Overview of Quantity and Quality of Water Resources in the Faria Catchment, Palestine

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Abstract

This paper presents, describes, and discusses the quantity and quality of the water resources in the Faria catchment. Faria catchment (320 km^2), located in the northeastern part of the West Bank, Palestine is characterized as arid to semi-arid region. In the catchment, water resources are either surface runoff or groundwater. Surface runoff in the Faria catchment is considered high compared to other catchments in the West Bank. Most surface runoff generated in the catchment is usually lost in winter as there are no storage structures in the catchment to store that excess water. The groundwater aquifer system of the Faria catchment is usually utilized through springs and wells. Within the catchment, there are 13 fresh water springs and about 70 groundwater wells. Based on the available data, annual discharge from springs varies from about 4.1 to 37.8 MCM with an average amount of 14.3 MCM. While the total annual utilization of the groundwater wells, do not exceed 11.5 MCM. During wet years, when the spring's discharges are high, abstraction from wells reduces while pumping increases in dry years. Sampling and analyzing water quality for different water resources in the catchment revealed that most of these resources are polluted with different levels of potential environmental risks. The upper catchment springs, which are far away from the pollution source of untreated municipal wastewater, are polluted from cesspits. Detected Fecal coliform bacteria, in these springs, indicate cesspits are the potential source of pollution. In the middle areas, wells and springs water qualities were increasingly affected from untreated municipal wastewater. An increasing trend of chemical and biological pollution was found in groundwater wells and springs therein. Downstream of Shibli spring, the last spring in the middle part of the catchment, wadi flow (spring flow and the remaining untreated municipal wastewater) is diverted into a conveyance pipeline. Therefore, the risk of pollution of the downstream wells is eliminated.

Key words: Faria Catchment, Groundwater Wells, Springs, Wadi flow, Water Quality, and Untreated Municipal Wastewater

1. Introduction

Water pollution, together with loss of biodiversity, climate change, energy and socioeconomic issues, consider one of the main threats and challenges humanity faces today. Human activities and resulted wastes introduced into different water resources (e.g. rivers, lakes, groundwater aquifers and the oceans) change the environmental water quality and make huge quantities of water unsuitable for various uses. This is the case not only for domestic, agricultural and industrial uses but also for terrestrial and aquatic ecosystems for which clean freshwater is a prerequisite for life (Ganoulis, 2009). In general, the availability of adequate freshwater of appropriate quality has become a limiting factor for development, worldwide.

Water pollution is a serious problem for human health and the environment. The extent of the problem has been confirmed by many international environmental related statistics and reports. For example, UNEP (2000) published the Global Environment Outlook report which included the following statistics:

1. Already one person in five has no access to safe drinking water.
2. Polluted water affects the health of 1.2 billion people every year, and contributes to the death of 15 million children less than 5 years of age every year.
3. Three million people die every year from diarrhoeal diseases (such as cholera and dysentery) caused by contaminated water.
4. Vector-borne diseases, such as malaria, kill another 1.5–2.7 million people per year, with inadequate water management a key cause of such diseases.

Water resources in arid and semi-arid regions are often very vulnerable to anthropogenic and natural changes. The problem is further exacerbated in these regions where long-term droughts have decreased the available amount of water, while the needs for water have increased. At the same time, preservation of good water quality for different water resources is necessary to protect public health and ecosystems. A sufficient supply of fresh water has become a necessary condition to ensure economic growth and development. As demand for water for different uses increases and pollution deteriorates water quality, economic development is put under stress and conflicts result between different direct and indirect users.

Water resources quantity and quality problems are very much inter-related and should be studied within an integrated framework. Hence, the development of sustainable fresh water supply is a challenging task and the increasing demands for water for different uses require a broad range of water management strategies and tools.

In the Faria catchment, untreated wastewater from the eastern part of Nablus city and also from Al-Faria refugee camp are discharging into Faria wadis and mixing with fresh spring water therein. Wastewater contains a cocktail of pollutants, some biodegradable and others are very persistent. The polluted water infiltrates to a large extent into shallow and deep groundwater bodies and, consequently, pollutes the water resource in the catchment. Additionally, farmers along the main wadis, where the wastewater flowing, are commonly used the untreated wastewater to irrigate their crops. Thus, local population in the catchment (who rely on groundwater as the main drinking water source) is exposed to chemical and microbiological contamination of the drinking water and additionally through the consumption of agricultural products that were irrigated with untreated wastewater.

This paper aims to introduce a general overview of water quantity and quality in the Faria catchment. Sampling and analyzing water quality for different water resources in the catchment conducted at WESI through UNESCHO-IHE funded project revealed that most of these resources are polluted with different levels of potential environmental risks.

2. Study Area

The Faria Catchment is one of the major arteries draining into the Lower Jordan River. Geographically, it is located in the northeastern part of the West Bank, Palestine, and has a total area of about 320 km^2, accounting for 6% of the total area of the West Bank (**Figure 1**). Faria catchment is an important agricultural area as a part of the Jordan Valley which is considered as a food basket that provides the West Bank with the main agricultural products. This is because of the climatic variability, the availability of fresh water from the natural springs and wells and the high fertility of the soils. In addition to agriculture, the upper part of catchment has a few recreational activities and touristic facilities.

Ground surface elevations range from 350 m below sea level to 900 m above sea level. The native population of the catchment, primarily rural, is estimated to be about 21 000. The climate in the Faria Catchment is arid to semi-arid, characterized by mild rainy winters and moderately dry and hot summers. Climatic parameters are highly variable and influenced by topography and circulation of air masses.

