Regionalization of Surface Water Catchments in the East Bank ofJordan

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Abstract

A regional division of 30 surface water catchments in the East Bank of Jordan was carried out by utilizing four components identified from a principal component matrix of 12 variables representing catchment size, relief, altitude rainfall, climatic index, drainage density, stream flow, soil and land use characteristics. Climatic index, rainfall, and runoff characterisfics are the best reflection of watersheds variation. The resultant hierarchy of surface water regions is fitted with the northern and southern planning regions elaborated recently by Hunaiti (1978). Hence, the proposed regionalization scheme will enable the decision makers to plan more efficiently surface water supply systems, to solve regional water supply problems, and to sustain rapid development with the projected future water demand on a more confident basis.

Introduction

The water resources of Jordan are considered to be sufficient to satisfy the water demand expected to result from the implementation of present development plans (NRA, 1977a). The mean annual area rainfall in the East Bank catchments (including the Syrian area of the Yarmouk River Basin) is 8065 X 10^6 M^3. About 75% (or 6000 X 10^6 m^3) of this annual area rainfall is generated on the Jordanian territory. Likewise, the estimated annual surface water resources as stream flow are 880 X 10^6 m^3. Meanwhile, about 220 X 10^6 m^3 can be considered as available annual groundwater resources.

It should be emphasized that 45.5% of the total annual stream flow in Jordan (or 400 X 10^6 M^3) is attributed to the resources in the Yarmouk River at Adasiya, which originate primarily from the Syrian catchments. Thus only 480 X 10^6 m^3 can be considered as annual resources of the Jordanian catchments. Considerable parts of these flows are result from baseflow rather than from direct rainfall runoff during the rainy season which extends from November to May (NRA, 1977c). Stream flow of the Jordan River has not been considered in the above estimations due to its high salinity and deteriorating quality which eliminate these flows from the resources suitable for exploration. The abovementioned estimations indicate that the corresponding total annual stream flow is small compared to the rainfall volume and to the characteristics for the particular conditions of the surface water resources in Jordan.

The estimated potential annual stream flow shows the general tendency of decreasing annual surface water resources from the north to the south of Jordan (NRA, 1977c). Annual and seasonal variations of stream flows are also pronounced. Therefore, factors associated with varied regional pattern of surface water resources must be considered in water resources allocation, utilization, and development.

Generally, water resources appraisal and assessment of water supplies in Jordan are directed to satisfy one or more of the following:

(i) domestic and industrial water supply,
(ii) irrigation and drainage,
(iii) flood control and flood damage reduction,
(iv) environmental and water pollution control (NRA, 1977c).

The present paper describes a preliminary attempt to classify 30 surface water catchments in the East Bank of Jordan (Table I) by incorporating 12 hydrographic, geomorphic, and climatic parameters. With the use of principal component analysis the relative contribution of each parameter to the regional pattern of surface water resources can be assessed and a regional division involving a hierarchy can be established. The derived classification scheme will enable decision makers in Jordan to allocate, utilize, and develop the large supplies of surface water resources to meet the requirements of rapid development in the country. In addition, a regional organizational structure is suggested to coordinate the functions of water resources utilization and development, given the fact that water resources assessment in Jordan is becoming more and more comprehensive and interventionist process.

Table (I) The surface water catchments used in the study
1 - Yarmouk River - Adasiya 2 - Yarmouk River - Maqarin 3 - Wadi Arab 4 - Wadi Ziqlab 5 - Wadi Jurum 6 - Wadi Yabis 7 - Wadi Kufrinja 8 - Zerqa River - Jerash Bridge 9 - Wadi Um ed Dananeer 10 - Wadi Seleihi 11 - Zerqa River - Deir Alla 12 - Zerqa River - Sukhna 13 - Wadi Abdoun 14 - Zerqa River - Ain Ghazal 15 - Wadi Dhuleil 16 - Wadi Sheib 17 - Wadi Kafrein 18 - Wadi Hisban 19 - Wadi Mujib 20 - Wadi Wala 21 - Wadi Qatrana 22 - Wadi Sultani 23 - Wadi Swaqa 24 - Wadi Karak 25 - Wadi Hasa - Karak 26 - Wadi Hasa - Chor Safi 27 - Wadi Musa 28 - Wadi Dilagha 29 - Wadi Yutum 30 - Wadi Jurdhan

Surface Water Resources in East Bank of Jordan

The East Bank of Jordan is well drained by a reasonably close network of rivers and wadis. Most of the northern and central catchments derive their source from the paleocene, Ebcene and Cretaceous sedimentary rocks, meanwhile, the southern catchments take their source from the Precambrian Basement complex and Palaeozoic and Mesozoic sandstone. The Yarmouk, Zerqa and Mujib Rivers dominate the drainage system in Jordan. All the rivers and wadis selected in this investigation except Wadi Jurdhan, which drains to Qa El Jafr drain into the rift zone which consists of the River Jordan, the Dead Sea and Wadi Araba catchments. An approximate north-south devide seperates the rift zone catchments from the centripetal drainage systems which drain to inland closed depressions (Figure l).

