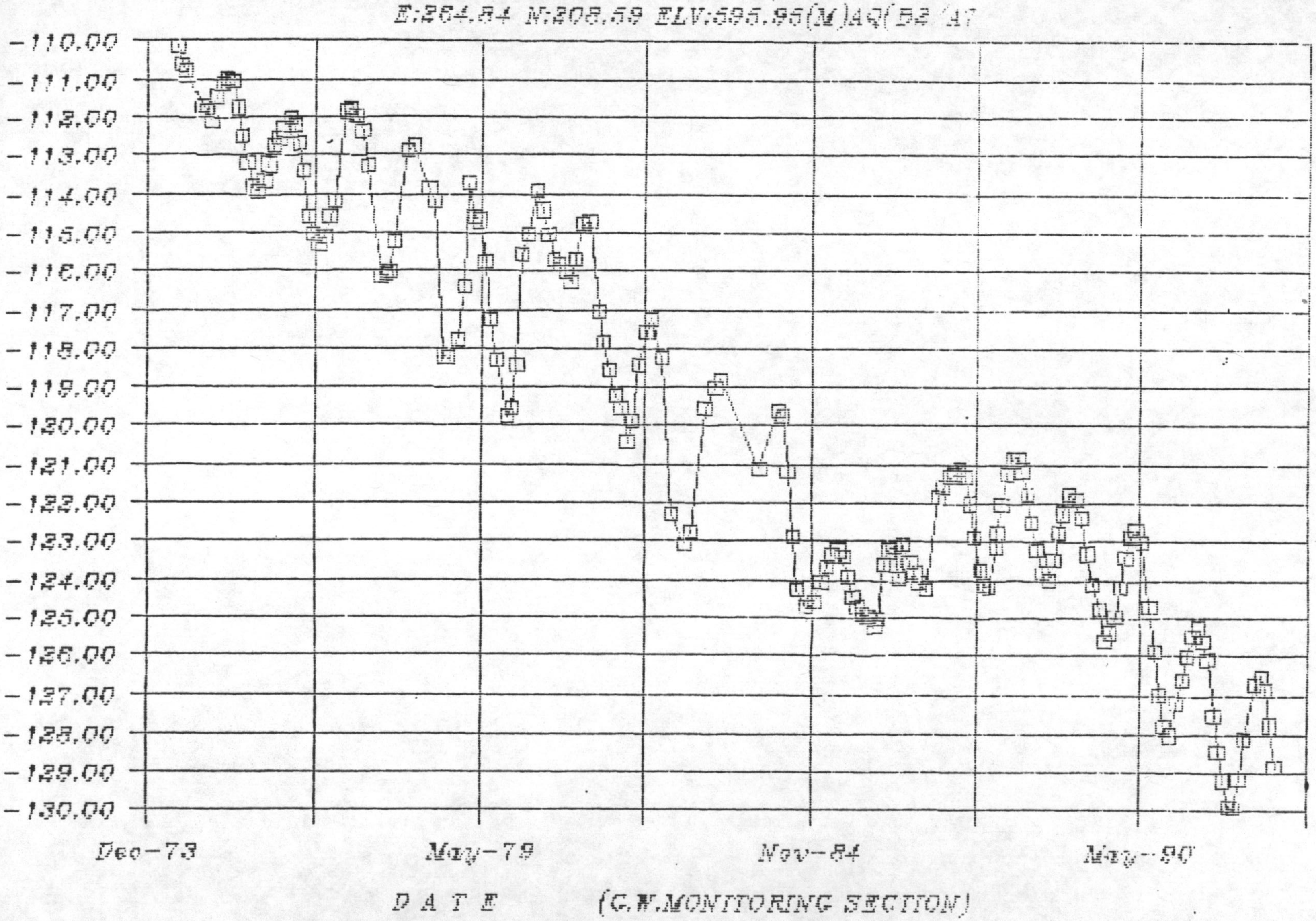

Fig.(5) : Turqi Somaya - 2 Observation Well *which has been chosen to represent the area of direct recharge of Ajlun montains at Nuaymeh area, is the Yamoon observation well. Unfortunately, the available hydrograph represents only two years (see Fig. 6). However, the hydraulic head difference between the minimum water level (Sept. '91) and the maximum water level (June 2) is equal to 24 m. This abnormal increase in the water table is can only be referred to the direct recharge as a result of the unusual precipitation rates.*

In an attempt to quantify the change in storage, the following equation was applied:

$$\text{Change in storage} = \text{Area} * \text{Specific Yield} * \text{Head Difference}$$

$$= 95\ Km^2 * 0.02 * 24m$$

$$= 45.6\ MCM$$

In comparison with the mean annual direct recharge calculated by the North Jordan Water Resources Project (WAJ, 1989) using Darcy's low approach was about 21.5 MCM/year. This means that the amount of water which is reached the aquifer in the year (1991/92) is two times greater than that of the normal year.