The catchment is characterized by high temperature variation over space and time. The mean annual temperature is 18 ℃ on the western side of the catchment and 24 ℃ on the eastern side. Potential evaporation is particularly high in the summer due to high insulation. Evaporation greatly exceeds rainfall from April to October.

Land use in the Faria catchment is classified into eight classes; bare rocks (2.8%), built-up areas (4.7%), natural forests (0.9%), olive plantations (6.4%), agricultural areas (22.1%), natural grassed hill slopes (28.3%), scattered olive plantations (8.2%) and sparsely vegetated hill slopes (26.6%).

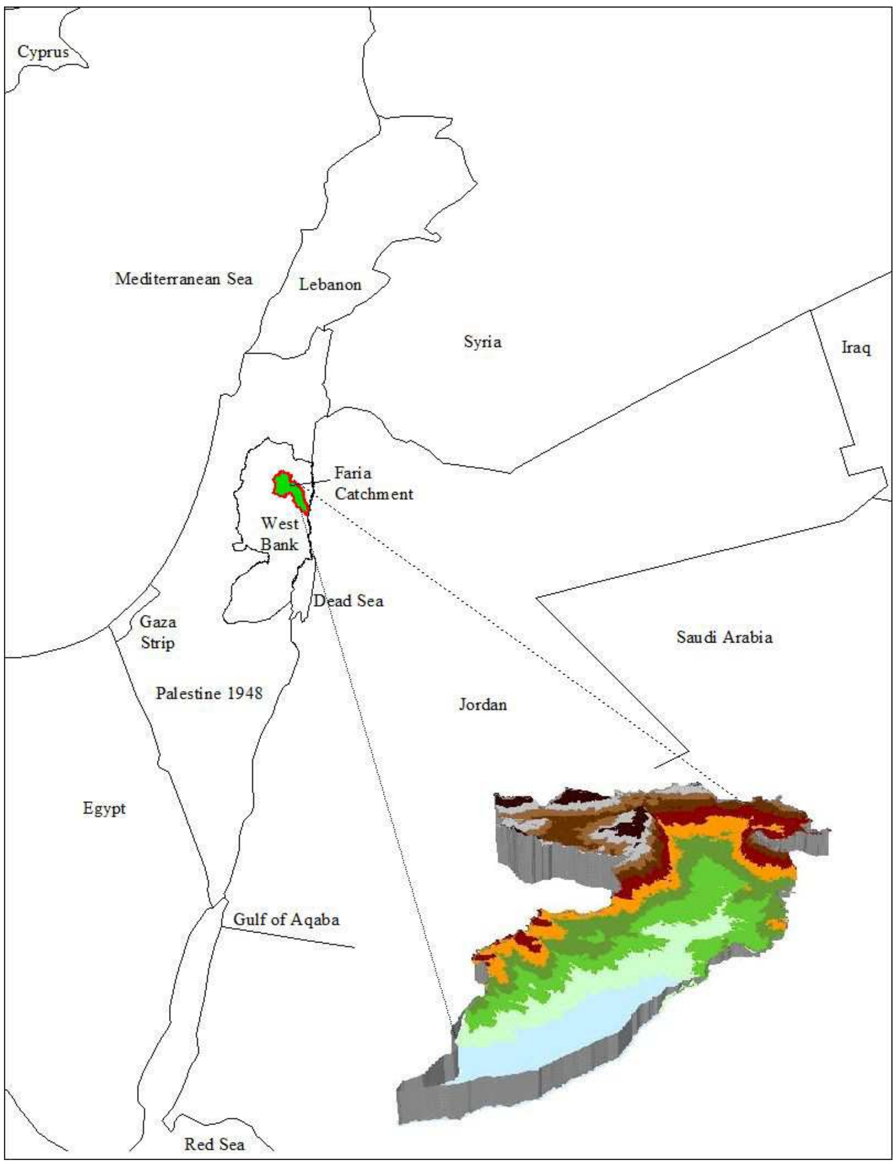

Figure 1: Regional Location of the Faria Catchment

3. Overview of Water Resources Quantity

In the Faria catchment, water resources are either surface or groundwater. Water resources are replenished from rainfall. Characterization of rainfall magnitudes and patterns is of great importance in the management and development of scarce water resources in the catchment. In the winter, the majority of generated surface runoff leaves the catchment, as there is no infrastructure to store excess water. The groundwater aquifer system of the Faria catchment comprises several rock formations from the Triassic (Lower Cretaceous) to recent age. These formations are composed mainly of limestone, dolomite and marl. Groundwater aquifers are usually utilized through springs and wells. Most of the springs are located in the upper and middle parts of the catchment.

3.1 Rainfall

Rainfall events predominantly occur in autumn and winter, a period that accounts for 90% of the total annual precipitation. Rainfall measurements within the Faria catchment are highly variable because of the relationship with the topography. In the catchment, June, July and August are completely devoid of rain.

The Faria catchment is gauged by six rainfall stations that record rainfalls. These stations are: Nablus, Taluza, Tammun, Tubas, Beit Dajan and Al-Faria. The Nablus station is a regular weather station in which most climatic data are measured. Monthly and annual rainfall data of this station is available for more than 50 years. Al-Faria station is located in Al-Jiftlik village in the lower part of the catchment and is still under Israeli control. Therefore, data available from this station is limited to only few years. The other four rainfall stations are located in the schools of Taluza, Tubas, Tammun and Beit Dajan. These stations are simple rain gauges which measure daily rainfall.

