Water Balance in the Northern Wadi Araba Basin

Tariq M. Ghonmieen

***Abstract*—Jordan is among the countries that suffer from scarcity in their water resources because they fall within the dry and semi-arid zones, in addition to the urgent need evaluating groundwater and surface water resources for management and usage within the most urgent sectors especially in Wadi Araba basin, where there is variation in the air elements and water balance elements between the eastern highlands of the basin which form part of the Shara Mountains and the western areas of the basin, is dominated by dry and hot desert climate. In spite of the importance of the basin and its breadth and the diversity of its land surface, there is a lack of available information about the quantity of groundwater, surface, snow and rain, and the springs that flow in its valleys. In addition to the fluctuation and irregularity in the distribution of quantities of precipitation during different years, and the implications for agricultural pastoral potential, and land use, as well as the loss of large amounts of rainwater and springs through evaporation.**

In this paper, the water resources in the Wadi Arba basin were evaluated. Moreover, many aspects of water usage and quality, have been studied. The obtained results show that it is scarce, look out, and bad management of the water resources. However, there is variance in the decreasing of water levels of the aquifer wall in the Wadi Araba basin where the variance was between 0.03 m\ year to 0.5 m\year.

***Index Terms*— Ground water, North Wadi Araba Basin, Water balance , Water resources, Water levels.**

I. Introduction

Jordan is one of the most water-scarce countries [6]. In addition to the growing demand for natural resources in Jordan due to the natural increase in population, high fertility rates and forced migration to Jordan from neighboring countries for political reasons during the previous periods, which led to a sudden increase in population numbers, in addition to the effects of Potential climate change, which has recently had its effects on the marginal ranges in the Middle East in particular, accompanied by a decrease in annual rainfall rates, a change in the distribution of rainfall during the rainy season, as well as successive droughts periods affecting the quantities of Groundwater. Excessive pumping from groundwater wells is also affected by pollution and constant degradation of the water balance, leading to a disruption of the water balance its graph line generally tends towards deficit at increasing rates [3]-[4]-[20]-[21]-[24].

Groundwater is a major source of drinking and domestic use in Jordan, which contains 12 geological basins, some of which are entirely located within Jordan, while the rest of the basins extend to neighboring countries. There are 15 surface basins receiving about 8 billion m³ of rain annually, and surface water is the main source of irrigation in the Jordan Valley region. Where the flow of most of the valleys and basins of the surface from West to East across AL- Sharah mountains to fill the area of the Jordan Valley and Wadi Araba floodwaters. The Wadi Araba basin is a model of these valleys, extending from the heights of the AL- Tafila, Shobak, and Petra mountains.

In this critical water situation, available groundwater and surface water resources must be evaluated. This is undertaken through the use of different techniques that contribute to the presentation of hydrological and spatial data and information that help to draw a clear picture of the water situation, the potential of the aquifers and surface, In decision-making, to establish water policies based on available information. Remote sensing and GIS are basic techniques used to provide important hydrological data [10]. Remote sensing provides the spatial information of natural resources and the natural morphological variables that are employed by GIS to produce Integrated data, spatial analysis and multi-layered information production [29].

GIS is becoming increasingly important to understand and address the pressing problems in the field of water and to manage locally and globally resources. GIS concepts help in collecting and organizing evidence regarding these problems, to understand their spatial relationships, as well as due to GIS capabilities for analysis and provision. Methods for modeling and aggregating information contribute to decision making supporting resource management within a wide range of standards, both local and global. It provides a means of visualizing resource characteristics and providing data with different templates and formats supporting the decision-making process[11].