The local direct recharge in this area could be supported by the fluctuation of Tritium Centent in the area, which ranges from 5-10 T.U Ex. Nuaymeh No.1,2 and Al Farhan wells.

1.4 Comparing Infiltration and Change in Storage

The calculated amount of infiltration from the surface water data was calculated to be around 124 t0 128 MCM, which represents about 15-16% of the total amount of precipitation. Using the groundwater observation well, the change in storage was calculated to be 45.6 MCM. This amount represents about 36% of the total infiltration. The remainder of the infiltration is discharged as springs and/or seepage along the wadis. The Shallow aquifer (B4) in northern Irbid and Ramtha areas is identifier of that. A small amount of infiltration might be underway to the aquifer as a result of long residence time from the overlying strata and aquitards. However, one can calculate the actual amount of water which has been reached the aquifer from the total amount of precipitation to be about 5%.

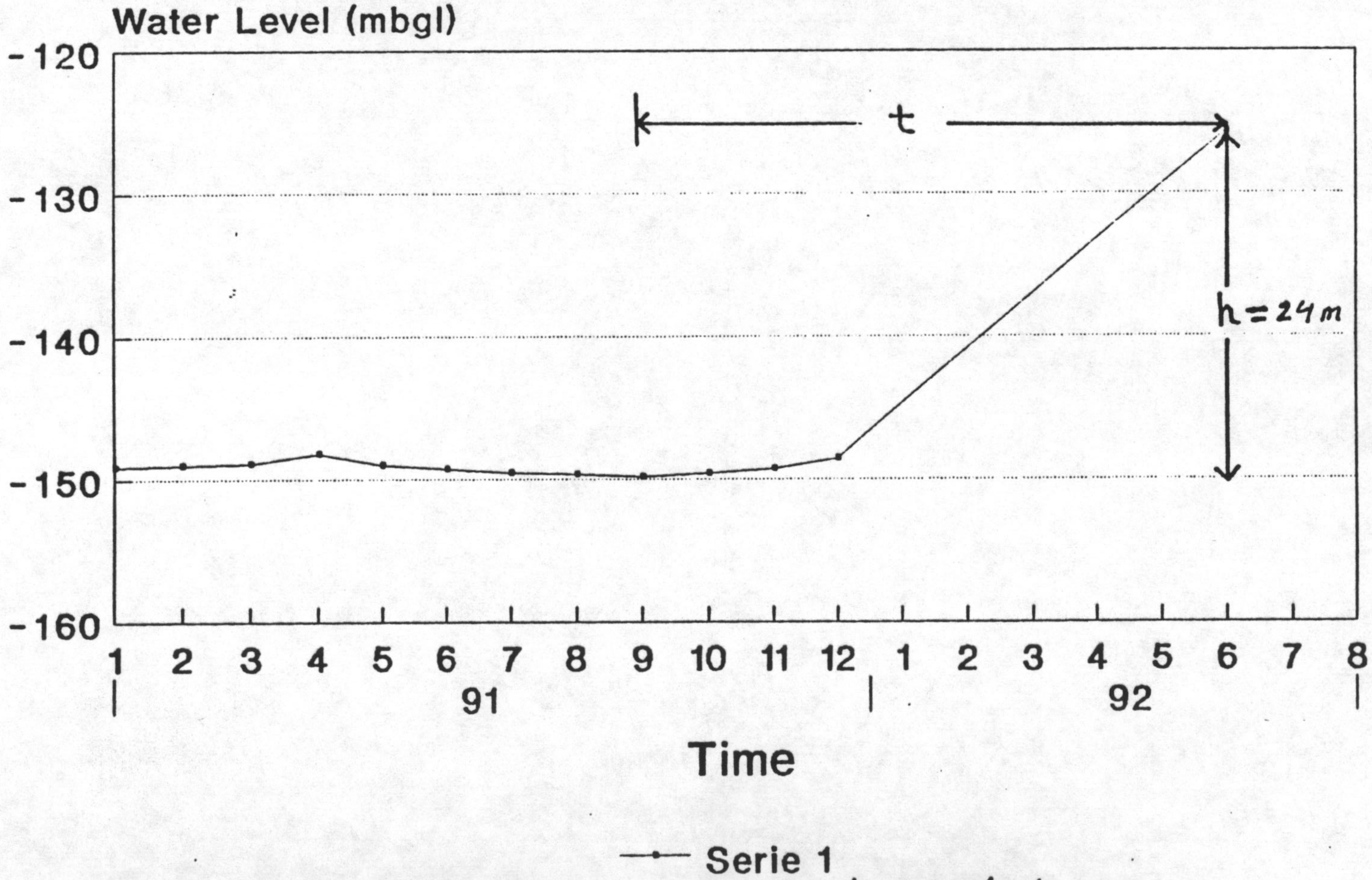

Fig. (6) : Yamoon Observation Well

PART II

WADI AL ARAB BASIN

2. Wadi Al Arab Basin

2.1 Introduction

Wadi Al Arab Basin is situated between the coordinates 212-235 E and 215-237 N (according to Palestine grid) and covers an area of about 267 Km^2 (see Fig.1 of part I).