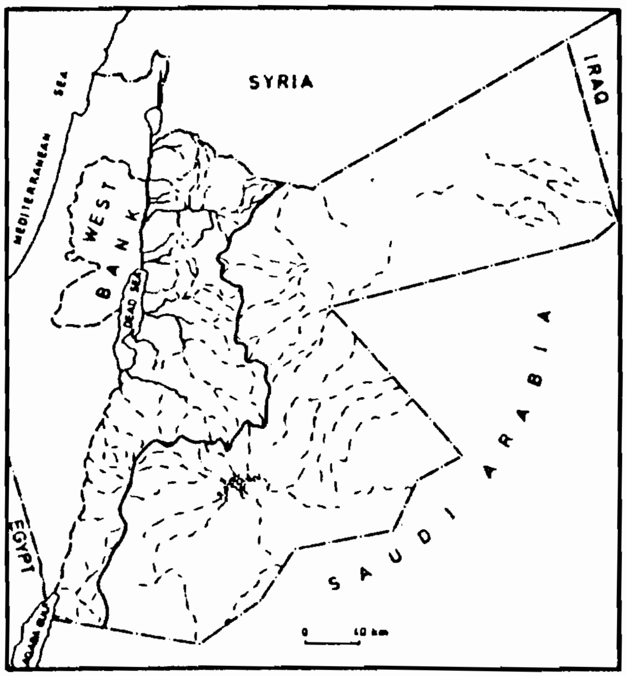

Figure 1 Drainage network in Jordan.

Estimates of the average stream flow of some main rivers and wadis are as follows:

River Yarmouk at Adasiya	$400 \times 10^6 m^3$/year
Wadi Arab	$31 \times 10^6 m^3$/year

River Zerqa at Jerash bridge	$28.8 \times 10^6 m^3$ / year
River Zerqa at Deir Alla	$22.3 \times 10^6 m^3$ /year
Wadi Sheib	$9.77 \times 10^6 m^3$ / year
Wadi Kafrein	$6.64 \times 10^6 m^3$ /year
Wadi Mujib	$22.08 \times 10^6 m^3$ / year
Wadi Wala	$21.2 \times 10^6 m^3$ / year
Wadi Karak	$18.17 \times 10^6 m^3$ / year
Wadi Hasa at Ghor Safi	$34.16 \times 10^6 m^3$ / year
Wadi Yutum	$1.41 \times 10^6 m^3$ / year

The dominant method of surface water exploitation in Jordan is by impounding water, e.g. dams and reservoirs construction. Several reservoirs were constructed on the main rivers and wadis, and put into operation. Example of such reservoirs are:

King Talal dam with a storage capacity of $48 \times 10^6 m^3$ / year

Ziqlab dam with a storage capacity of $4.3 \times 10^6 m^3$ / Year

Sheib dam with a storage capacity of $2.3 \times 10^6 m^3$ / Year

Kafrein dam with a storage capacity of $4.8 \times 10^6 m^3$ / Year

Qatrana dam with a storage capacity of $4.2 \times 10^6 m^3$ / Year

Sultana dam with a storage capacity of $1.2 \times 10^6 m^3$ / Year

King Talal dam is the largest reservoir in Jordan at Present. Unfortunately, the stored water is used for irrigation only, and it is not utilized for domestic supply as it was planned due to pollution constraints. Several dam projects and water conservation reservoirs are suggested or under study. Among these projected reservoirs are:

Magarin dam at the Yarmouk River with a storage capacity of $200 \times 10^6 m^3$ / Year,
Wadi Arab dam at Wadi Arab, With a storage capacity of $20 \times 10^6 m^3$/ Year, and
Wadi Yabis dam at Wadi Yabis with a storage capacity of $2.8 \times 10^6 m^3$/ Year (NRA, 1977 c).

As far as surface water quality, the water of Yarmouk river and the water of the East Bank Wadis does not indicate any significant pollution and is generally suitable for drinking purposes, Providing that it is given basic treatment. Apart from that, the water of the River Jordan is characterized with high salinity, therefore, the strean flow of the River Jordan has not been considered in the estimation of surface water resources. Although water resources of the Dead Sea and Wadi Araba catchments are affected by spring flows with high salinity, salt content is generally below the maximum permissible level according to international drinking water standards. An exception to this are the Zerqa Ma'in sprins. The Zerqa river, on the other hand, is polluted from chemicals and domestic effluents coming from the major urban centers in central and northern Jordan. In this regard, Amman, Jerash, Ajlun and Suweileh are the most urban areas threatening the surface water with pollution hazards generated from domestic effluents and uncontrolled dumping of garbage along the watercourses (NRA, 1977 a).