II. Procedure

A. Study Area

The northern Wadi Araba basin is located south of the Dead Sea, between the latitudes of 30°47¯ and 31°21¯N and the longitudes 34° 57¯ and 35¯36° E as shown in Figure 1. It reaches a height of 1734 m above sea level. The western part of the basin falls to 425 m below sea level, which is part of Wadi Araba. The study area is characterized by its location within the groove of the wrecked hole, in addition to climate diversity. The climate of the Mediterranean basin prevails in the eastern part of the basin, where the moderate temperature in summer, cold, snow and rainy in winter, which reflects on the vegetation in generally and pastoral particularly, the continental hot climate prevails in the western part of the basin [8].

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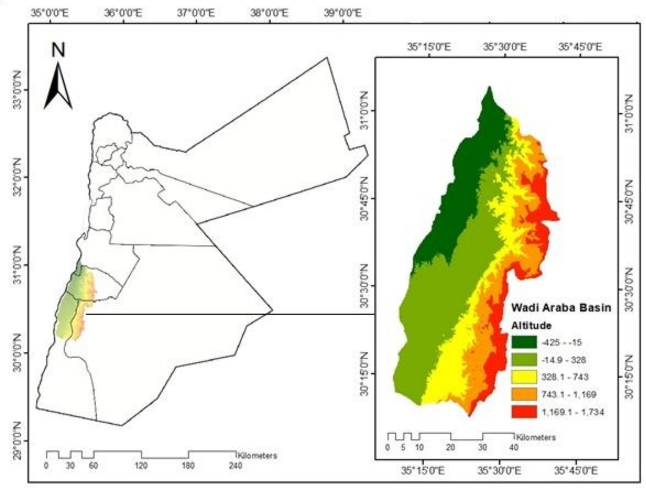

Fig. 1: Location of the study area

B. The Topographic of the study Area

Wadi Araba is considered one of the topographical formations of the Dead Sea Rift. The basin borders begin at a distance of 85 km north of the Gulf of Aqaba, specifically North of Jabal al-Risha at an altitude of 250 m above sea level. The sea, which descends northward, and its waters flow towards the Dead Sea, see figure 2. The basin also begins to rise from the Wadi Araba region Eastward to the Eastern highlands of the basin, which are more than 1700 m high. The valley of the Wadi Araba basin ends with many valleys where water flows permanently or intermittently, as well as floodwaters that flow during the rains on the eastern highlands of the basin [15]. Granite and rhyolite, as well as sedimentary and sandy sedimentary rocks abound in the lower part of Wadi Araba[1].

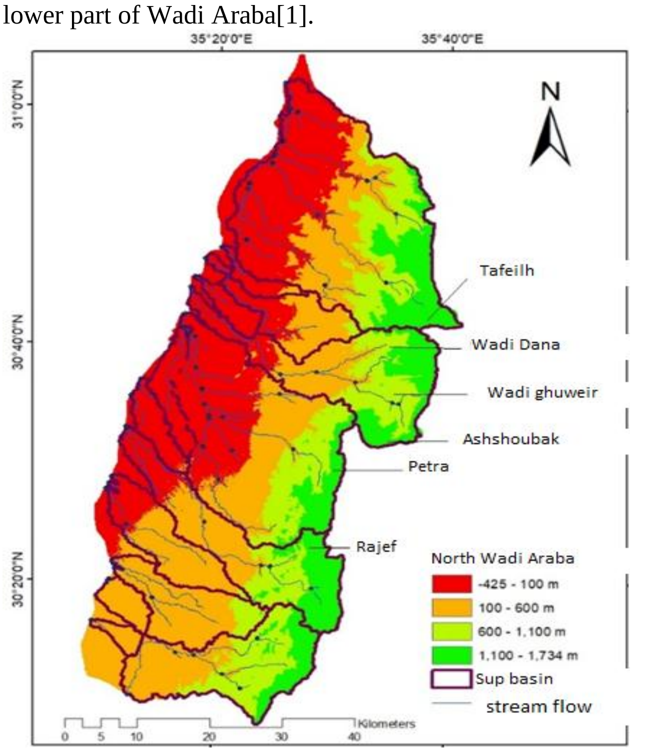

Fig. 2 : Borders the Northern Wadi Araba Basin showing the main and secondary waterways

C. The Climate

The climate in the Northern Wadi Araba basin is considered a product of the geographic location and the topography of the basin, which is reduced to 400 m below sea level in the Wadi Araba basin, and to high more than 1700 m in the highlands of Sharah, which forms the eastern boundary of the basin.