The general Shape of the basin is oval with the longer axis oriented SE-NW direction. The general slope of the area is from East to West. The highest elevation in Wadi Al-Arab Basin is about 850 m near Irbid city and the lowest elevation is - 170 m at the river bed of Wadi Al-Arab dam site.

The Wadi Al-Arab flows through a deep V-shaped valley to the confluence with the Wadi Zahar, the biggest tributary of Wadi Al-Arab, situated at about 2 km upstream of the dam site.

2.2 Hydrology

2.2.1 Rainfall

The average annual rainfall is approximately about 400 mm. The precipitation is relatively concentrated from October to May with a definite dry season of 4 to 6 months.

There are 6 rainfall stations in and around the Wadi El-Arab Basin. Five of them were selected to construct the Thiessen Polygons of the basin (Fig.1). The Thiessen Polygons methods were used to estimate the areal rainfall occurred in Wadi Al-Arab Basin.

The mean annual rainfall calculated from Figure (1) for the water year 1991-1992 in Wadi Al-Arab is about 977.05 mm. The annual rainfall ranged between 793.6 mm at Kharga Station and 1052.3 mm at Kufr-Assad Station. Table (1) listed the monthly and annual rainfall precipitated over the stations in Wadi Al-Arab Basin of the water 1991/1992.