Data Source

The data matrix employed in this study is obtained from the records included in the National Water Master Plan (NRA, 1977 c)[1] and the drainage density map of Jordan compiled by the Jordan National Geographic Centre (1980). Twelve hydromorphological and hydroclimatic parameters (Table II) for 30 surface water catchments were utilized. The parameters include expressions of geomorphological, climatic, hydrological, soil and land use conditions for each catchment. Parameters 1, 2, 7 and 11 describe the catchment area (Km^2), relief altitude (m), drainage density (Km/Km^2), and soil factor. Climatic conditions were expressed by paramters 3 to 6 which include, average annual area rainfall (mm), average rainfall (MCM), basin climatic index (wet), and basin climatic index (dry). The hydrological parameters are described by storm runoff (MCM), base flow (MCM), and spring flow (MCM). Land use factor for each catchment area is incorporated as a measure for the human intervention in the hydrological behaviour of surface water. Nevertheless, there are a number of limitations on the value of the present data for regional classification. Firstly, the hydrological data for each catchment are of different lengths of record. Secondly, the spatial distribution of the hydrometeorological stations is irrigular and therefore, sufficient measurements are not available, where 60 percent of the catchment areas of interest are not gauged satisfactorily. Thirdly, there is lack of accuracy in the measurements related to stream-flow amounts, e.g. owing to changing rating curves caused by extreme floods (NRA, 1977 c). To overcome these limitations, most of the hydrological information included in the National Water Master Plan (1977) were estimated by utilizing standard statistical techniques adopted by Smith (1973), and the rainfall records, which proved to be the most reliable long-term data base available (NRA, 1977 a).

Principal Component Analysis

The raw data matrix (12 x 30) is initially standardized and the original parameters were transtormed to a distribution of Z-scores, so that each had a mean of zero and a standard deviation of one. The matrix is then subjected to principal component analysis (Mather, 1976). By means of this statistical technique, the 12 parameters were reduced to four components (table II), which when combined, explain 82.8% of the variation observed in the original data. Taking loading values equal to or greater than $\pm$ 0.6, the first component which explain 34.8% of the total variation is highly loaded on four parameters, namely, the average annual area rainfall, drainage density, wet catchment climatic index, and land use factor. The second component comprising strong loading for average rainfall, storm runoff volumes and catchment size accounts for an additional 21% of the variation. The third component, made up largely of the dry catchment climatic index, catchment altitude and base flow volume, explains 15%. Meanwhile, the fourth component explains a further 12% of the variation, and is highly loaded on soil factor and spring flow volume.

Regionalization of Surface Water Catchments

The resultant four components were employed to classify the 30 catchments and to delimit surface water regions and sub-regions. The scores of each of the four components of the 30 catchments were calculated and subjected to Ward's method of cluster analysis (Ward, 1963). Clustering is stopped when the catchments are combined into two major surface regions (Figure 2), namely, the southern region which comprises three sub-regions, and the northern region which consists of five sub-regions. The spatial distribution of the major regions and sub-regions is illustrated in Figure (3). The obtained groups appear logical and coincides with the regionalization scheme developed recently by Hunaiti (1978) for regional development planning purposes (Figures 4 and 5).

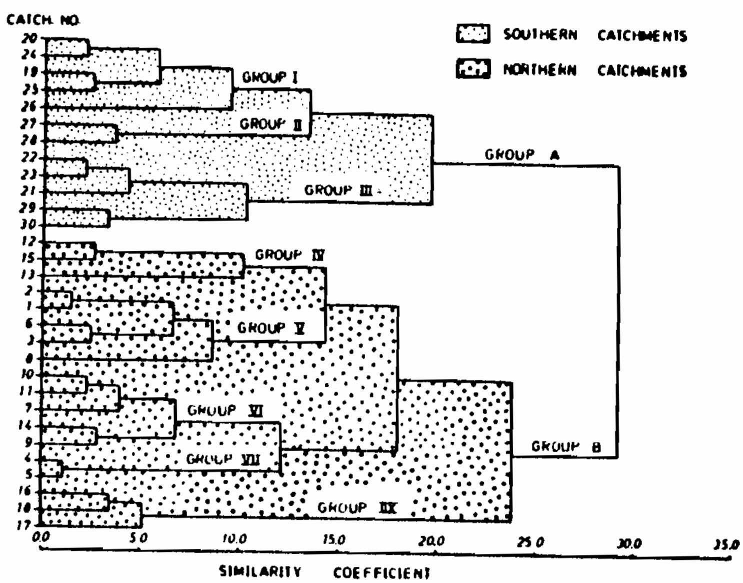

Figure 2 Cluster dendrogram of 30 surface water catchments.