Generally, the magnitude of rainfall in the Faria catchment varies with space and time. The rainfall distribution within the catchment ranges from 640 mm at the headwater to 150 mm at the outlet to the Jordan River (**Figure 2**). In general, rainfall averages decrease from north to south and west to east. The annual rainfall variation for different year periods for various rainfall stations in the Faria catchment are depicted in **Figure 3**.

Drought frequently occurs in the Faria catchment. Analysis of rainfall data for the last 43 years from the six rainfall stations proved that, on average, drought occurred in 23 out of the last 43 years in the Faria catchment (Shadeed, 2011).

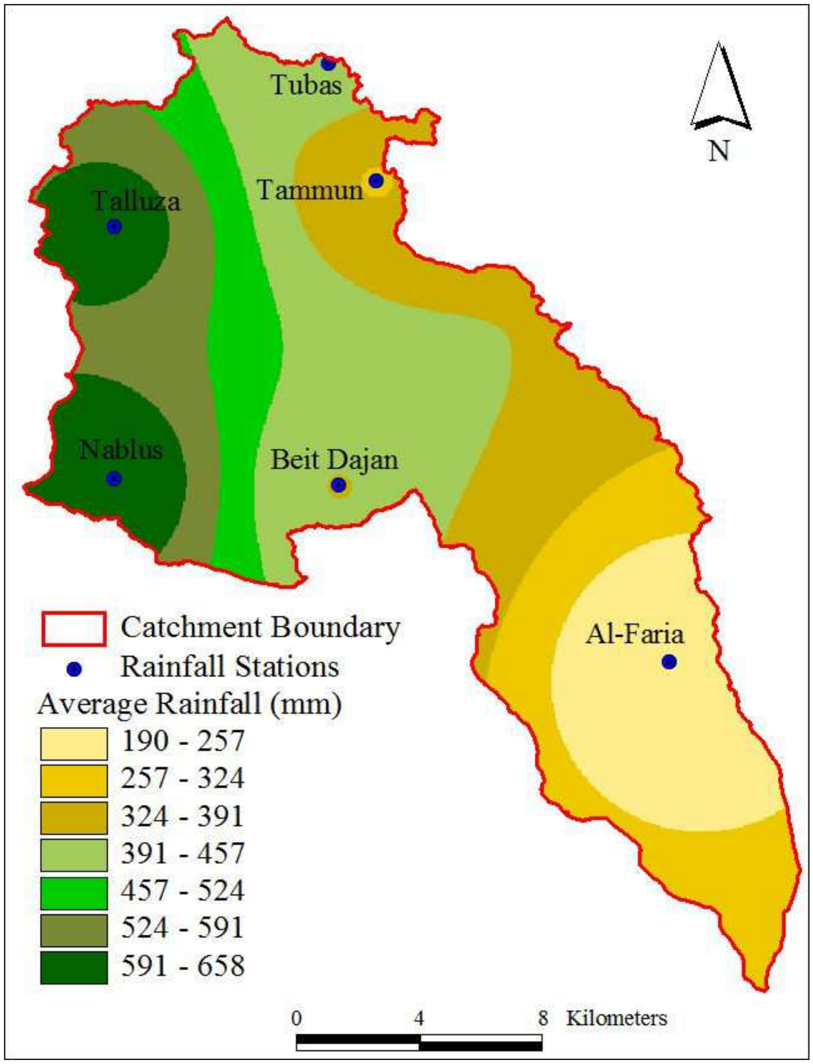

Figure 2: Rainfall Stations and Rainfall Distribution within the Faria Catchment

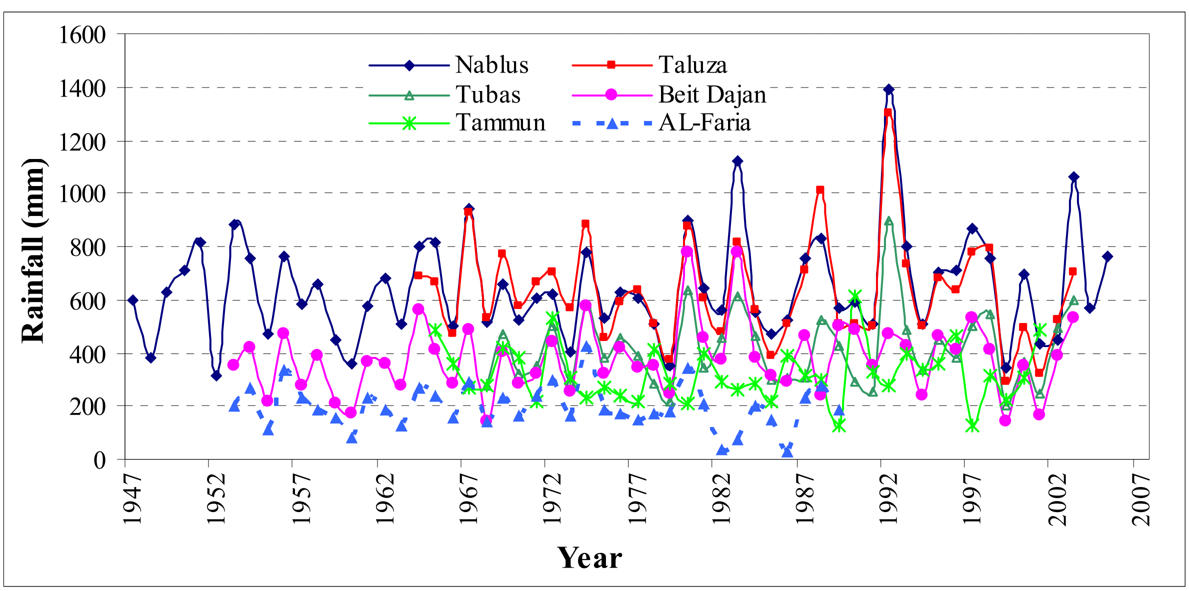

Figure 3: Yearly Rainfall Variability for the 6 Stations in the Faria Catchment

3.2 Groundwater Wells

There are 70 wells in the Faria catchment; of which 61 are agricultural, 4 are domestic and 5 wells are totally utilized by the Israelis. Based on the available data from the Palestinian Water Authority (**PWA**), the total utilization of the Palestinian wells ranges from 4.4 to 11.5 MCM/year. Water from agricultural wells is used in conjunction with spring discharge in most of the catchment. During wet years when the spring discharge is high, abstraction from wells reduces while pumping increases in dry years. Data on the pumping rates from the Israeli controlled wells are available for four wells for only four years from 1997-2000. The average total abstraction from these four wells was found to be about 8 MCM/year. Average well abstraction from Israeli controlled wells is about 2 MCM/year. Thus, considering the fifth Israeli controlled well without data available, the total abstraction from the 5 Israeli controlled wells in the Faria catchment is estimated at 10 MCM/year, which is more than the 61 Palestinian agricultural wells combined. Depth to water table in the Faria catchment is in the range from 10 to 190 meter. **Figure 4** illustrates the location of wells and springs within the Faria catchment. The percentages of the average annual abstraction from the Faria catchment wells are shown in **Figure 5**.