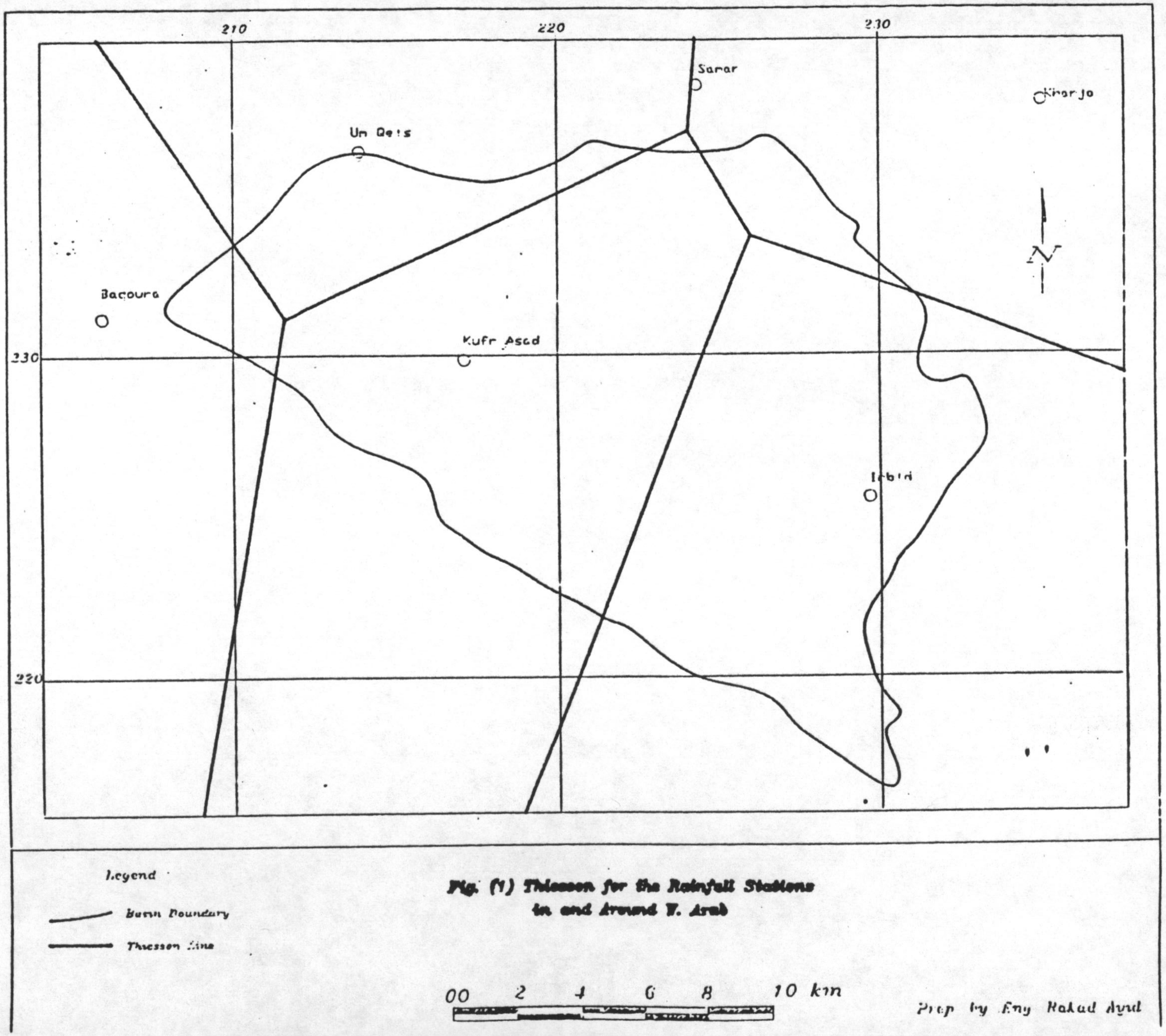

Fig. (1) Thiessen for the Rainfall Stations in and Around W. Arab

Table (1) Monthly and Annual Ranfall Pricipitated over the Stations in Wadi Arab Basin (1991/1992)

Station Name	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Annual
Kharja		75	193.9	176.6	305.5	30.2	8.6	3.8	793.60
Irbid		62.3	233.3	244.6	346	41.2	4.4	12.1	943.90
Kufr Asad	5.2	108.2	252.5	240	382.5	42	10	11.9	1052.30
Um Qeis		106.3	220	187.5	302	17.8	2.8	8.4	849.00
Baqoura		122.5	238.1	174.1	330.1	19.4	8.9	6.2	899.30

Table (2) Mean Monthly Temperature for the Stations in Wadi Arab Basin (1991/1992)

Station Name	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Sammer	23.1	17.6	8.7	6.1	7.5	10.8	16.5
Baqoura	26.3	20.1	12.8	10.7	10.8	12.3	18.8
Ras muneif	18.2	13	4.4	5.1	6.3	9.4	13.9

2.2.2 Runoff

The volume of runoff for Wadi Al-Arab Basin is calculated using the runoff coefficient estimated for a wet year condition. A runoff coefficient of 10 percent is selected for this purpose. The annual runoff is calculated to be about 26.01 MCM.

2.2.3 Evaporation

The rates of evapotranspiration were calculated using the empirical evaporation formulas of Wundt and Turc. These formulas depend on the relation between precipitation and Temperature.

There are 3 evaporation Stations in and around Wadi Al-Arab Basin. The Thiessen Polygons Figure (2), of these evaporation Stations were constructed to calculate the average temperature over Wadi Al-Arab Basin. The average temperature was found to be about (11.7 C; Table, 2) shows the mean monthly temperature for the stations in and around Wadi Al-Arab Basin. As it is mentioned before, the empirical formulas of Wundt and Turc were applied and the evapotranspiration is calculated. The mean annual evaporation is calculated to be about 161.6 MCM by Wundt and 150.4 MCM by Turc, Table (3).

2.2.4 Infiltration :

The "Water Budget" approach is used to calculate the infiltration amount and rate in Wadi Al-Arab Basin as explained previously in the Yarmouk Basin.

The infiltration amount is found to be about 73.26 MCM or 28 percent of the precipitation according to Wundt and 84.46 MCM or 32 percent according to Turc, Table (3).

2.3 Hydrogeology

The B2-A7 aquifer system is the major aquifer in the Wadi Al Arab area. The groundwaters of this basin are under confined to unconfined conditions. There are