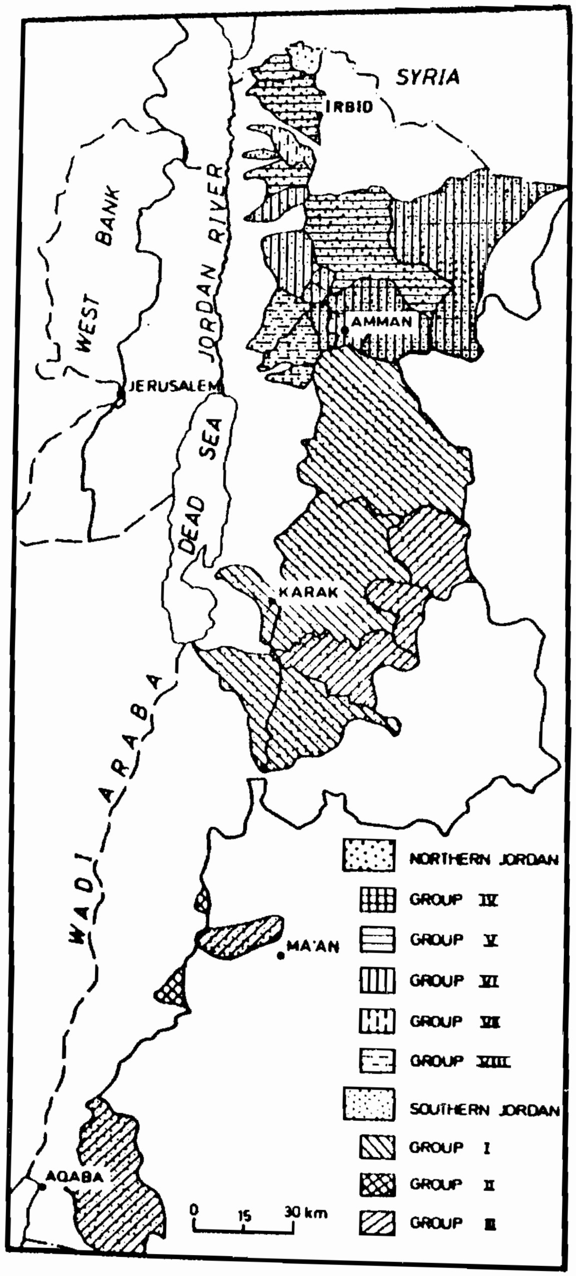

Figure 3 Spatial distribution of surface water regions.

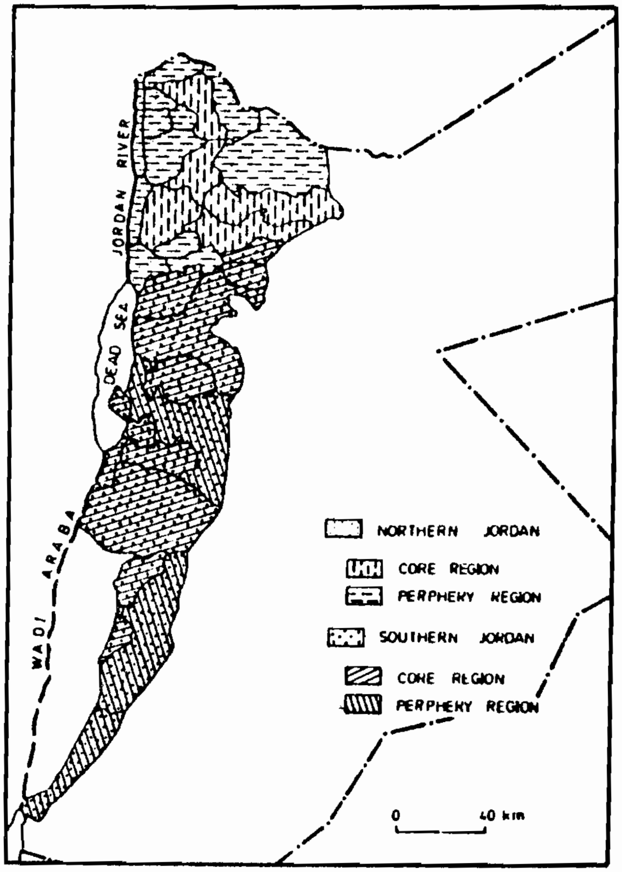

Figure 4 Development planning regions in Jordan.
(After Hunaiti, 1979)