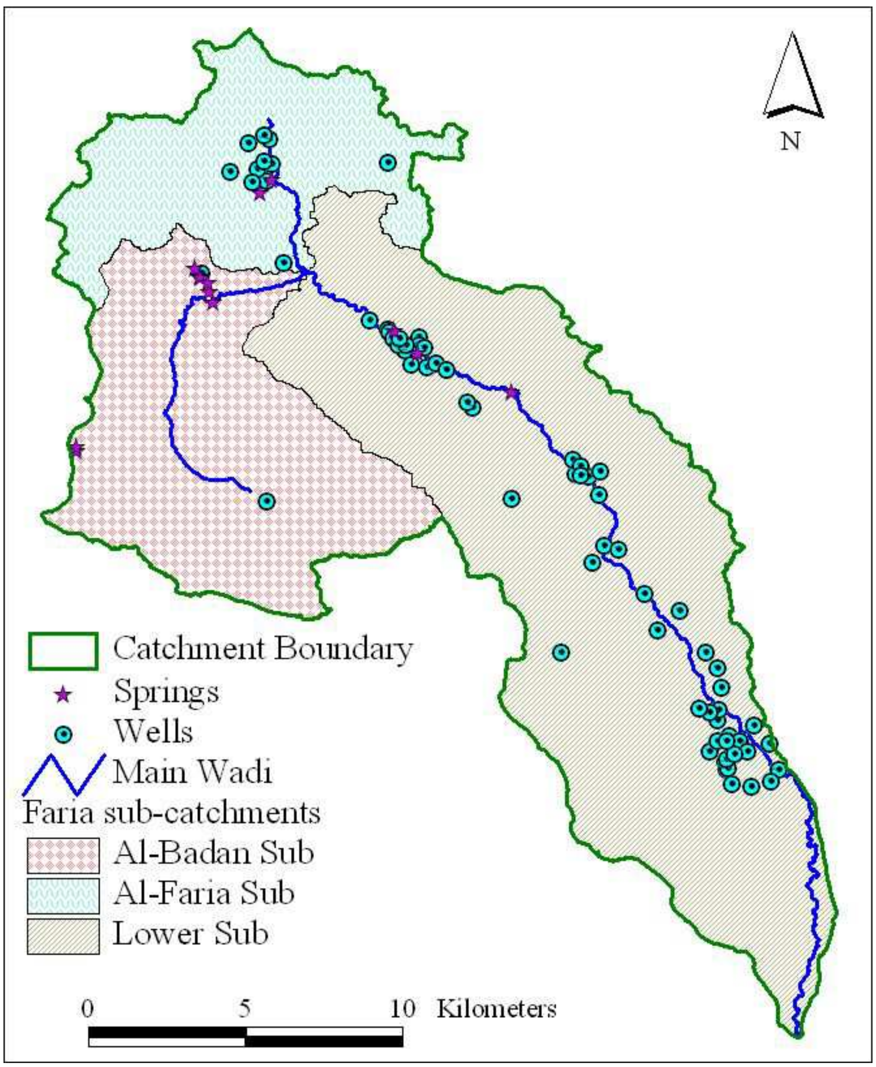

Figure 4: Location Map for Springs and Wells in the Faria Catchment

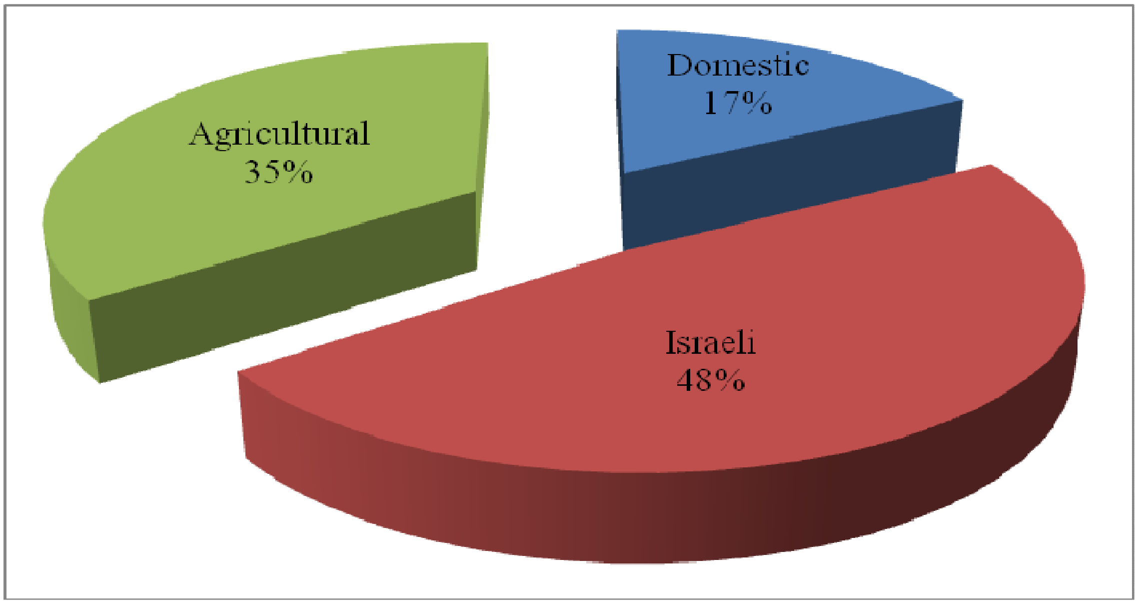

Figure 5: Percentages of the Average Annual Abstraction from the Faria Catchment Wells

3.3 Springs

Springs are the only natural drainage outlets for groundwater in the Faria catchment. Within the Faria catchment, 13 fresh water springs exist and fully utilized. These springs are divided into four groups: Faria, Badan, Miska, and Nablus.

The basic data summarized in **Table 1** were obtained from PWA. This table summarizes the spatial location coordinates, average annual discharge, minimum annual discharge and maximum annual discharge of the 13 springs located in the Faria catchment. Discharge data, for 30 years (1970-1999), of the springs show high spring discharge variability. Annual discharge from these springs varies from about 4.1 to 37.8 MCM with an average amount of 14.3 MCM. From table 1, it is clear that the annual discharges for some springs (e.g. Jiser) are very small comparing to others (e.g. Faria).

As depicted in **Figure 4**, the majority of the springs are located in the upper and middle parts of the catchment. Recently and due to either reduced amount of rainfall or excessive pumping from the nearby wells, some springs in the Faria catchment where frequently getting dried. From the field visit on March 2011, it was observed that seven springs in the catchment were still dry. Among which, Faria spring, that used to discharge the largest amount of water in the catchment.

