Influence of Urbanization on Water Quantity and Quality at Wadi Shueib Catchment Area (Jordan)

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ABSTRACT

Hydrological and hydrochemical characteristics of Wadi Shueib Catchment Area were evaluated to investigate relationship between water quantity and quality. Catchment area is located at western part of Jordan and covers an area of about 185 km^2. Average annual rainfall varies from 292 to 581 mm, surface runoff depths were between 18.2 and 77 mm and runoff coefficients were between 6 % and 13 %, for stations of Deir Alla and Salt, respectively. Effective rainfall ranges between 49 % and 63 % for the same respective stations. There are 22 springs that discharge water from Wadi Es-Sir, Hummar and Naur carbonate aquifers. Steep slope of topography as a result of Jordan Rift System is a major factor accelerating pollution rate. Spring discharges range from less than 1 m^3/h to about 350 m^3/h. Two hundred twenty two water samples were collected from 10 representative springs during period 1972 to 2000. They were analyzed for their physical and chemical characteristics. Analyzed parameters are electrical conductivity (EC), pH, cations (Na, K, Mg and Ca) and anions (Cl, HCO_3, SO_4 and NO_3). Relatively high NO_3 concentration of some springs is attributed to the high and unplanned urban extension around these springs and to the agricultural activities at the recharge area. The relation between EC, NO_3 and discharge shows that recharge water accelerates pollution for some springs like Jadour Tahta. They are located in urban areas and dilute others, which area located in non-urban areas like Shoreai. The springs are classified biologically into three groups (non polluted, moderately polluted and highly polluted), presence of total coliform, faecal coliform and faecal streptococci of Mahis and Hummar springs indicates availability of faecal pollution.

INTRODUCTION

Wadi Shueib catchment is located at western part of Jordan between Palestine grids 209-229 East and 144-165 North and covers an area of about 185 km^2. The shape of the catchment area is rectangular with long axis oriented in NE-SW direction (Fig. 1). General slope is from east to west with an average slope of stream channels varies from 4 to 7.5 percent. Elevations range from 1118 m above mean sea level (amsl) at Salt City to about 100 m below mean sea level (bmsl) at Shuneh Janoubiyeh with an average elevation of the catchment area of about 600 m (amsl).

Mean annual rainfall ranges between 292 mm at Deir Alla and 581 mm at Salt station. It is a function of land surface altitude. There are several wadis in the catchment area. Main wadis are Salt, Es Sabil, El Amir, Shueib, Hadiya, Tarazin and Jaria (Fig. 2). All of these wadis drain from east to west toward

Jordan Valley. They flush floods during winter into Wadi Shueib Dam Reservoir, which was constructed at low part of study area.

The area is dominated by carbonates of the Upper Cretaceous carbonate rocks (Balqa and Ajlun groups). They are underlain by Kurnub sandstone that is exposed at low limit of Wadi Shueib Catchment Area. Vegetation cover is typical of semi-arid climate zone. Soil is derived from top weathered rocks and alluvial deposits.

Twenty-two springs discharge their water from three aquifers in Upper Cretaceous carbonate rocks (Wadi Es-Sir, Hummar and Naur). Average annual surface runoff at outlet of the catchment area ranged from 0 to 92 and from 21.5 to 309.3 for the stations of Deir Alla and Salt, respectively. Annual baseflow ranges between 17 mm and 46 mm (Water Authority of Jordan (WAJ files)).

MATERIALS AND METHODS

1. Hydrogeology

Two aquifer systems are prominent in the catchment area and are divided into Upper Cretaceous and Lower Cretaceous Aquifers (GTZ, 1977).

Upper Cretaceous Aquifer consists of Ajlun and Balqa groups. The Ajlun group forms the main aquifer system in the study area. Water bearing formations are mainly limestone, dolomite limestone and marlstone. Two formations of Balqa group are exposed at the peaks of the Wadi Shueib catchment (B_1 and B_2). It is composed of limestone separated by chert horizons. The Ajlun group ($A_{1/7}$) consists of marine sediments of Cenomanian-Turonian age (Mac Donald, 1965). It overlies Kurnub sandstone and consists of about 350-460 m of alternation limestone, marly limestone and dolomitic limestone. This group has been distinguished over most of the area.

The Lower Cretaceous aquifers consist of the Kurnub sandstone and is composed of massive white sandstones and varicolored sandstones reaching a total thickness of about 300 m (Bender, 1974). The aquifer does not provide adequate conditions for economic extraction of groundwater because of considerable drilling depths, large pumping lifts, low permeability and poor chemical quality.

Geological structures of the area are highly related to structural faults of the Jordan Rift Valley. Wadi Shueib Catchment is extensively faulted, which increases permeability of aquifers and produces discharges as spring flow. The aquifers have good potential because of extensive development of solution channels, fractures and a large thickness. Infiltration and interflow are controlled mainly by steep slopes. They are quite good due to high rainfall in the area (Hirzalla, 1973).

2.Springs

The discharge of springs is produced by contact springs, which discharge from permeable material overlying impermeable ones as Mahis, Hummar, Tureim, Um Jurban, Shoreai, Baqouriyeh, Jadour Fauka, Jadour Tahta, Shuneh Janoubiyeh and Azraq-Fuheis springs. Discharge quantity and quality of the springs is highly affected by recharge amounts during flood periods (October to May).

3.Floods

Floods result from storms that occur in the area from October to May. These floods are discharged into low part of Wadi Shueib catchment. Small baseflow quantities can be seen at bottom of the wadi. There are no measurements for both runoff and baseflow.

For lack of flow observations, flows were calculated using the United States Soil Conservation Service Method (SCS, 1972) or Curve Number Method (CN) for the available rainfall data. The method was developed after conducting worldwide experiments on different soils and watersheds. It combines soil groups, land use and treatment classes into hydrologic soil cover complex. It can be used for uncultivated land, as well as for agricultural, suburban and urban areas

The Curve Number Method is used to determine flood characteristics and volumes. The method takes into consideration catchment characteristics, antecedent moisture conditions, soil type, initial abstraction of rainfall, slope and length of longest channel, watershed boundaries, urbanization and soil cover. The formula shows the relation between accumulated runoff and the accumulated rainfall (Wanielista, 1990):

$$Q = (P-I_a)^2/(P-I_a+S) \qquad (1)$$

where Q is accumulated depth of runoff in mm, P is the accumulated depth of storm rainfall in mm, I_a is depth of initial abstraction in mm and S is depth of potential abstraction in mm.

Initial and potential abstraction are related to soil deficit, interception and evapotranspiration. The relation between these parameters for the different watersheds was calculated as:

$$I_a = 0.2\ S \qquad (2)$$

The accumulated runoff formula is:

$$Q = (P - I_a)^2 / (P + 0.8\ S) \qquad (3)$$

Relation between CN and S is:

$$S = (1000/CN) - 10 \qquad (4)$$

where S is in inches

The Curve Number (CN) is defined in terms of the watershed land cover and hydrologic soil group types (Rango, 1985). This number can be obtained from a graphical solution. A higher number means that great amount of direct runoff is expected from storm.

Four soil types were classified by the SCS to extract the CN. The hydrologic grouping of soil textures are presented in Table 2. Saturated hydraulic onductivity and hydrologic soil group were found according to percent of sand-silt-clay and were based on predicting green and ampt parameters from soil texture, organic matter content and tillage practice factors. Zero percent porosity change is found according to initial soil state. Runoff Curve Numbers for land cover delineations that are defined from landsat photographs are presented in Table 3. Due to the soil type and the high slope of the area, the CN was estimated to be 60, then:

$S = (1000/60) - 10 = 6.66$ inch or 169.33 mm........................(5)

$I_a = 0.2\ (169.33) = 33.87$ mm ....(6)

$Q = (P-33.87)^2 / (P+135.46)$ ....(7)

The relation between total rainfall, effective rainfall and surface runoff is presented in Figs 3 and 4 for Deir Alla and Salt stations, respectively.