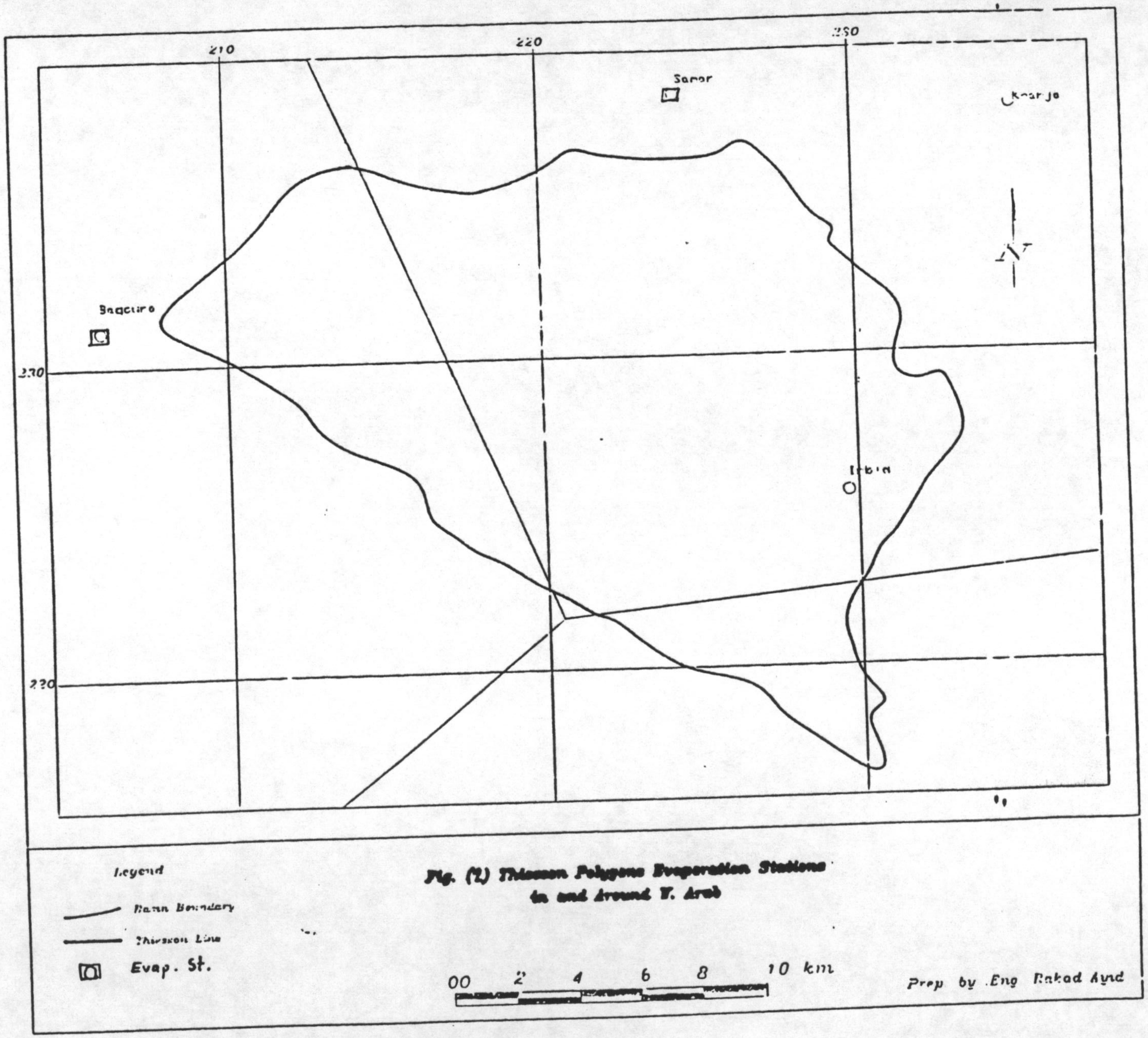

Fig. (2) Thiesson Polygons Evaporation Stations in and Around W. Arab

Table (3) Calculated Water Budget For Wadi Arab Basin (1991 / 1992)

Water Year	Precipitation (MCM)	Temperature C	Evaporation (MCM)		Runoff (MCM)	Infiltration Amount (MCM)		Infiltration Rate	
			Wundt	Turc		Wundt	Turc	Wundt	Turc
1991 – 1992	260.87	11.7	161.6	150.4	26.01	73.26	84.46	28	32

six wells taping the aquifer at various depths; namely Wadi Al Arab 1 to 5 and North Shuneh well. At the time of drilling all wells were flowing, as a result of overpumping most of these wells cease to flow.
Kufar Assad well is the only observation well at in the basin, which lies in the area of the semi-confined.

2.4 Comparison Between Wet and Normal Year

In the course of the North Jordan Water Resources Project (WAJ, 1989), the average infiltration rate was calculated about 15.7 MCM/yr from the total amount of precipitation (130.6). The average infiltration , however, represents around 12% of the precipitation. In comparison, the average infiltration rate of the wet year (1991/92; 28 -32 %) exceeds the normal year (12%) by 2 to 3 times.

2.5 Groundwater Recharge

Fig. 3 of part one shows the gropundwater flow system of the B2-A7 aquifer system of Wadi Al Arab basin (El-Naser, 1991). However, most of the recharge is comming from the Ajlun region and Yarmouk basin.