For the period from 1971 to 2000, the Faria spring nearly dried in only two months in 1979 (August and September). The spring dried completely for 3 months in 2007, 8 months in 2008 and dried since April in 2009. This frequency and/or the extent of drying have never been observed before (Mizyed and Haddad, 2009).

Box plots were used for better visualization of the annual spring yield for each springs group of the Faria catchment as depicted in **Figure 6**. The figure shows that Faria springs group has the highest annual yield with median and maximum values of 5.9 and 6.6 MCM. Whereas, Nablus springs group has the lowest statistical values.

Table 1: Springs of the Faria Catchment

Group	Spring Name	Coordinates			Ave. Annual Discharge MCM	Min. Annual Discharge MCM	Max. Annual Discharge MCM
		X (km)	Y (km)	Elevation (m)			
Faria	Faria	182.40	188.40	160	5.32	1.71	10.53
	Duleb	182.00	187.95	155	1.24	0.00	8.60
Badan	Asubian	180.52	184.56	130	0.20	0.14	0.23
	Beida & Hamad	180.12	185.32	215	0.83	0. 01	1.75
	Sidreh	179.95	185.58	240	1.39	0.00	8.12
	Tabban	180.42	184.82	160	1.35	0.97	1.69
	Qudeira	180.13	185.28	215	1.13	0.00	2.47
	Jiser	180.37	185.10	170	0.12	0.00	0.24
Miska	Miska	187.03	182.90	-38	1.32	0.02	2.20
	Shibli	189.90	181.28	-80	0.91	0.71	1.15
	Abu Saleh	186.26	183.57	-19	0.18	0.00	0.53
Nablus	Balata	176.20	179.77	510	0.20	0.05	0.55
	Dafna	176.20	179.90	560	0.14	0.02	0.49
Total					14.33	4.07	37.81