4. Water Analyses

Two hundred twenty two water samples were collected and analyzed on annual basis for their electrical conductivity, pH, cations (Na, K, Mg and Ca) and anions (Cl, HCO_3, SO_4 and NO_3). Also, 20 microbiological samples (2 samples from every spring) were collected between November and May. The samples were collected from 10 representative springs. They discharge their water from A_7, A_4 and $A_{1/2}$ carbonate aquifers.

Chemical analysis of the springs water quality indicates that some of the spring waters are characterized by high electrical conductivity, such as Jadour Fauka, Um Jurban, Jadour Tahta and Mahis springs (Fig. 5). The high concentrations of elements in the spring water could be attributed to contamination of water from domestic water and/or cesspools of urbanized areas that are located in the catchment of the springs. NO_3 is most affected parameter. It fluctuates rapidly with the quality of recharge water (Fig. 6).

The relationships between the electrical conductivity (EC) and nitrate (NO_3) with springs discharge indicates that, the EC and NO_3 of some springs correlate directly and significantly with the discharge (Q). Some of them have negative (reversal) correlation with the discharge of the springs (Q).

Direct relationship between EC, NO_3 with Q indicates high concentration of NO_3 and EC by the increase of springs discharge. This means that, pollutants are carried by floodwaters recharge or transport to the springs sources and consequently pollute them. This can be obviously seen in Jadour Tahta and Shuneh Janoubiyeh springs (Fig. 7). On other hand, negative or reversal relationships between EC, NO_3 with Q indicate that, the EC and NO_3 decrease as the discharge increases. The direct recharge to groundwater from rainfall in winter season dilutes the springs water quality and consequently decreases the pollutants and salinity at the same time. A good example for this case can be given on Jadour Fauka and Shoreai springs (Fig. 8).

Purpose of microbiological examination is to investigate if there is potentially dangerous faecal coliform pollution. The analyses indicate that some of the springs are free from any biological contamination such as Tureim and Jadour Fauka. It was due to the absence of pollution sources or polluted water that pass through soil layers which work as a filter in removing pathogenic bacteria. Um Jurban, Jadour Tahta and Baqouriyeh analyses indicate that the springs are moderately polluted. Also Shoreai spring is subjected to non-continuous source of pollution as indicated by difference in contamination level in the analysed water samples.

RESULTS AND DISCUSSION

Scarcity of water resources and their pollution are considered gravest environmental challenge facing Jordan, due to arid to semi-arid climate, high population growth and depletion of available water resources. Gap between water supply and demand is expected to continue. For example, the population of Wadi Shueib Catchment area at western part of the country is increased from 41200 in year 1985 to 66595 in the year 2000 (Fig. 9). It increases stress on springs water, which are considered major source to cover the demand of population and development of agricultural activities.

1. Rainfall and Runoff Characteristics

Wadi Shueib Catchment is highly effected by the Jordan Rift system. It can be seen from the high slope of the catchment area and mountainous characteristics of topography. For last 2 decades (1980/1981 to 1999/2000), annual rainfall varied from a minimum of about 102 mm to a maximum of about 600 mm with an average of 292 mm for Deir Alla station. It was almost two times higher at Salt station (around 1200 m elevation difference), where annual rainfall varied from a minimum of about 223 mm to a maximum of about 1191 mm, with an average of about 581mm.

Surface runoff for the soil surface cover depends mainly on rainfall amounts, intensity and distribution. Increasing amount of rainfall does not necessarily increase amount of effective rainfall that caused surface runoff (Table 4). At Deir Alla station, 102 mm rainfall amount (1998/1999) produced 49 mm (48 % of total rainfall) effective rainfall, whereas 169 mm rainfall amount (1993/1994) resulted in 0.0 mm effective rainfall (no surface runoff). Also, at Salt station during 1992/1993, 75 percent of the total rainfall (667 mm) was effective rainfall (500 mm). It dropped to about 34 percent during the winter season of 1987/1988 for almost the same (even high) amount of total rainfall (697 mm). The variation can be attributed to type of storms, which varies from orographic to thunderstorms during the same year. It is due to initial soil moisture and rainfall distribution.

Based on field observations, topography, soil type (sandy to silty), vegetation cover and hydrologic soil group (Table 3), the curve number (CN) was estimated to be about 60. For the last 2 decades average surface runoff varies from 0 to 92 with an average of 18.2 mm at Deir Alla station and from 21 to 309 with an average of 77 mm at Salt station. Runoff coefficient was only about 6 percent at Deir Alla station and increased to more than 2 times (13 percent) at Salt station (Table 4).

The effective rainfall (portion of rainfall that produces surface runoff) ranges form an average of 49 % at Deir Alla station to about 63 % at Salt station from the total rainfall. In general, for the years of annual rainfall that has an average more than 50 percent of the total rainfall appears to have effective rainfall for almost 75 % of time.

2. Water Quality

The lower part of the catchment area is suffering from urban expansion along direction of groundwater flow (Fig. 2). Electrical conductivity of the different springs increases in the direction of groundwater flow. It is almost two times high at low part (Shuneh Janoubiyeh) as compared to the electrical conductivity at the upper part of the catchment area (Azraq-Fuheis).

Table 5 shows that HCO_3 is most dominant anion and SO_4 is least at all springs, except for Shuneh Janoubiyeh where NO_3 is the most dominant anion. The HCO_3 concentration originates from the dissolution of rocks forming spring aquifer. Anion concentrations are in order of $HCO_3 > Cl > NO_3 > SO_4$ at upper part. They are in the order of $HCO_3 > NO_3 > Cl > SO_4$ at the lower part of catchment area. Also, for all springs the most dominant cation is Ca and the least is the K. Cations concentration are in the order of Ca > Mg > Na > K for the upper part and in the order of Ca > Na > Mg > K at the lower part of the catchment area.

In general, cations and anions concentrations followed the same trend as electrical conductivity. They increase toward the low part of the catchment area. The NO_3 concentrations exceed the international standards for drinking water for Jadour Fauka, Jadour Tahta and Um Jurban springs at the low part of the catchment area. The increase in NO_3 concentration is attributed to contribution of excess nitrogen fertilization due to increase of agricultural activities, root nodule bacteria, algae, and pollution that results from urban extension in the recharge area.

The SO_4 composition is contained in organic compounds such as plants, animals and came mainly from magmatic gases (Matthess, 1982). The relatively high SO_4 value (58±14) at Shueh Janoubiyeh spring water indicates that it is recharged partly from lower aquifer through artesian pressure of confined aquifers.

The average annual chemical composition of the springs water shows alkaline earth water. It has prevailing hydrogen carbonate and alkaline earth waters. They have increased portion of alkalines and prevailing hydrogen carbonate and chloride (Langguth Classification, 1966) (Fig. 10).

Relation between EC, NO_3 and discharge (Q) indicates that the springs can classified into two groups according to their recharge source and urbanization. The recharge of first group as Jadour Tahta is polluting the springs and destroying their quality. The recharge of second group as Shoreai is diluting the water quality in spring reservoir and making their water quality good for all uses. Most prominent factor that affects quality of the recharge water is urbanization around the recharge sources of the springs at different parts of the catchment area (about 4 percent population growth). High slope of the catchment are accelerates the pollution and makes the springs directly influenced by the pollutants a long the line of spring recharge.