Direct recharge to the aquifer system is taking place at the southern borders of the basin. Therefore, the data of the observation well of Kufor Assad was used to quantifiy the amount of recharge that reached the aquifer. The hydrograph of the observation well (Fig. 3) shows an increase in the water table of around 15 meters. Such water level elevation did not reached in the well since March 1987, which means that considerable amount of water was infiltrated to the aquifer. The Wadi Al Arab wells no. 1 and 4 of the confined section show an increase in the water level of around 4 meters. However, the infiltrated amount to the aquifer (change in storage) was quantified as follows:

unconfined section (80% of the basin) = Area * Specific Yield * Head Difference

$$= 215\ km^2 * 0.02 * 15m$$
$$= 64.5\ MCM$$

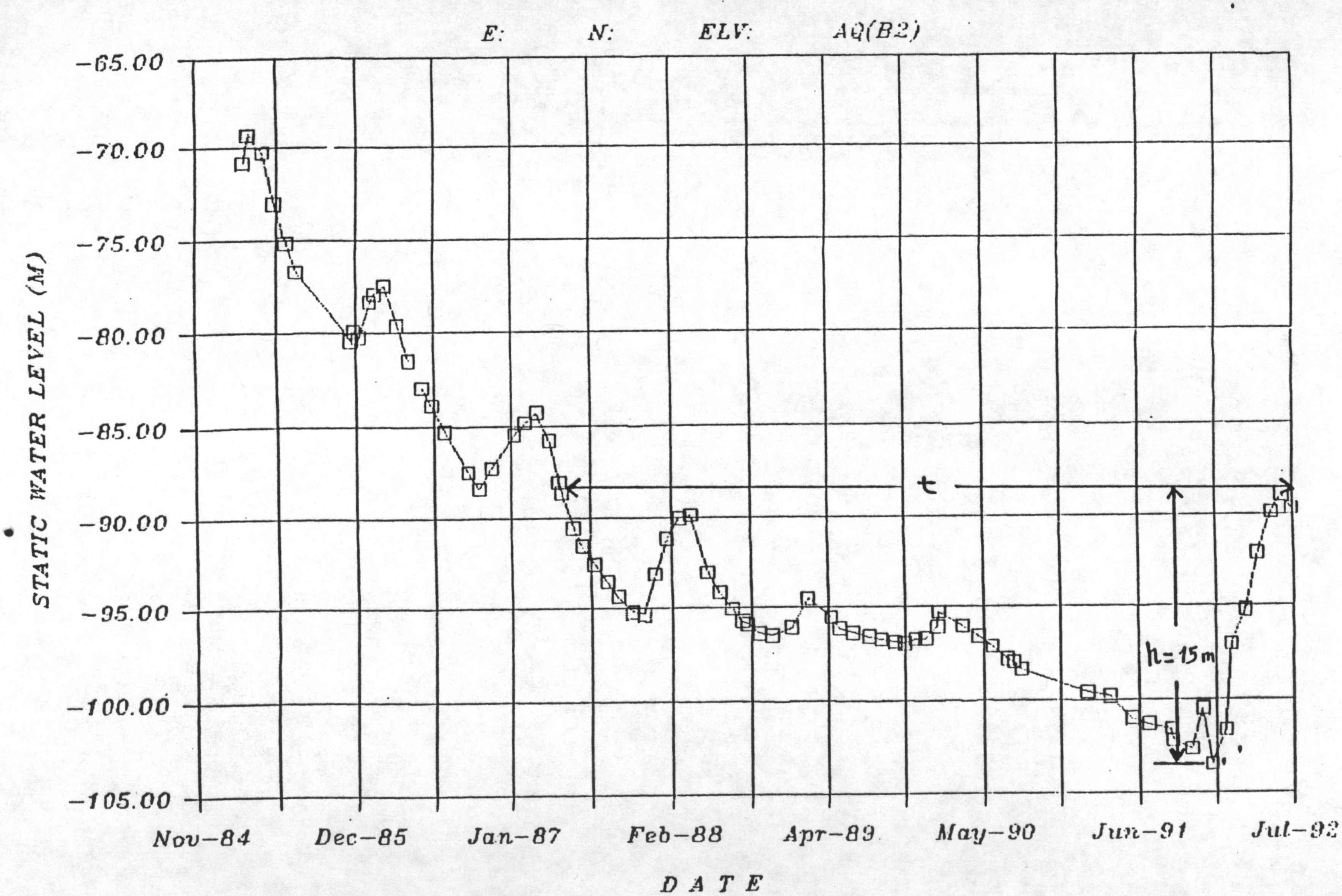

Fig.(3): Kufor Assad Observation Well

*Confined section (20 % of the basin) = Area * Specific Yield * Head Difference*

$= 52\ km^2 * 0.001 * 4m$

$= 0.2$ MCM

.Total of change in storage = 64.5 +.2

= 64.7 MCM

Comparing the calculated amount of water that already reached the aquifer (64.7 MCM) with the total amount of infiltration (84.46 MCM according to Turc and 73 MCM according to Wundt), means that around 77 to 89% of the infiltration is reached the aquifer. The remainder of the infiltration discharged as springs and seapage or might be underway to the aquifer from the overlying strata. However, the leakage from the overlying strata seems to be small or negligible, because the hydrograph of the observation well shows the maximum peak of recharge, which means that the significant amount of recharge is reached the aquifer. The total amount of recharge to the aquifer (64.7 MCM) represents around 25% of the total amount of precipitation. This can be only attributed to the large area of outcrop, which represents around 80% of the basin. Considering the average infiltration to the aquifer of a normal year (15.7 MCM) with that of the wet year (64.7 MCM), indicates that the inflow to the aquifer in the wet year is around 4 times as that of the normal year.