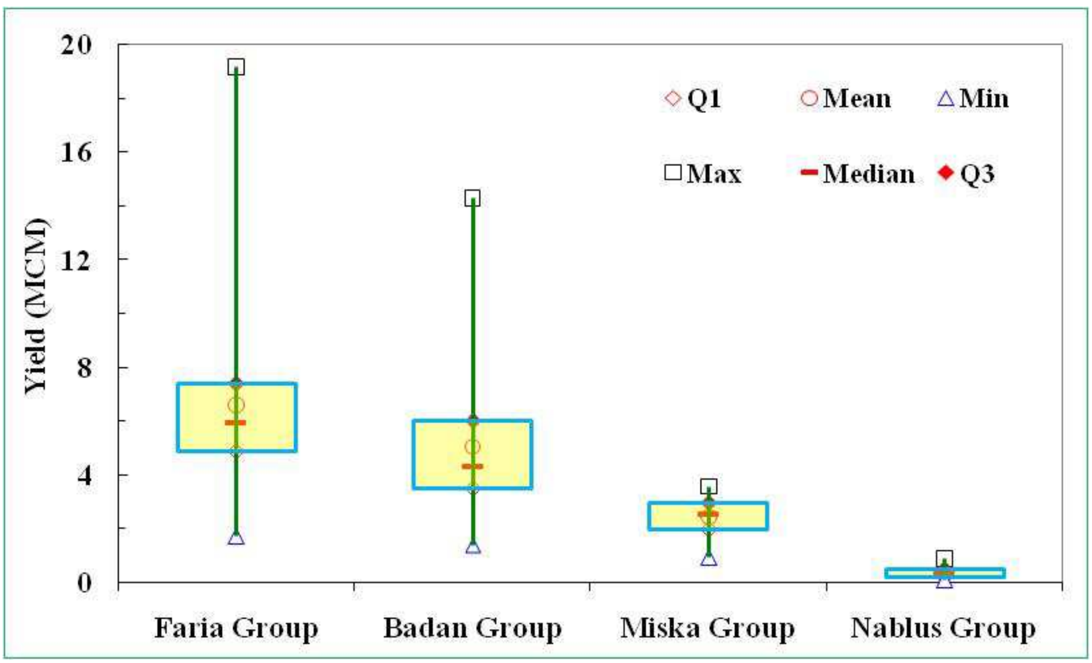

Figure 6: Box Plots of the Annual Yields for the Springs Groups of the Faria Catchment

3.4 Surface Runoff

No detailed runoff data were available for Faria catchment. The only hydraulic structure which was constructed in the early 1970's for measuring surface runoff in the Faria catchment is located next to Ein Shibli in the lower central part of the catchment. This hydraulic structure is a wide crested weir which is used as a diversion structure to Al-Faria irrigation project. The structure has an upstream stage gauge which could be monitored to estimate runoff flows. However, the structure does not have an automatic recorder to register water stage continuously. Therefore, only a few sporadic measurements are available. These measurements are not sufficient to estimate the volume of annual runoff through the structure. In August 2003, An-Najah National University in coordination with GLOWA-JR project established two Parshall Flumes at the upper part of the catchment to measure runoff rates from both Al-Badan and Al-Faria wadis (see **Figure 4**), which meet at Al-Malaqi Bridge, 10 km east of Nablus City.

Surface runoff in the Faria catchment is considered high compared to other catchments in the West Bank. Within the catchment the runoff decreases from west to east with decreasing rainfall. The city of Nablus discharges untreated industrial and domestic wastewater effluents to Al-Badan wadi while Al-Faria Refugee camp discharges untreated domestic wastewater to Al-Faria wadi. Therefore, the wadi flow of the Faria catchment is a mix of:

1. Runoff generated from winter storms. This includes urban runoff from the eastern side of Nablus City and other built up areas in the catchment.
2. Untreated wastewater of the eastern part of Nablus City and of Al-Faria Refugee camp.
3. Fresh water from springs which provides the baseflow for the catchment main wadi preventing it from drying up during hot summers.

For example, runoff measurements for both Al-Badan and Al-Faria Flumes for the season 2005/06 are illustrated in **Figures 7**. From the figure, it can be inferred that the flow in the flumes varies from time to time, particularly during and in response to rainstorm events. As rain falls and moves through the catchment, water levels in the Flumes rise and may continue to do so after the rainfall has terminated. There are not many events which caused high floods within this recorded period. For each year, one major runoff event, low-frequency and high-amplitude, is observed as part of the obvious continuous, high-frequency and low-amplitude baseflow.