Results of microbiological analyses indicate that the spring water can be classified into three groups:

1. Non polluted springs as Tureim and Jadour Fauka. Their water is completely free from faecal coliform streptococci.
2. Moderately polluted springs like Jadour Tahta, Shuneh Janoubiyeh, Um Jurban, Hummar, Baqouriyeh, Shoreai and Azraq-Fuheis. The faecal coliform of this group ranges between 7 and 400 MPN/100 ml. Faecal streptococci ranges between 1 and 17 cfu/ml. Disinfecting treatment is sufficient to obtain good quality of potable water.
3. Highly polluted water like Mahis spring. Disinfecting treatment of high dosage chlorine might be sufficient to obtain good quality of potable water.

Presence of three indicator organisms (total coliform, faecal coliform and faecal streptococci) in the analysed water samples of Mahis and Hummar springs indicates availability of faecal pollution. Disinfecting treatment (chorination) is necessary to obtain continuous microbiologically accepted water. Monitoring of the springs is essential. Presence of bacteria possibly suggests direct infiltration of water through limestone fissures and joints. The microbiological analyses of the studied springs are presented in Table 6.

CONCLUSION

For the last two decades, effective rainfalls annual averages were about 49 % and 63 % at Deir Alla and Salt stations respectively. In the years where annual rainfall exceeds the average, 50 % of total rainfall appears as effective rainfall for almost 75 % of the time. The high slope of the catchment area affects the water quantity and quality of the springs. The recharge of some springs pollutes their water quality due to urbanization around the recharge sources. Biologically, the springs are classified into three groups: non polluted, moderately polluted and highly polluted.

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Table 1. Springs located at Wadi Shueib catchment and their discharge quantities.

No.	Spring Name	Palestine Grids		Aquifer	Discharge (m^3/h)		
		East	North	Type	Maximum	Minimum	Average
1	El Khandaq	218.7	166.6	A_4	96.0	0	36.0
2	Jadour Tahta	219.2	160.0	A_7	92.6	1.9	39.8
3	Jadour Fauka	219.2	159.8	A_7	40.2	3.0	18.9
4	Farkha	219.5	159.4	A_7	20.9	3.0	8.6
5	Deek	220.0	159.4	A_7	17.0	1.7	5.6
6	Hazzir	219.6	158.4	A_4	332.0	10.1	83.9
7	Mukarfat	218.7	156.1	A_7	2.8	0.3	0.8
8	Um Zarura	227.6	159.3	$A_{1/2}$	4.6	0.1	0.6
9	Hummar	227.1	158.6	A_4	19.1	0	5.1
10	Ain Um Juma	226.1	158.2	$A_{1/2}$	1.0	0.2	0.6
11	El Balad Fuheis	223.2	156.7	$A_{1/2}$	27.0	0.4	11.2
12	Azraq-Fuheis	222.1	158.8	A_7	583.0	50.0	252.0
13	Shoreai	221.1	157.8	A_7	352.0	60.1	143.7
14	Baqouriyeh	219.4	155.3	A_7	860.0	61.0	350.0
15	Es Sabra	218.6	154.8	A_4	95.0	3.3	10.0
16	Mahis	222.7	155.0	$A_{1/2}$	60.1	19.9	40.0
17	Tureim	222.7	155.1	$A_{1/2}$	22.5	8.6	12.7
18	Nazzazat Mahis	222.8	155.2	$A_{1/2}$	1.6	0.8	1.1
19	Um Ghannoum	222.5	154.9	$A_{1/2}$	10.3	3.0	5.9
20	Um Jurban	222.3	154.0	$A_{1/2}$	42.1	5.6	12.1
21	Shuneh Janoubiyeh	211.0	147.2	A_4	46.9	2.6	15.5
22	Al Alali	223.3	156.4	A_7	14.4	0	7.2

Table 2. Hydrologic grouping of soil textures.

Hydrologic Soil Grouping	Soil Textures
A	Sand, loamy, and sandy loam
B	Silt loam and loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay and clay

Table 3. Runoff Curve Numbers for land cover delineations defined from landsat investigations (Ragan & Jackson, 1976)*.

Land Use Description	Hydrologic Soil Group			
	A	B	C	D
Forest Land	25	55	70	77
Grassed Open Space	36	60	73	78
Highly Imperviousness (Commercial Industrial, Large Parking Lot)**	90	93	94	95
Residental	60	74	83	87
Bare Ground	72	82	88	90

* The soils B and C were chosen for Wadi Shueib catchment.

** According to Ragan and Jackson (1976), CN = 93 Probably sufficient for all soils.

Table 4. Total rainfall, effective rainfall and surface runoff depth in mm for the stations of Deir Alla and Salt.

Water year	Deir Alla			Salt		
	Total rainfall	Effective rainfall*	Surface runoff	Total rainfall	Effective rainfall*	Surface runoff
1980/81	255.7	157.0	9.5	640.3	394.4	93.6
1981/82	246.7	128.3	12.2	494.1	312.1	78.8
1982/83	426.6	265.0	17.5	829.2	660.1	117.3
1983/84	183.5	60.4	3.6	482.3	394.0	45.8
1984/85	166.7	51.0	1.6	542.6	364.0	93.1
1985/86	235.5	105.8	4.9	396.6	169.8	25.2
1986/87	344.2	200.4	83.0	599.2	400.0	109.8
1987/88	350.6	236.4	15.6	696.7	240.3	21.5
1988/89	255.6	49.0	1.3	568.7	476.5	74.4
1989/90	303.7	68.3	0.3	512.5	251.0	42.6
1990/91	252.3	137.4	2.6	535.7	234.5	40.9
1991/92	599.6	424.3	92.0	1190.7	941.3	309.3
1992/93	287.3	154.7	26.9	666.5	499.7	114.9
1993/94	169.0	0	0	442.7	300.5	33.4
1994/95	381.2	205.8	53.0	598.4	266.8	47.5
1995/96	266.6	181.2	4.6	492.4	355.7	92.6
1996/97	366.0	178.9	12.0	600.4	302.6	74.3
1997/98	352.3	63.4	4.4	518.3	274.2	25.3
1998/99	102.1	48.9	1.2	223.4	109.2	23.4
1999/2000	103.4	50.2	1.1	265	119.5	22.3
Average	282.4	138.3	17.4	564.8	353.3	74.3
Runoff coefficient (%)		6			13	

* Rainfall resulted in surface runoff

Table 5. Chemical characteristics of Wadi Shueib Springs.

Spring Name	Period (Years)	EC (µS/cm)	pH	Cations (mg/l)				Anions (mg/l)			
				Na	K	Mg	Ca	Cl	HCO_3	SO_4	NO_3
Jadour Tahta	1980-2000	890±71	8±0	44±8	22±8	23±4	96±6	67±7	296±18	33±10	105±22
Jadour Fauka	1979-2000	818±47	8±0	36±6	17±6	24±4	84±7	63±5	251±16	26±10	94±24
Azraq-Fuheis	1973-2000	480±62	8±0	13±6	3±3	18±8	63±12	28±10	219±20	13±12	28±11
Shoreai	1979-2000	479±39	8±0	12±3	2±1	16±3	60±8	26±5	212±12	13±7	26±4
Baqouriyeh	1975-2000	582±54	8±0	20±5	4±1	18±3	68±10	38±5	235±19	22±8	36±5
Hummar	1979-2000	562±53	8±0	15±4	2±2	18±3	73±10	30±5	262±30	11±7	26±5
Mahis	1987-2000	620±54	8±0	19±5	1±1	20±4	79±9	38±5	273±26	17±11	33±7
Tureim	1985-2000	594±63	8±0	18±4	1±1	21±3	75±9	35±3	269±26	14±5	30±8
Um Jurban	1980-2000	800±83	8±0	36±9	6±2	23±4	90±8	65±10	278±43	23±6	73±11
Shuneh Janoubiyeh	1972-2000	856±140	8±0	52±14	6±2	30±5	81±10	94±22	285±22	58±14	30±12

±: standard deviation

Table 6. Microbiological Analyses for the Studied Springs at Wadi Shueib Catchment Area.