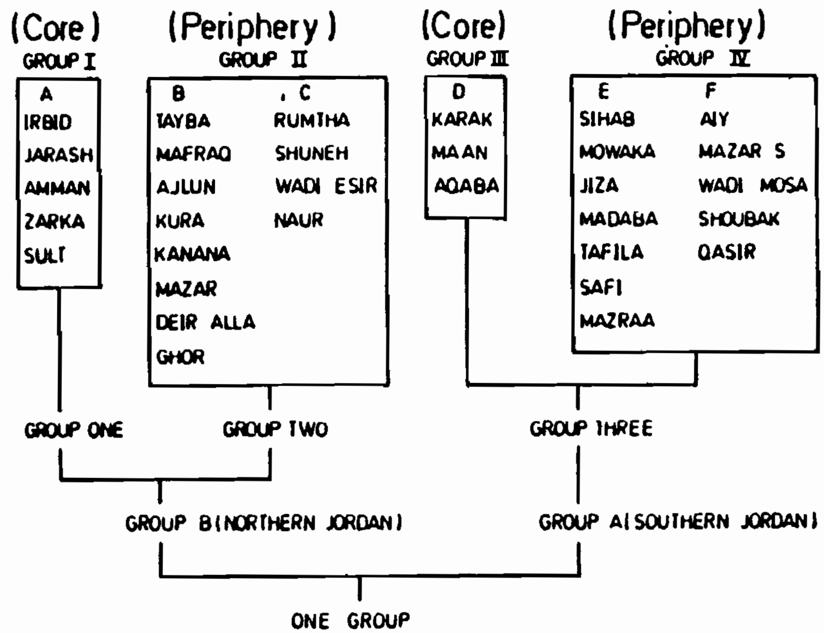

Figure 5 The administrative units which represent the core and periphery regions. (After Hunaiti, 1979)

Table (II) Component matrix

Components	I	II	III	IV
Eigenvalue	**4.18**	**2.52**	**1.80**	**1.44**
Cumulative %	**34.8**	**55.8**	**70.8**	**82.8**
1) Catchment area (Km^2)	0.12	0.78	-0.17	-0.25
2) Catchment altitude (m)	0.18	-0.18	0.78	-0.27
3) Average annual area rainfall (mm)	-0.94	-0.06	-0.14	-0.14
4) Average rainfall (MCM)	0.18	0.94	0.02	0.17
5) Catchment climatic index (dry)	0.01	-0.01	0.99	-0.01
6) Catchment climatic index (wet)	0.71	0.38	0.06	-0.05
7) Drainage density Km/Km^2	-0.78	-0.12	0.21	0.30
8) Storm runoff (MCM)*	0.44	0.88	0.03	-0.09
9) Base flow (MCM)**	-0.10	0.05	0.73	0.14
10) Spring flow (MCM)	-0.12	-0.09	0.11	0.71
11) Soil factor	-0.06	-0.01	-0.16	0.82
12) Land use factor	0.60	0.30	0.01	-0.24

*** According to the National Water Master Plan for Jordan, the storm runoff is defined as the rainfall - affected runoff, a combination of surface flow. interflow and short-term groundwater flow (vol. III, p. 7)**

**** Baseflow in the same text defined as the flow which can be seen during the dry season, independent of actual rainfall (Vol. III, p. 7.)**

The percentage explanation of the variation in the data afforded by each component indicates that the first and second components are twice as important as both the third and the fourth. This means that parameters such as average annual area rainfall, wet catchment climatic index, land use factor, catchment size, average rainfall and storm runoff volumes account for the most of variation in the surface water regime and that base flow, spring flow, and soil factor are only secondary in importance [(2)]. The present findings are in opposite to what was concluded by the NRA (1977 c) that the surface water resources in the East Bank of Jordan result mainly from base flow rather than from direct runoff during the rainy season. However, a recent investigation carried out to recognize the main factors responsible for stream flow behaviour in Jordan indicates that stream flow is dependent mainly on the average rainfall (MCM), wet catchment climatic index, and land use factor (Farhan, 1985).

Linear discriminant analysis was used to test the two major groups of surface water catchments (the northern and southern catchments) illustrated in Figure (2). The present test was carried out on the four components recognized previously. The critical value of F with $V_1 = 4$ and $V_2 = 25$ degrees of freedom at 99% of confidence is 4.18. The computed F-test statistic is 51.6 which highly exceeds the critical value calculated from F- distribution tables. The latter value of F denotes that there is indeed a high level of statistical significant difference between the two groups of water catchments, and they are well seperated and scattered about the means of the two groups.

The discriminant index R_0 (Which is - 9.12) provided by the computer programme (Davis, 1973) was found to be not far from half way between the centres of the two groups representing the northern and southern catchments.
The computed R^1 and R^2 define the centres of the two catchment groups along the discriminant function line. For the northern catchments group, $R_1 = 6.9$, and for the southern catchments group $R_2 = 25$. The discriminant scores of each catchment included in both groups were plotted along the discriminant function line (Figure 6), where the two groups are distinct and separated.