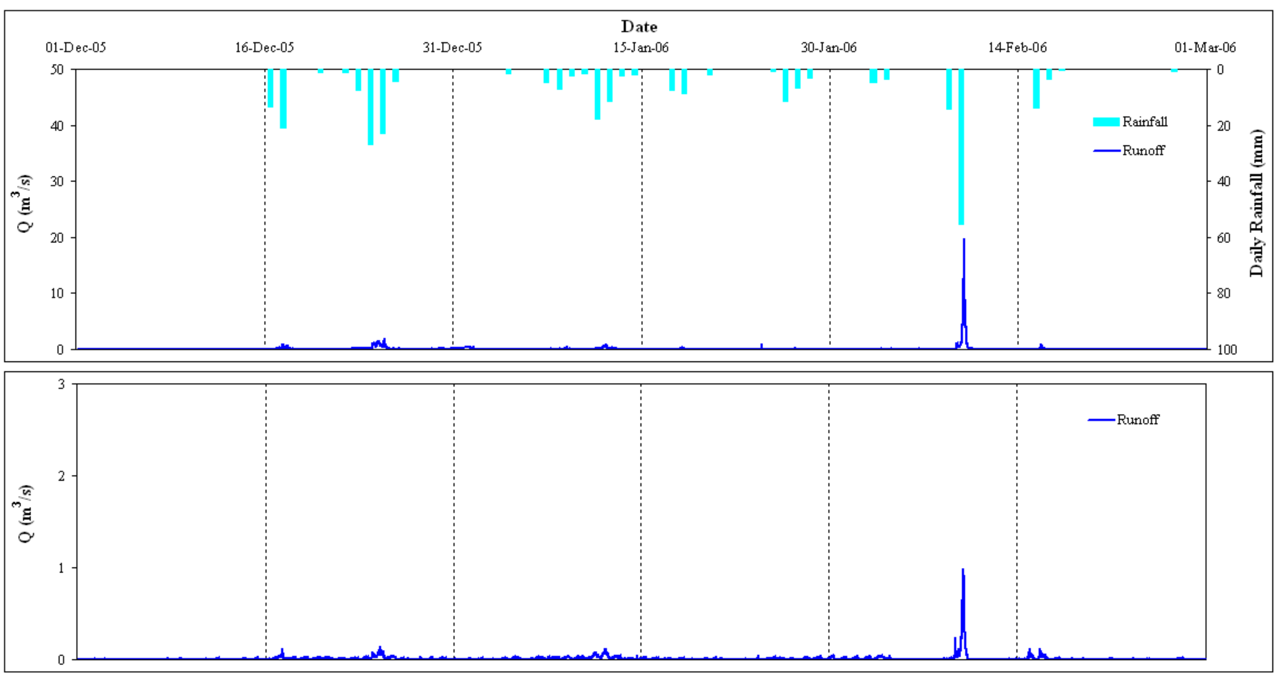

Figure 7: Rainfall and the Corresponding Runoff for the Season 2005/06; upper part: Al-Badan Sub-catchment and lower part: Al-Faria Sub-catchment

From the figure, it can be also inferred that the amount of runoff generated in Al-Badan sub-catchment is greater than that of Al-Faria sub-catchment. This can be attributed to the following reasons (Shadeed, 2008):

1. The surface area of Al-Badan sub-catchment (83 km^2) is greater than that of Al-Faria (56 km^2);
2. Slopes of Al-Badan sub-catchment are steeper than Al-Faria slopes; this makes the potential of runoff generation in Al-Badan sub-catchment greater than that of Al-Faria, and
3. Landuse types of Al-Faria sub-catchment have more infiltration rate compared to that of Al-Badan. In Al-Badan sub-catchment, the highest amounts and intensities of rainfall usually falls over Nablus area which is an urban area that generates a considerable amount of runoff. On the other hand, Taluza area in Al-Faria sub-catchment mostly covered with olive plantation; receives the highest amounts of rainfall and generates negligible amount of runoff.

For the entire Faria catchment, Shadeed (2008) found that the annual runoff volume for the three years from 2004 to 2007 is in the range of 0.24 to 1.5 MCM. In addition, he estimated that the volume of wadi flow (baseflow and direct runoff) that can be utilized, in winter season, downstream of Al-Malaqi Bridge is about 4 MCM. Unfortunately this is usually lost as there are no storage structures in the catchment to store that excess water.

4. Overview of Water Resources Quality

4.1 Wells Water Quality

Two sets of criteria may be used to assess the quality of groundwater depending on the type of water use, namely domestic or agricultural purposes. The quality of water for domestic purposes is highly affected by the existence and count of pathogenic microorganisms in water resources and the concentration of certain ions that affect the health or preferences of users such as the concentration of nitrate or water salinity. On the other hand, the assessment of water quality for agricultural purposes depends on the type of crops irrigated, their tolerance to low quality waters, the amount of water applied to the crop and the irrigation system through which the water is applied (EQA, 2004).

In this study, water quality for a selected number of domestic and agricultural wells in the Faria catchment was determined at different dates. Four sampling rounds were conducted during the period from December 2010 to February 2011. These samples were collected from four agricultural wells, one in the upper Faria catchment and three in middle part at An-Nasarya village, and two domestic wells utilized by Nablus municipality. Results of analyses of these samples are shown in **Table 2.** From the table, it is clear that the readings of nitrate, chloride, calcium, magnesium, pH, turbidity, and TDS were found to meet the drinking water Palestinian standards. The microbiological analysis for the samples collected from Al-Badan and Al-Faria domestic wells, utilized by the municipality of Nablus, were free from Fecal coliform bacteria. However, these wells have chlorination units which are capable of eliminating any bacterial growth.

Table 2: Results of Water Quality of Sampled Wells in the Faria Catchment

Parameter	Min (ppm)	Max (ppm)	Average (ppm)	Palestinian Standards
NO_3^{-2}	28	13	21	50
HCO_3^{2-}	302	412	323	*na
Cl^-	58	203	103	250
SO_4^{2-}	0.0	11.3	5.8	*na
PO_4^{3-}	0.0	0.0	0.0	*na
Ca^{2+}	82	120	97	200
Mg^{2+}	3.6	9.7	6.9	50
pH	7.0	7.4	7.2	6.5-8.5
EC	781	1201	935	*na
Turbidity	0.2	1.6	0.7	5 NTU
TDS	500	769	598	1000

*na: no Palestinian standard available

In the middle part of the catchment, at An-Nasarya area, Fecal coliform bacteria were detected in the tested agricultural wells. Bacterial contamination might be attributed to the flowing of untreated wastewater in the wadi where these shallow wells were drilled in the vicinity of the polluted wadi. Counts of detected Fecal coliform bacteria show that the tested wells are suitable for irrigation but not for drinking use. Although, most farmers in the area are using such polluted wells for drinking use. Therefore, they are subjected to water-born deceases since there are no chlorination units installed on these wells.