Spring Name	Total Coliform (MPN/100 ml) 1999/2000		Faecal Coliform (MPN/100 ml) 1999/2000		Faecal Streptococci (cfu/ml) 1999/2000		Total Heterophic Plate Count (cfu/ml) 1999/2000	
	1/11/99	5/4/2000	1/11/99	5/4/2000	1/11/99	5/4/2000	1/11/99	5/4/2000
Shuneh Janoubiyeh	>2400	>2400	400	150	0	0	1280	38000
Shoreai	160	>2400	9	>2400	0	0	0	18700
Jadour Tahta	350	420	160	425	3	0	850	9700
Jadour Fauka	38	142	<3	7	4	0	280	940
Um Jurban	87	235	11	210	2	0	150	14200
Hummar	1850	>2400	110	180	33	17	450	6950
Mahis	>2400	>2400	>2400	1200	52	11	275	5220
Tureim	65	87	7	0	0	0	90	392
Azraq-Fuheis	120	>2400	3	>2400	0	9	1982	8750
Baqouriyeh	43	400	4	37	3	0	112	25

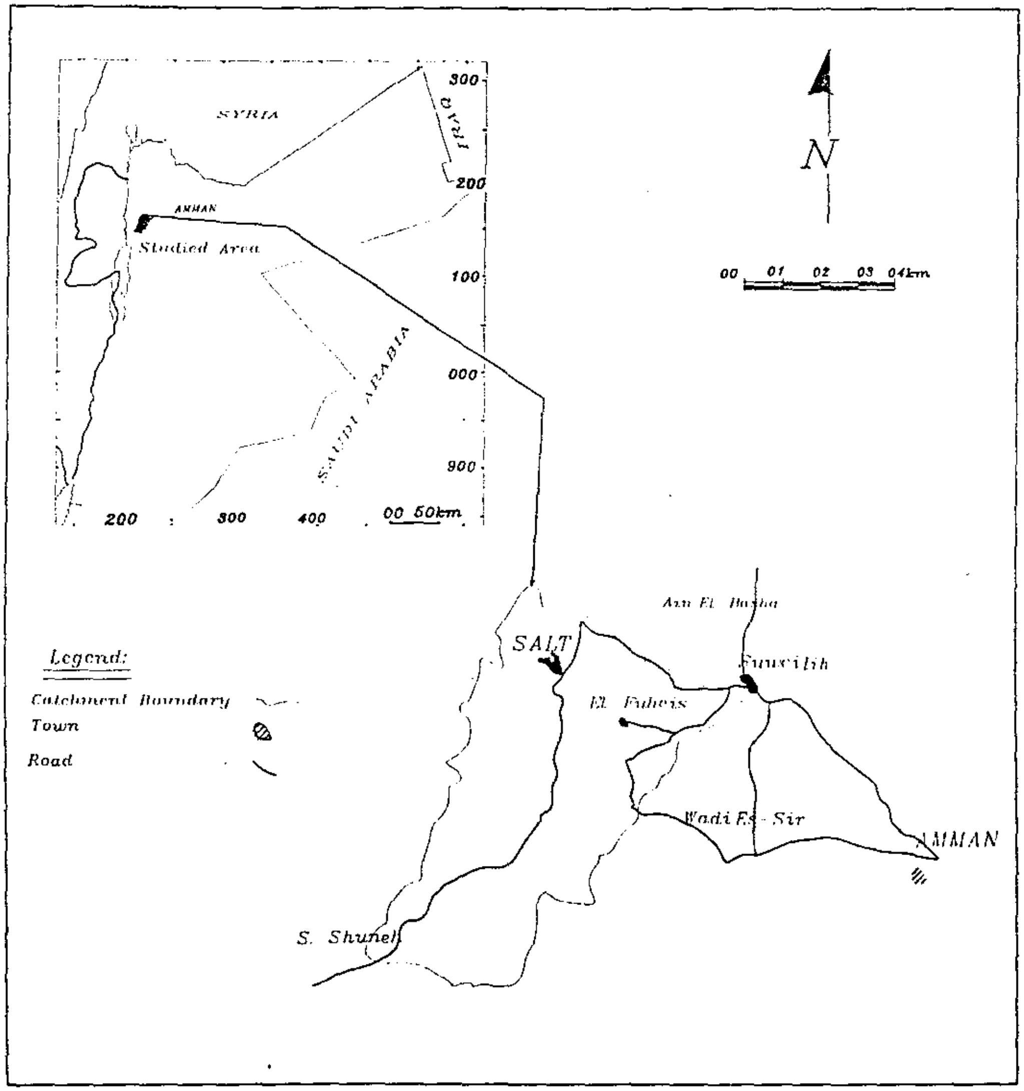

Fig. 1. Location Map of Wadi Shueib Catchment Area.