CONCLUSIONS

Yarmouk Basin

The aquifers of the northeastern desert (including Somaya and Mafraq) did not receive any valuable amount of recharge, beccause there is no direct recharge to this aquifer, as shown by the observation wells of that area (Turqi-Somaya 2).

It was approved that most of the recharge is occured over the exposed parts (Ajlun mound) of the B2-A7 aquifer, where direct recharge is taking place. However, the total amount of precipitation over the Yarmouk basin was calculated to be 823.3 MCM. The total amount of infiltration from the surface data was calculated to be around 124-128 MCM, which represents about 15-16% of the total amount of precipitation. In comparison, the average infiltration rate of of the year 1991/92 exceeds the normal year (7-9%) by two times. Using the groundwater observation wells (Yamoon well has shown an increase in the water level of about 24 m), the change in storage was calculated to be 45.6 MCM. This amount represents about 36% of the total infiltration. The remainder of the infiltration (64%) is discharged as springs and seeapage along wadis. A small amount of infiltration might be underway to the aquifer as aresult of long residence time from the overlying strata and aquitards. However, the actual amount of water which has been reached the aquifer from the total amount of precipitation is 5%.

Comparing the mean annual direct recharge (21.5 MCM) with that of the year 1991/92 (45.6 MCM), means that the amount of water which is reached the aquifer is two times greater than that of the average year.

Wadi Al Arab Basin

The total amount of precipitation over the Wadi Al Arab Basin was calculated to be around 261 MCM. The average infiltration rate (73 - 84 MCM) corresponds to about 28 to 33% of the total precipitation. In comparison, the average infiltration rate of the year 1991/92 exceeds the normal year (12%) by 2 to 3 times.

The infiltrated amount to the aquifer (change in storage), using the observation wells (Kufor Assad well has shown an increase of about 15 m), was calculated to be around 64.7 MCM. Comparing the calculated amount of water that already reached the aquifer (64.7 MCM) with the total amount of infiltration, means around 77 to 89% of the calculated infiltration is reached the aquifer. The remainder of the infiltration is discharged as springs and seepage . The total amount of recharge to the aquifer (64.7 MCM) represents around 25% of the total amount of precipitation. Comparing the average inflow to the aquifer of the normal year (15.7 MCM) with that of the year 1991/92, indicates that the inflow to the aquifer in this year (64.7), where direct recharge occurs, is around 4 times as that of the normal year.

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Monthly and seasonal rainfall amounts "mm" in some stations of the Kingdom during the season 1991/1992