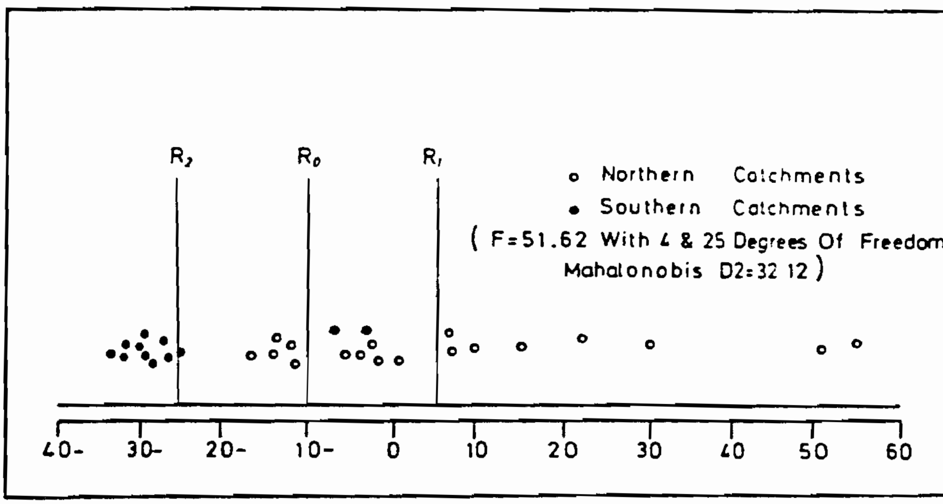

Figure 6 The scores of each surface water catchment plotted on the linear discriminant function line according to the cluster sets in Figure (2).

Surface Water Regions

Two main surface water regions which comprise eight sub-regions are delimited on the basis of the four components identified earlier. The main hydrological characteristics of these regions are described in Table (III). The division into northern and southern surface water regions is a true reflection of the climatic conditions and development levels in the country. The north represents the wet parts and the developed region of Jordan (Hunaiti, 1978, p. 105), meanwhile, the south represent the dry areas and the developed sub-sectoral region. The northern region consists of 18 catchments or specifically the catchment areas that extend between Yarmouk River in the north and Wadi Hisban in the south (Figures 2 and 3). Five sub-regions or groups are recognized in this region with a total catchments area of 4409. 3Km^2. The average annual area rainfall ranges between 277.7 (mm) on the eastern and southern steppe margins of this region to 461.5 (mm) on the wet Ajlun heights catchments. On the other hand, the average annual area rainfall for the northern region is 339 (mm). The annual storm runoff available here is 235.9 (MCM), and 86.5% of the total storm runoff, or 204.11 (MCM) are derived from group V which includes the River Yarmouk and the Zerqa river catchments. The total annual base flow estimated for this region is 349.2 (MCM), and again 75.6% of the total base flow (or 263.9 MCM) is contributed by group V. In addition, the total spring flow available in this region is 83.62 MCM, where 76.6% of this amount (or 64.1 MCM) is contributed by group V and group VIII only. In this regard, group V contributed 42.6% (or 35.6 MCM) of the total spring flow, meanwhile group VIII offered 34% of the total spring flow 28.5 MCM.

The southern surface water region covers an area of 6796 Km^2, and consists three sub - regions - groups - (Figures 2 and 3) which include 12 catchment areas. Although it is larger in area than the northern region, the surface water budget is smaller due to climatic and hydrological constrains. The average annual area rainfall is ranging between 206.2 (mm) in the central Jordan catchments (group 1) to 114.8 (mm) in the eastern marginal and Aqaba area catchments (group III). The total annual storm runoff available is 47.26 (MCM), and 82.9% of this amount (or 39.21 MCM) is contributed by the central catchments or group I which includes Wadi Wala, Wadi Mujib[3], Wadi Karak, and Wadi Hasa. Group III contributes 7.74 MCM of storm runoff, meanwhile group II contributes very small amount which doesn't exceeds 0.31 MCM. The estimated base flow in this region is 64.76 MCM. About 99.4% of this amount is obtained from group I, and the rest from group II only, while group III contributed nothing. Again the annual spring flow budget in the south is 29.06 MCM. About 96.4% of this quantity or 28 MCM is delivered from group I, and the rest obtained from group II. In this regard, group III contributed nothing.