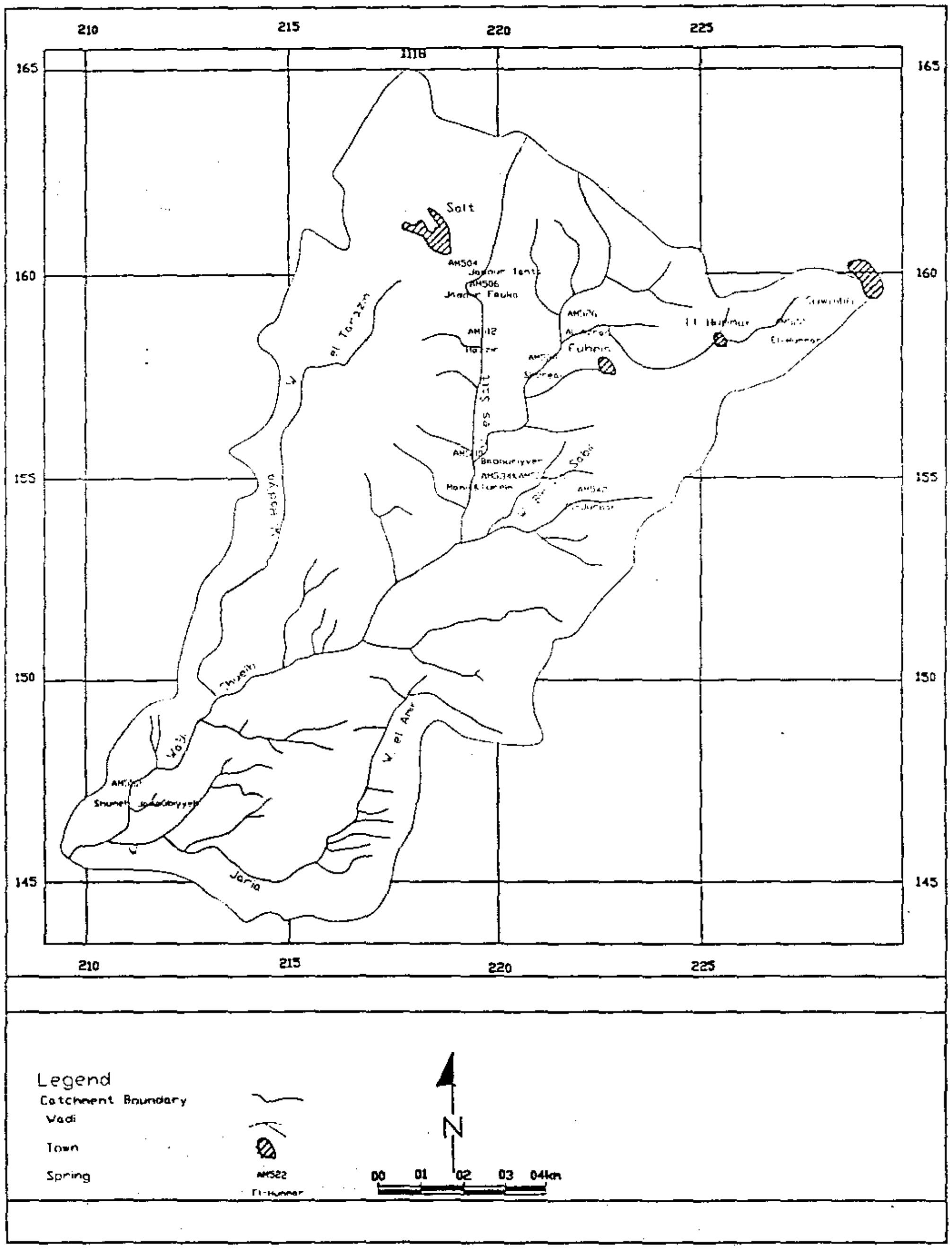

Fig. 2. Location Map of the Major Springs in Wadi Shueib Catchment Area.

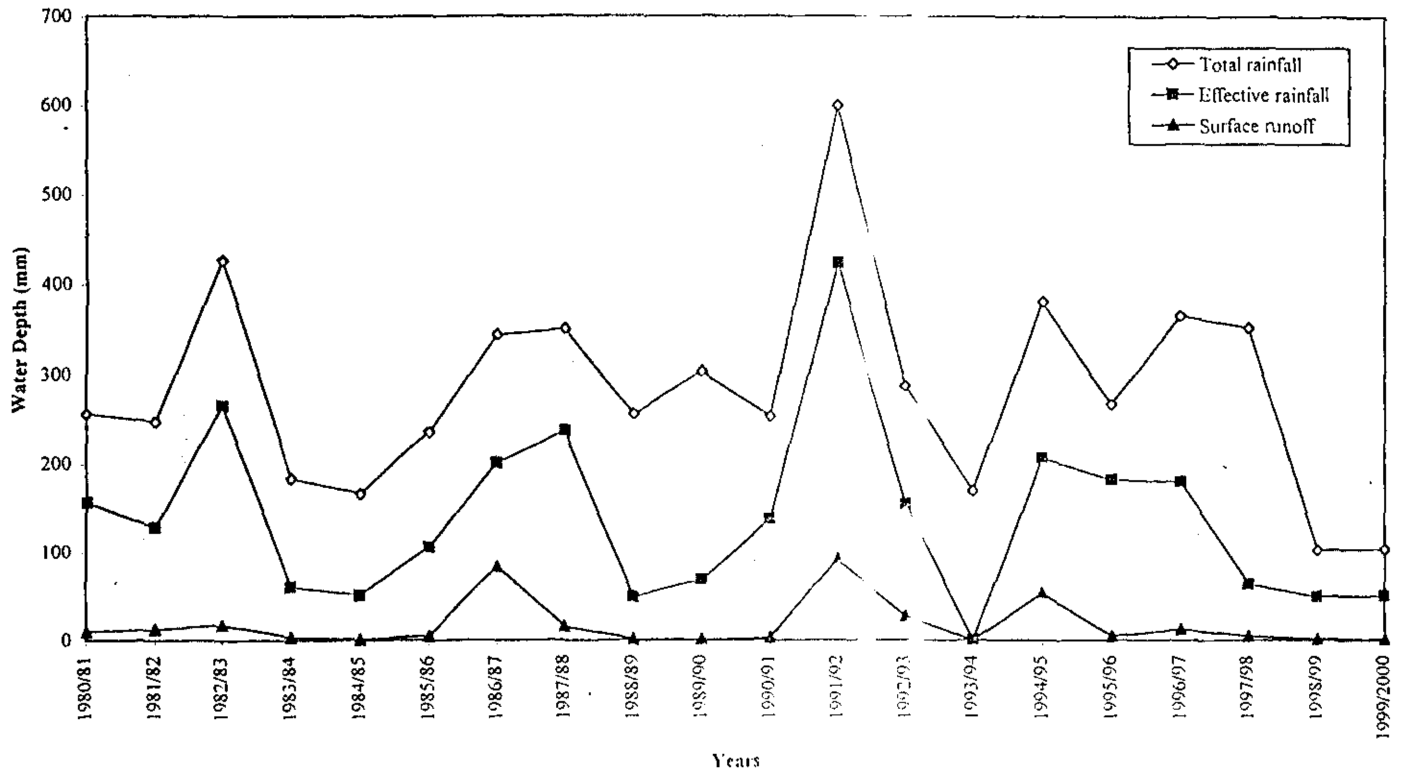

Fig. 3. Rainfall-Runoff Relationship for Deir Alla Station.