In the Wadi Araba region there is a subtropical climate which is mild in winter and very hot in summer and the average rainfall in this valley is 50 - 100 mm. The daily temperatures rates in the summer months exceed 28 degrees Celsius and the average temperature in the wet months is around 16 degrees Celsius. Evaporation reaches 2200 mm / year - 2500 mm/year, with relative humidity ranging from 53% - 62% in winter and 30% - 40% in summer [25]. Local storms linked to the Red Sea depressions and foci of depressions are active in the southern part of Jordan. Due to the lack of vegetation and the dominance of clay and alluvial soils, dust storms are particularly active during spring and early summer [26].

The Sharah Mountains are characterized by cold and rainy winters, and moderate in summer, and snowfall during the winter on these highlands, while the rate of rainfall on the Eastern highlands of the Wadi Araba basin such as the mountains of Shobak and Tafila reaching up to 300 mm / year For several months, from October to March, in some years the rains from the Red Sea depressions fall during April and May months [8].

D. Hydrogeological of Northern Wadi Araba Basin

The rock formation of aquifers in this basin is characterized by heterogeneity. It contains conglomerates, gravel, sand, silt, and mud, which are in some places completely mixed, or in the form of layers.There are several aquifers in the Wadi Araba basin, which can be summarized[19].

1. The Cambrian and Ardovish water-bearing sandstone unit, which forms the water-containing layers of the Disi and Rum groups, which are large aquifer-containing aquifers.
2. The cabbage unit which contains water, consisting of bottom chalk sandstone.
3. The unit of carbonate rocks containing water, upper Cretaceous, which forms the so-called Amman-Wadi Al-Seer basin.
4. Unit Cretaceous upper group differentiated water-bearing.
5. Shallow groundwater system in some of the Northern Wadi Araba valleys.

Rainfall in the Wadi Araba basin range from 50 mm / year in the area below 300 m above sea level, to more than 250 mm/year in the high eastern mountainous areas of the basin. The amount of rainfall and snow reflects the opportunities for groundwater recharge, as well as the amount of water flowing through the waterways of the basin [9]-[2]. The larger the precipitation, the greater the groundwater recharge and more runoff [27]-[28].

III. Methodology of the Study

This study relies on the collection of metadata from its primary sources through satellite visualization and cadastral data, from its secondary sources represented by aerial photographs, moreover, through the analytical method through analysis data derived from satellite images, satellite visuals and topographic maps, the study of atmospheric and hydrological elements and water balance of the study area and collecting the necessary data from the Meteorological

Department, the Ministry of Water and Ministry of Agriculture, to contribute to realizing the hydrological situation in general.

Using the analytical method to:

1. Collect hydrological, climatic, hydrogeological and water information and data to establish an information system on water resources

2. Interpret the collected data in the form of technical information such as water resources information system, and assess the state of water resources.

3. Interpret and evaluate the technical data and information provided by the previous two phases and convert them into knowledge to make appropriate decisions to establish priorities in this basin, to develop proposals and recommendations for mitigating the effects of natural disasters such as floods and droughts [5].

4. Analyze the DEM model in order to analyze the water network to see opportunities for expanding the construction of dams, fossils, and the volume of water that can be collected.