Coordination between regional planning and surface water resources allocation and development

As outlined earlier, the regional patterns of surface water in Jordan are controlled by geographic, geologic, and climatic factors. Similarly, the development planning regions delimited by Hunaiti (1978) were crystallized partially on the basis of natural resources potential including surface water resources: Hunaiti's finding indicates that water resources have a major influence on the present and projected socio-economic and regional structure of the country. Since surface water is the main source of water supply in Jordan, efficient planning of water supply systems necessitates firstly, the projection of present and future demand of water supply for each development planning region. Secondly, the spatial delimitation of suitable sources along with their hydrological characteristics, i.e. the possible maximum or

Table (III) Main surface Water regions and sub regions of the East Bank of Jordan

Main Regions / Sub-regions	Catchments area (Km^2)	Average annual area rainfall (mm)	Storm runoff (MCM)	Base flow (MCM)	Spring flow (MCM)
Southern Region	(6796)	(163.5)	(47.26)	(69.76)	(29.06)
Group I	4340	206.2	39.21	64.4	28.0
Group II	87	169.5	0.31	0.36	1.06
Group III	2369	114.8	7.74	negligible	negligible
Northern Region	(4409.3)	(339.12)	(235.9)	(349.2)	(83.62)
Group IV	1815.4	277.7	12.04	13.1	8.7
Group V	1507	443	204.11	263.9	35.6
Group VI	533.9	444.4	13.86	26.1	10.8
Group VII	128	461.5	2.43	19.8	0.02
Group VIII	425	369	3.46	26.3	28.5

Note: The figures of different water resources are variable from year to due to rainfall variability pattern in Jordan, so these figures represent the averages for surface water catchments in Jordan as mentioned in the National Water Master Plan.

optimum yield, water quality, and the long term variation, etc.(Hahn, 1983), and thirdly, the institutional coordination between regional planning policy and surface water.

Referring to Table (III), the annual regional surface water budget are capable to facilitate the development beyond the present and projected water use in both northern and southern planning regions of Jordan (Table IV). It is also clear that a significant surplus of surface water resources is further available in the northern periphery of the southern region (especially Wadi Mujib Catchment) which indeed exceeds the projected demand for water in the depressed south. Thus, water surplus may be exploited to sustain development progress in the north. These resources include a considerable component of perennial base flow (NRA, 1977 a). However, in the southern region, a large amount of the annual water resources are not used at present, and any further water resources development in the region may depend on the potentials of exploitation of stored ground water rather than surface water due to technical and operational problems related to access and control of water.

In view of the present water resources problems in Jordan, the integration of comprehensive planning and water resources management is required for optimum and full utilization of water resources. Nevertheless, the characteristics of surface water resources such as its quality, quantity, spatial distribution, and variability with time may impose a limit on its potential development. As is the case in many semiarid countries, quantity and / or the quality of surface water in Jordan doesn't meet user's demand. Indeed, about half of the total population of Jordan, for example, is found in the Amman core.....

Table (IV): Municipal and Industrial Water Demand (MCM) for the Major Northern and Southern Development Regions in the East Bank of Jordan (1975 - 2000).

Region	consumption	Demand		
	1975	1975	1985	2000
Northern Region	38.9	70.61	127.8	246.46
Southern Region	6.8	10.8	52.0	—

Compiled from: NRA, 1977 d.

region (Amman and Zerqa urban centres) whose resources constitutes only 6% of the total national water resources (Joudeh and abu Taha, 1978). Therefore, periodic shortages of water supply is one of the main problems in the developed regions of Jordan (i.e. Amman and Irbid core regions). Subsequently, water transfer from regions of surplus to regions of shortage is essential for full utilization of surface water resources. At present, the Yarmouk catchment area (which is spatially part of Irbid core region) definitely is the most important catchment of potential water resources for Jordan. Considering rights of other water users in Syria and the Yarmouk Triangle and the estimated present diversion of irrigation water for the Jordan valley, on the average some 200 MCM of annual surface flows are still available for exploration (Frantz, 1978). Nevertheless, the procedure of water transfer and supply is difficult to achieve without reorganization of the present institutional arrangements as a first step towards establishing and operating efficient water supply systems.

For a long time in Jordan, the task of water management was fragmented among several bodies such as the Natural Resources Authority (NRA); the Jordan Vally Authority (JVA); the Water Supply Corporation (WSC); and the Amman Water and Sewerage Authority (AWSA). Recently, reorganization of water resources bodies in Jordan has been recommended by the United Nations Institutions, the U.S. Aids, and the German Technical Aids in an attempt to improve and strengthen the machinery of water management. Due to this recommendation, the Jordanian Government has decided on the fifth of February, 1984 to establish "The Water Authority" as a national central water body comprising three previous governmental institutions: the hydrological, irrigation and drilling departments of the Natural Resources Authority: the Water Supply Corporation: and the Amman Water and Sewerage Authority. tne responsibilities ot the new water authority are to carry out water resources exploration, water supply, quality control and recycling waste water on the national level. On the other side, water resources management of the Jordan Valley is kept under the control of the Jordan Valley Authority. In spite of resource management centralization, the co-ordination between the water Authority, socio-economic planning policy, and other non governmental institution has not been mentioned in the recent legislations.