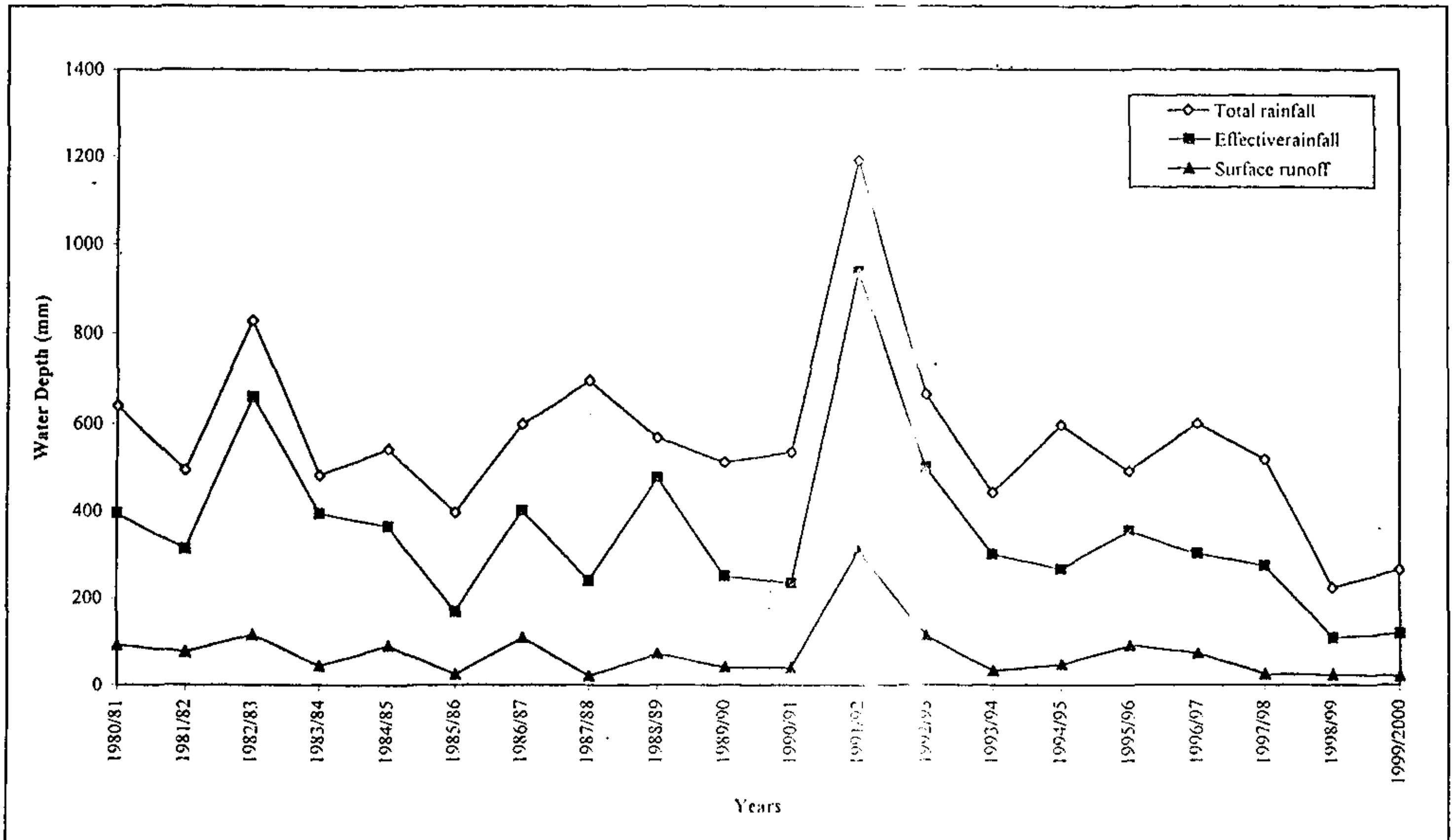

Fig. 4. Rainfall-Runoff Relationship for Salt Station.

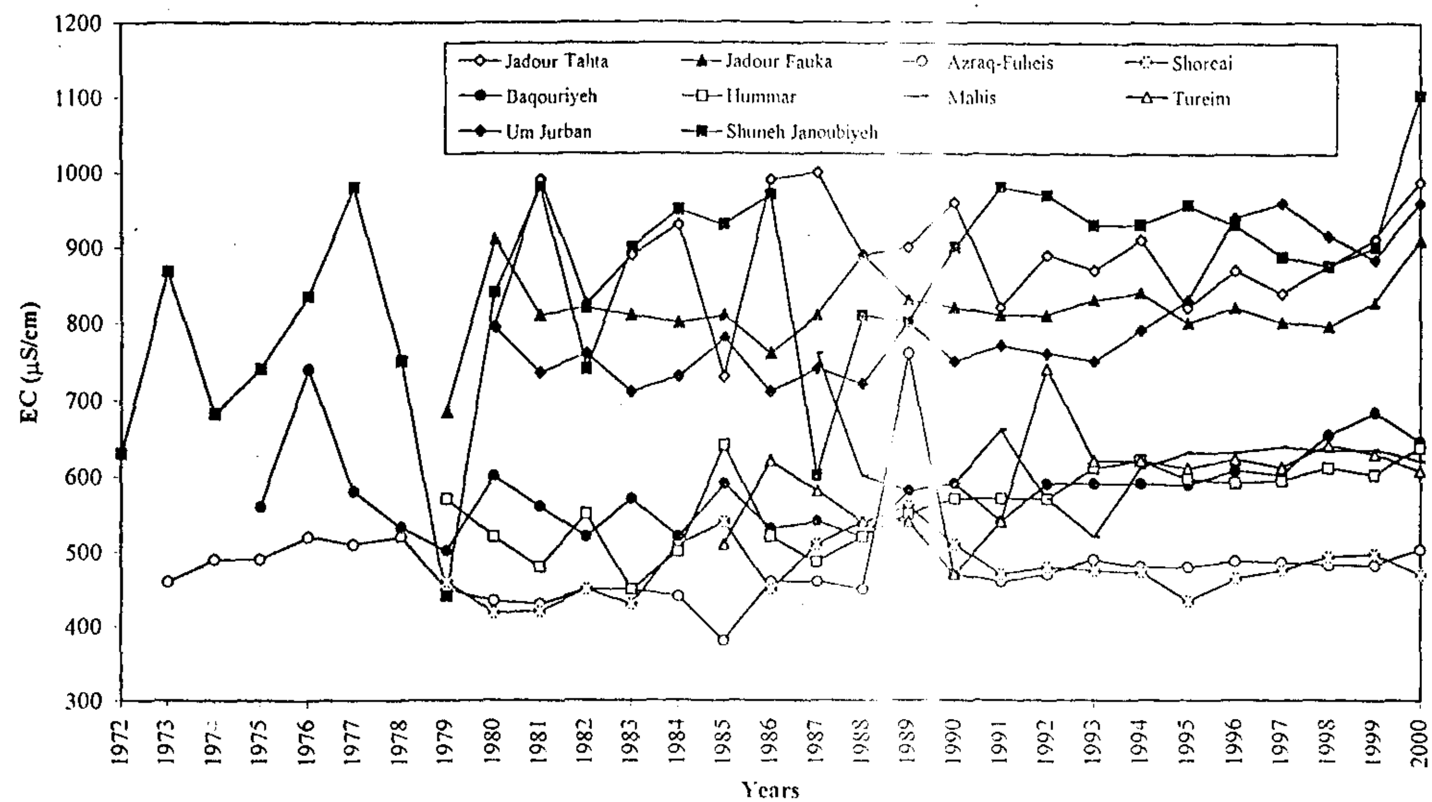

Fig. 5. Variation of Electrical Conductivity of Wadi Shueib Springs during 1972-2000.