4.2 Springs Water Quality

Water quality for a selected number of springs in the Faria catchment was determined at different dates. Samples were collected from the three discharging springs during the sampling period from December 2010 to February 2011. These springs are Hamad, Tabban, and Shibli. Results of some studied chemical parameters are summarized in **Table 3**. From the table, results of the tested springs, for chemical parameters, and comparing to the drinking water Palestinian standards showed that these springs are generally of good water quality. Fecal coliform bacteria were detected in the tested springs. For Hamad and Tabban springs located in the upper part of the catchment, at residential area of Al-Badan village, the source of increased levels of biological contamination is due to pollution by seepage from wastewater cesspits, whereas the source of biological contamination of Shibli spring is due to the untreated wastewater flowing in the nearby wadi and cesspits in Ein-Shibli park. It is worth mentioning that these springs are being used for drinking purposes. Therefore, people in the area are exposed to water-born deceases since there are no chlorination units installed on these two springs.

Table 3: Results of Water Quality of Sampled Springs in the Faria Catchment

Parameter	Min (ppm)	Max (ppm)	Average (ppm)	Palestinian Standards
NO_3^{-2}	25	18	21	50
HCO_3^{2-}	263	393	296	*na
Cl^-	42	142	66	250
SO_4^{2-}	1.2	16.7	6.9	*na
PO_4^{3-}	0.0	0.1	0.0	*na
Ca^{2+}	60	120	82	200
Mg^{2+}	2.4	25.5	13.3	50
pH	7.0	8.5	7.8	6.5-8.5
EC	484	1201	706	*na
Turbidity	0.1	25.0	451.8	5 NTU
TDS	310	769	452	1000

*na: no Palestinian standard available

4.3 Wadi Water Quality

As indicated earlier, wadi flow includes both direct runoff and baseflow (fresh water springs and wastewater). In the Faria catchment, the wadi water is mainly used for irrigation in the areas where the wadi passes. In winter and after a considerable rainstorm event occurred, runoff is generated and mixed with wadi baseflow. Moreover the amount of spring water discharging into the wadi is also increased in winter due to two reasons. Firstly, the rainfall which replenished the groundwater aquifers and secondly, the minimum utilization of spring water for recreational use, comparing to summer, in the upper part of catchment. Hence, more wadi flow is expected which dilute the discharging wastewater and accordingly improving the quality of wadi flow. This is mainly due to the mixing factor.

A visual observation to the wadi and the wastewater entering it gives an indication of the high deterioration in its quality. However sampling and analysis are still going to characterize the wadi water quality. The current available data obtained from different locations along the wadi over a period of four months show the significant concentration of some contaminants.

5. Summary and Conclusions

In the Faria catchment, water resources are either surface (wadi runoff) or groundwater (springs and wells) which could be characterized by high temporal and spatial variation. The obtainable water resources in the catchment are limited and not sufficient to fulfill the increasing demand for both domestic and agricultural purposes. The problem is further exacerbated in the catchment where long-term discharge of untreated wastewater, containing a cocktail of pollutants, from the eastern part of Nablus City and also from Al-Faria Refugee camp. These two sources of pollution have been deteriorating the water quality in the catchment. The polluted water mixes with fresh spring water and infiltrates to a large extent into shallow and deep groundwater bodies and, consequently, pollutes the water resource in the catchment. At the same time, preservation of good water quality for different water resources is necessary to protect public health and ecosystems. Sampling and analyzing water quality for different water resources in the catchment revealed that some of these resources are polluted with different levels of potential environmental risks. The upper catchment springs, which are far away from the pollution source of untreated municipal wastewater, are polluted from cesspits. Detected Fecal coliform bacteria, in these springs, indicate that cesspits are the potential source of pollution. In the middle areas, water quality of wells and springs was increasingly affected from untreated municipal wastewater. An increasing trend of biological pollution was found in groundwater wells and springs therein. Quantitatively, the general conclusions are summarized as follows:

- There is an observable temporal and spatial variability in the catchment rainfall where the rainfall distribution within the catchment ranges from 640 mm at the headwater to 150 mm at the outlet to the Jordan River. Generally, rainfall averages decrease from north to south and west to east;
- Annual springs discharge, varies from less than 4 to almost 40 MCM with an average of about of 14 MCM;
- Faria springs group has the highest annual yield with median and maximum values of 5.9 and 6.6 MCM, respectively. Whereas, Nablus springs group has the lowest statistical values;
- The total annual utilization of the Palestinian groundwater wells in the catchment ranges from 4.4 to 11.5 MCM, whereas the depth to water table is in the range of 10 to 190 meter;
- Some springs in the Faria catchment where frequently getting dried due to either reduced amount of rainfall or excessive pumping from the nearby wells. From the field visit on March 2011, it was observed that seven springs in the catchment were still dry. Among which, Faria spring, that used to discharge the largest amount of water in the catchment. The depletion of the Faria spring is a direct result of the local aquifer depletion through over pumping from existing and newly drilled illegal wells;
- For the entire Faria catchment, the annual runoff generation volume for the three years from 2004 to 2007 was in the range of 0.24 to 1.5 MCM.
- Analysis and results of the tested wells and springs in the catchment and comparing to the drinking water Palestinian standards showed that these springs are generally of good water quality in terms of chemistry.
- Fecal coliform bacteria were detected in the tested agricultural wells and springs in An-Nasarya area. Although these sources are being used by the farmers in the region for drinking purposes
- Water quality of the Faria wadi is being deteriorated due to the continuous discharge of untreated wastewater into it. However continuous sampling and analysis are essential to have a solid conclusion about the wadi water quality.

Acknowledgements

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