Since the process of water management in Jordan is becoming more and more comprehensive and interventionist, water management should be visualized as a country-wide co-operative exercise. The shortcomings presented in the latest governmental reorganization of water resources bodies makes it essential to formulate a more efficient institutional framework to the national surface water plan of a smoothly operating regional and legal structure (NRA, 1977 a). The proposed regional structure has to be guided by a "Central" or first level "Water Resources Board". The functions of this high authoritative body are: to ensure the central control regarding national and regional water policies; decision-making process; legislation; integration of services and works; co-ordination between the regional water resources bodies (or the second level of governmental institutions) and the governmental planning agencies (Figure 7); and the co-ordination between the activities of governmental and non-governmental institutions (Figure 8). Above all, the Water Resources Board has to determine the policies and strategies which support the National Surface Water Plan, and it has supervise the implementation of the plan by the second level authorities which are in this case the "surface Water System" related to Irbid, Amman, and Kerak-Ma'an - Aqaba planning regions. These regional surface water systems should be involved with activities of water supply within their related space.

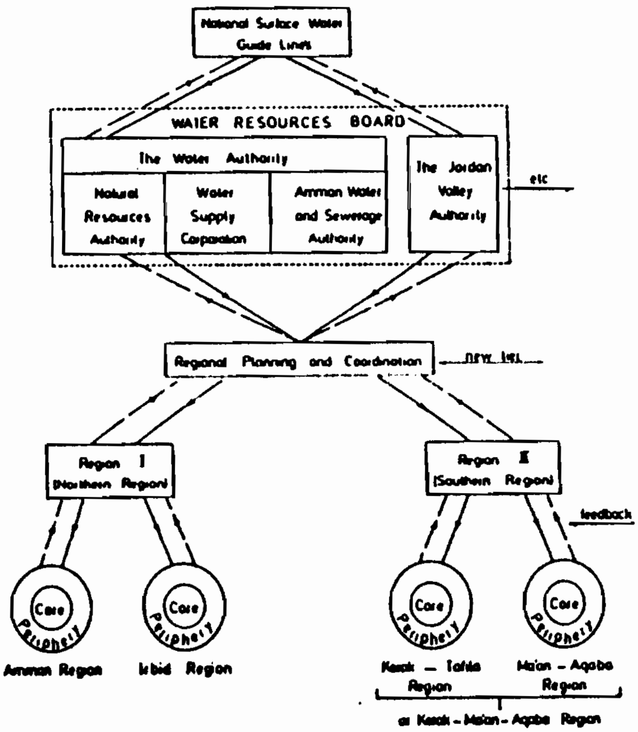

Figure 7 Functional organizational framework to co-ordinate the utilization of surface water resources.

interdisciplinary Functional Project Govern. & non-Govern. Institutions	water Resources Prospecting	water Supply	Water Pollution	Water Quality	Development of National Risk Profile	Waste Treatment
The Water authority	X	X	X	X	X	X
The Jordan Valley Authority	X	X			X	
Trade and Industry			X	X		
Rural and Urban Development		X		X		
Dept. of Regional Planning		X			X	
Public Health			X	X	X	X
Ibusing Corporation		X				
Royal Scientific Society				X	X	X
Dept. of Environment			X	X	X	X
The University of Jordan Centre for Water Studies	X		X	X	X	

Figure (8): Schematic matrix organization for water resources allocation, utilization, and development based on functional governmental and non-governmental institutions.

Notes

(1) The National Water master Plan for Jordan is the only Governmental document available in this regard, and water resources planning is implimented now in Jordan based on this document only. Up to now no other studies exist in this context.

(2) Statistical analysis reveals that storm runoff is more important than baseflow, although the actual amounts of baseflow are higher than those of storm runoff. This is true because the intercorrelation between the storm runoff and the rainfall parameters is higher than that for the baseflow and rainfall.

(3) The temporary dryness of the middle course of wadi Mujib which has been observed in the last four years is a direct result of the expansion of irrigated agriculture in the wadi terraces, and rainfall variability which is relatively high (40 - 55%) in the eastern tributaries of wadi Mujib. However, the eastern tributaries have flooded several times this winter (1985 - 1986). The present author observed and documented the storm runoff events for several wadis in Central Jordan. The high and frequent storm runoff events which occurred this year is resulted from high amounts of rains fall on the marginal and desert catchments. Such conditions caused a remarkable rise in spring and baseflow in favourable localities. Regardless of rainfall and runoff, still sharing a high amount of surface water resources in relation to the catchments of East Bank of Jordan.

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