Month / Station	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Total	No. of Rainy days>=0.1	No. of days with snow	Maximum Depth of Snow cm
Baqura Nursery	0.7	122.5	238.1	179.4	333.7	19.6	8.9	6.2	9.2	918.3	76	0	
Wadi Yabis	2.2	92.0	185.5	162.5	230.2	20.4	Trace	12.3	3.3	708.4	67	0	
Deir Alla	11.5	74.3	179.6	114.8	182.7	28.6	1.2	4.9	1.5	599.1	68	0	
Ghor Safi	0.7	2.2	18.8	25.2	31.8	4.0	0.3	0.1	0.0	83.1	35	0	
Aqaba Airport	0.2	0.0	3.6	6.4	1.6	0.0	0.0	0.0	0.0	11.8	9	0	
Irbid Nursery	Trace	58.3	233.3	214.6	336.0	36.2	4.4	12.1	18.0	912.9	80	12	100 cm
Ramtha	1.0	30.9	120.3	120.3	147.0	12.5	0.9	4.2	16.1	453.2	62	6	
Taiyba	0.2	103.6	220.0	218.0	350.1	40.3	3.2	14.7	7.7	957.8	71	5	
Ras-Muneif	6.2	110.8	344.9	241.5	376.8	43.3	4.4	11.9	28.2	1168	80	19	150 cm
Jordan University	6.9	83.0	378.5	221.7	370.2	53.9	2.5	10.8	8.1	1135.6	75	13	80 cm
Sweileh	27.9	89.5	345.2	169.0	344.0	42.3	2.9	13.9	Trace	1034.7	80	14	92 cm
Salt	3.6	116.8	379.0	142.5	401.1	59.4	2.6	9.5	3.6	1118.1	67	13	60 cm
Amman Civil Airport	4.7	35.0	171.6	112.1	199.8	16.4	0.9	6.0	1.2	547.7	67	16	30 cm
Amman/Roman Amphitheater	11.9	51.6	279.2	151.2	345.2	26.7	1.4	5.2	0.9	873.3	71	10	
Madaba	4.4	48.8	202.4	119.3	273.9	38.0	0.3	2.5	0.5	690.1	62	8	20 cm
Wadi Wala	1.5	36.3	130.5	70.0	118.2	22.8	0.0	0.5	0.0	379.8	44	X	
Al-Rabbah	13.0	29.8	178.9	135.3	194.7	21.2	0.5	2.8	0.2	576.4	57	13	30 cm
Mouta University	9.0	13.0	142.6	160.3	226.0	45.0	2.5	1.0	0.0	599.4			
Al-Hasan\Tafilah	3.8	8.7	78.6	81.8	105.9	15.9	0.0	0.0	0.0	294.7	43	13	80 cm
Shoubak	10.5	4.7	59.0	154.0	162.3	29.9	0.0	0.4	0.0	420.8	46	21	50 cm
Al-Qurein\Qasmiya	0.0	6.0	18.3	25.6	124.0	0.0	0.0	0.0	0.0	173.9	23	13	
Rwaished	4.7	1.3	7.1	5.9	51.7	0.2	2.0	21.2	4.5	98.6	36	4	4 cm
Mafraq	20.7	17.3	79.9	46.2	102.0	14.2	0.4	3.2	1.6	285.5	66	9	30 cm
Al-Safawi	12.4	0.4	15.5	10.3	44.6	2.1	Trace	3.0	0.0	88.3	34	3	
Wadi Dhuleil	5.2	12.9	90.5	46.7	80.5	15.1	0.5	3.1	2.8	257.3	58	8	
Zarqa Refinery	3.1	11.8	78.1	44.4	112.9	16.4	1.0	4.2	0.6	272.5	58	4	
Azraq South	8.8	4.4	19.9	13.7	16.7	4.0	Trace	0.4	0.1	68	35	2	
Queen Alia Int.Airport	2.1	17.8	92.2	47.6	148.6	16.4	0.2	0.8	Trace	325.7	52	7	
Daba'a	1.3	18.5	65.3	39.1	117.4	17.8	Trace	0.0	0.0	259.4	46	6	
Qutraneh	3.6	6.5	25.7	28.8	64.3	13.6	Trace	0.0	0.0	142.5	40	9	
Ma'an	1.4	0.2	7.0	14.6	8.6	0.6	0.0	0.9	0.0	33.3	25	6	
Wadi Mousa	4.5	3.8	28.0	116.5	107.6	6.5	0.0	0.0	0.0	266.9	31	8	
Jafr	0.6	0.0	3.9	3.3	1.5	1.4	0.0	0.2	0.0	10.9	16	3	

Rainfall amount's in "mm" of the rainy season 1991/1992 and

it is ratio of the mean in percentage

Station	Total	Percent	No. of Rainy days >= 0.1	No. of days with snow	Maximum Depth of Snow cm
Baqura Nursery	918.3	243%	76	0	
Wadi Yabis	708.4	248%	67	0	
Deir Alla	599.1	216%	68	0	
Ghor Safi	83.1	117%	35	0	
Aqaba Airport	11.8	37%	9	0	
Irbid Nursery	912.9	191%	80	12	100 cm
Ramtha	453.2	205%	62	6	
Taiyba	957.8	196%	71	5	
Ras-Muneif	1168	213%	80	19	150 cm
Jordan University	1135.6	239%	75	13	80 cm
Sweileh	1034.7	217%	80	14	92 cm
Salt	1118.1	189%	67	13	60 cm
Amman Civil Airport	547.7	199%	67	11	30 cm
Amman/Roman Amphitheater	873.3	208%	71	10	
Madaba	690.1	193%	62	8	20 cm
Wadi Wala	379.8	143%	44	X	
Al-Rabbah	576.4	177%	57	13	30 cm
Al-Hasan\Tafilah	294.7	118%	43	13	80 cm
Shoubak	420.8	134%	46	21	50 cm
Al-Qurein\Qasmiya	173.9	102%	23	13	
Rwaished	98.6	128%	36	4	4 cm
Mafraq	285.5	188%	66	9	30 cm
Al-Safawi	88.3	127%	34	3	
Wadi Dhuleil	257.3	172%	58	8	
Zarqa Refinery	272.5	192%	58	4	
Azraq South	68	110%	35	2	
Queen Alia Int.Airport	325.7	184%	52	7	
Daba'a	259.4	207%	46	6	
Qutraneh	142.5	135%	40	9	
Ma'an	33.3	82%	25	6	
Wadi Mousa	266.9	145%	31	8	
Jafr	10.9	32%	16	3	