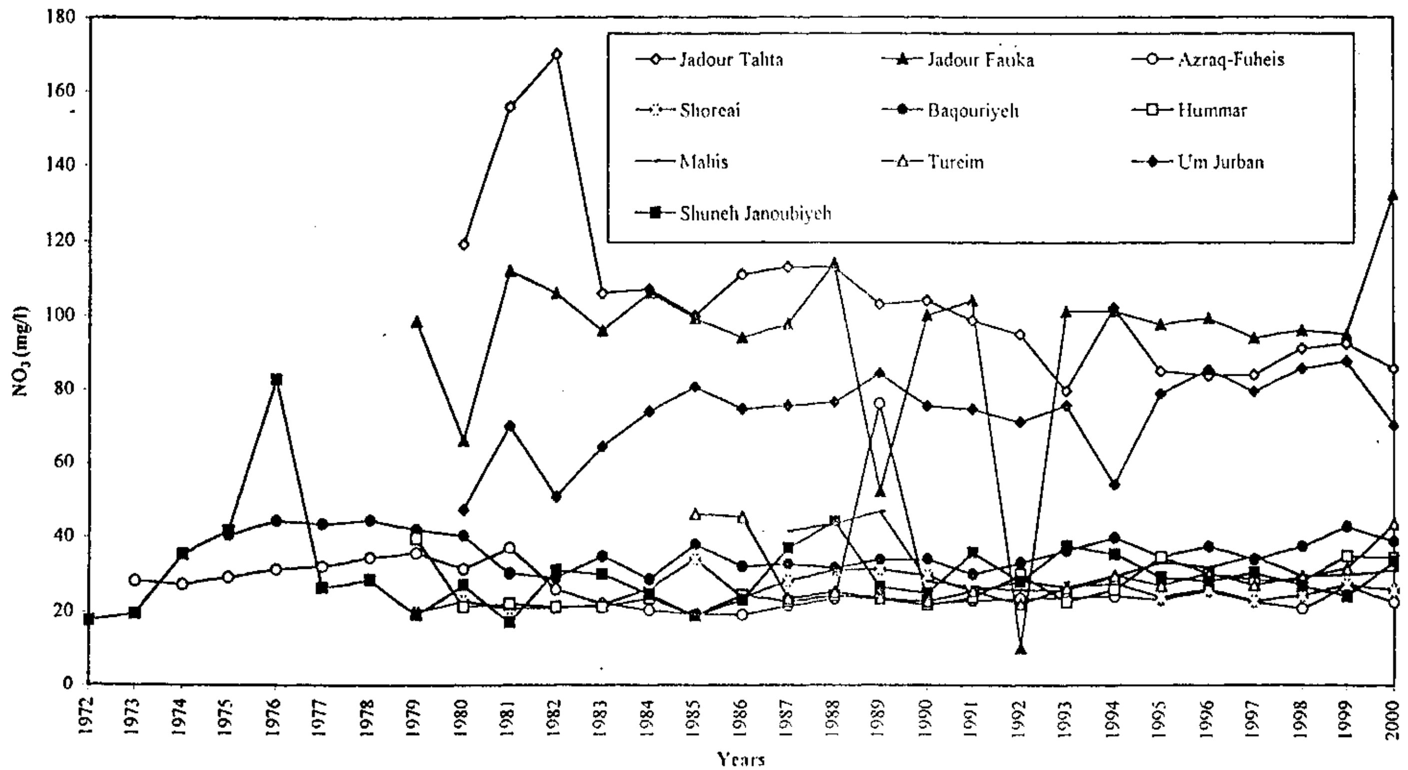

Fig. 6. Variation of NO_3 of Wadi Shueib Springs during 1972-2000.

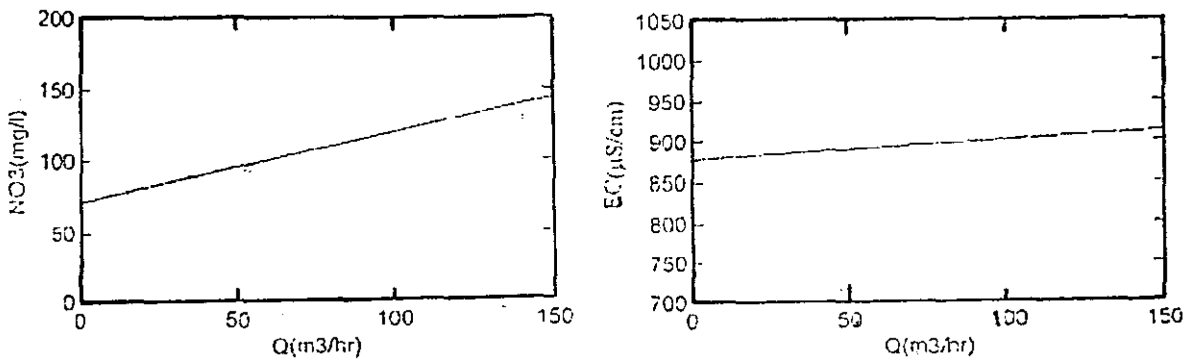

Fig. 7. Relationship Between EC, NO_3 and Discharge (Q) for Jadour Tahta Spring.

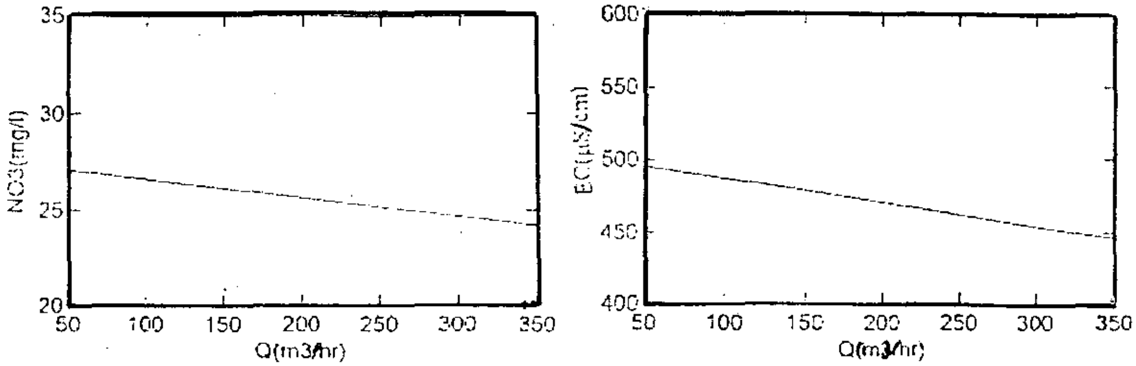

Fig. 8. Relationship Between EC, NO_3 and Discharge (Q) for Shoreai Spring.

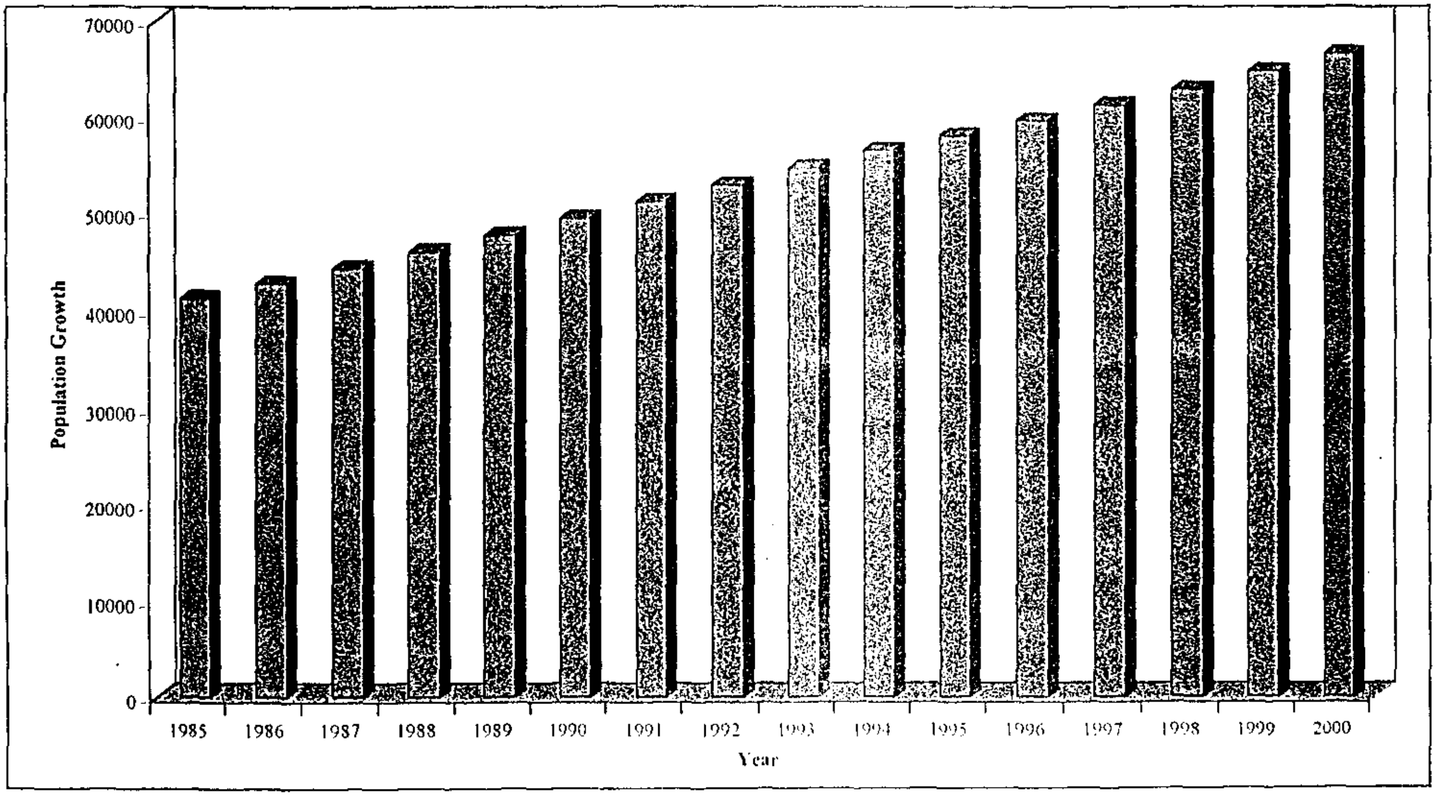

Fig. 9. Population Growth of Wadi Shueib Catchment Area during 1985-2000

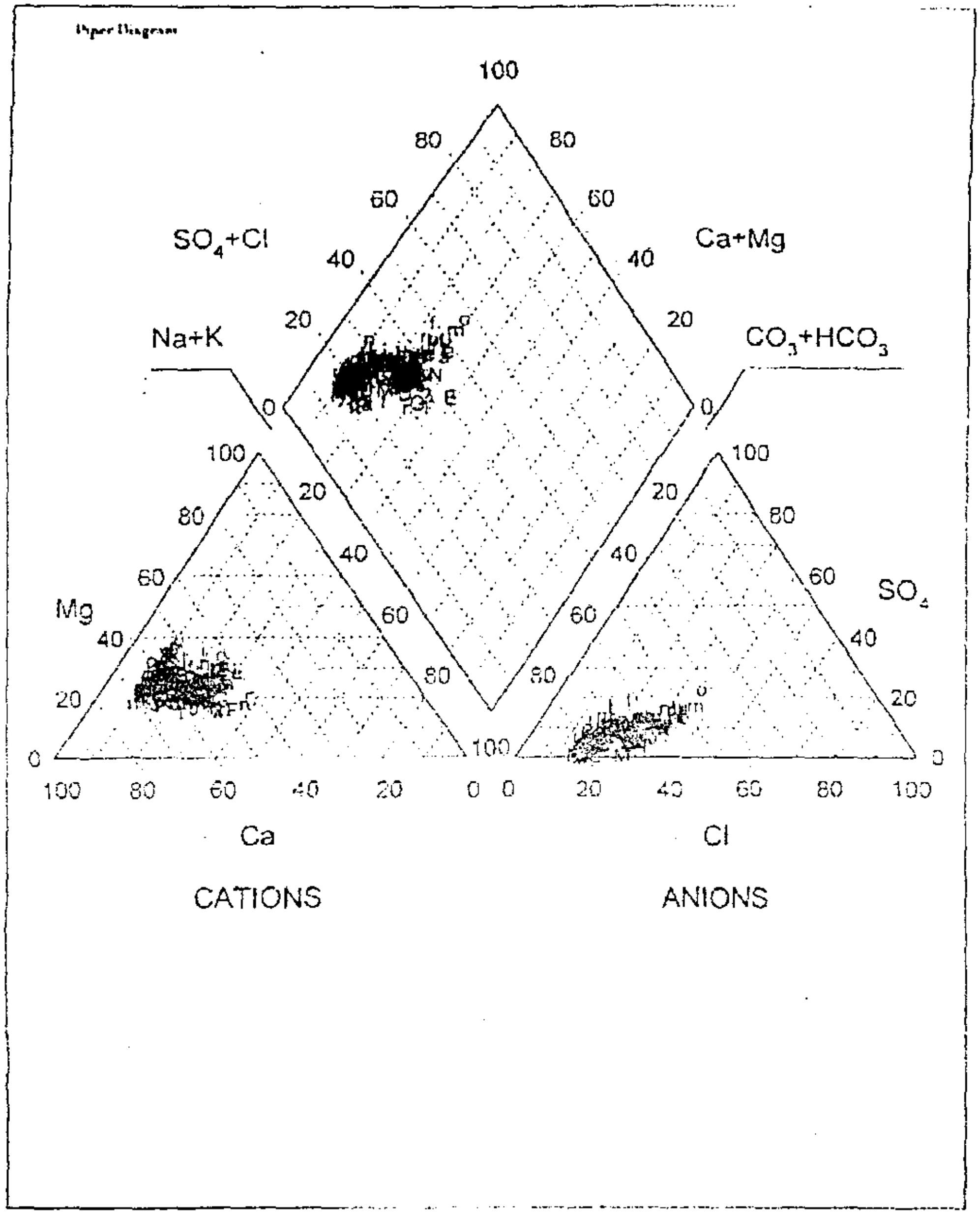

Fig. 10. Trilinear Presentation of Wadi Shueib Catchment Area Springs.

الملخص العربي

تأثير التمدن على كمية ونوعية المياه الجوفية في حوض وادي شعيب (الأردن)

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يهدف هذا البحث دراسة الخصائص الهيدرولوجية والكيماوية لحوض وادي شعيب لإيجاد علاقة بين نوعية و تصريف الينابيع. يقع الحوض في الجزء الغربي من الأردن و يغطي مساحة ١٨٥ كم٢. يتراوح معدل المطر السنوي بين ٢٩١ و ٥٨١ ملم و الجريان السطحي ما بين ١٨,٢ و٧٧ ملم و معامل الفيضان ما بين ٦ و ١٣ بالمائة وذلك لمحطات ديرعلا والسلط على التوالي. ويتراوح معدل المطر الفعال ما بين ٤٩ و ٦٣ بالمائة للمحطتين على التوالي. يتواجد في الحوض المائي ٢٢ نبعه تخرج مياهها من خزانات وادي السير والحمر وناعور الجيرية المشققة. يعتبر الميل العالي لطبوغرافية الصخور نتيجة حفرة الانهدام السبب الرئيسي في تسارع عامل التلوث. يتراوح معدل تصريف الينابيع ما بين اقل من ١م٣/ساعة إلى حوالي ٣٥٠م٣/ساعة. تم في هذه الدراسة تحليل ٢٢٢ عينة مياه من عشرة ينابيع ممثلة خلال الفترة ١٩٧٢ إلى ٢٠٠٠. حيث تم تحليل الخصائص الفيزيائية والكيميائية والبيولوجية مثل الموصلية الكهربائية ودرجة الحموضة والأيونات الموجبة (Na, K, Mg, and Ca) والأيونات السالبة (Cl, HCO_3, SO_4, and NO_3). إن تركيز النترات العالي يعزى إلى التوسع العمراني العشوائي حول الينابيع، إضافة للنشاطات الزراعية عند مصادر تغذية الينابيع. كذلك فإن العلاقة ما بين الموصلية الكهربائية وتركيز النترات أظهرت أن مصادر تغذية مياه الينابيع بالإضافة إلى العواصف المطرية تساهم في زيادة التلوث لبعض الينابيع الواقعة في المناطق المأهولة بالسكان مثل الجادور التحتا في حين يقل تركيز التلوث للبعض الآخر في المناطق غير المأهولة مثل الشرعة. تصنف الينابيع بيولوجيا إلى ثلاث مجموعات (غير ملوثة ومعتدلة التلوث، وملوثة) إضافة إلى أن التلوث مستمر لبعض الينابيع إذا بقيت الظروف على الوضع الحالي.