5- Estimating the water budget based on data from different sources such as the Water Authority and meteorological data

IV. RESULTS AND DISCUSSION

A. *Surface Water*

The general trend of decrease in annual precipitation and an increase in temperature is consistent with studies indicating climate change. The decline in annual rainfall and its distribution during the rainy season greatly affects surface water and floods that feed dams, as well as groundwater recharge, as the overall trend of water consumption in all sectors. At the national level and Wadi Araba basin, in particular, the steady increase in the number of working wells during the period from 1994 to 2016 is an indication of the quantities of pumping and consumption. However, there were an illogical relationship between the number of wells during this period and amount of pumping and consumption, according to the Ministry of Water and Irrigation data, and private wells used in the agricultural sector in the southern and eastern region of the Jordan.

In the northern Wadi Araba basin, floods were estimated in medium-term precipitation at 16.2 million m³/year, and in rainy years at 53.6 million m³/year . while the base flow rate is 11.6 million m³/year [19].

Flood water and springs flow in the Northern Wadi Araba basin from the Eastern mountains in the basin to the west, see figures 3. the region needs large dams on the main valleys in the basin to store water during the wet months in order to benefit in the dry months, where the demand for water increases and the expansion of the construction of dams and excavations increase the chance of groundwater recharge.

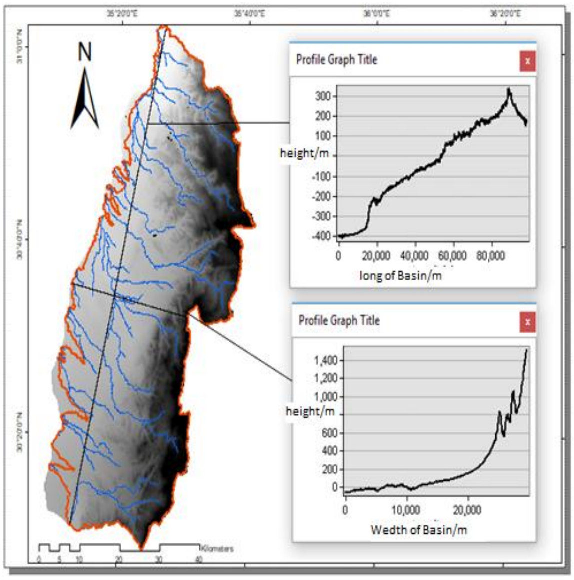

Fig. 3: Topography and slope of the direction

B. *underground water*

Flood water is considered the main source supply of recharge, unconfined aquifers along the flood plain in Wadi Araba. Furthermore, the amount of feeding depends on the length of the flood during the stream flows after precipitation. Moreover, increased evaporation reduces the amount of water that seeps down to the aquifers, Also, thick sand layers reduce the chances of evaporation and a thus greater possibility of groundwater recharge. However, unconfined groundwater is sensitive to any local climate change. According to[14], a 15% change in rainfall and a constant temperature lead to a 40-50% reduction in groundwater recharge in arid and semi-arid areas, indicating that small changes in rainfall rates significantly affect In groundwater recharge rates and consequently a change and decrease in groundwater resources [7]-14]-12].

The amount of rainfall in the Northern Wadi Araba basin during 2015/2016 was about 510 million m³ and the estimated groundwater recharge is about 24 million m³ is at 4.7% of the rainfall [18]. The foundation discharge of springs and valleys represents the discharge of groundwater from various upper and deep water layers. The amount of groundwater pumping is compared with long-term recharge rates. The estimated amount of groundwater extracted from the Northern Wadi Araba basin during 2016 is 6.65 million m³, and safe extraction is estimated at 3.5 million m³ thus 3.15 million m³ over pumping from this basin [18].

By tracking the water levels in a number of wells operating in the basin and observing the change during the time periods shown for each of the wells, there was a common denominator in all of them is the decrease of groundwater levels for all of them, but in different proportions. A decrease in water levels in the wells of Fidan, Wadi Hoor, and Fifa 4, for example, 3, 7, 7, and 7 cm/year, which are somewhat modest, while in the wells of Fifa 11 and Khnezira, the drop rates were 17 cm/year For both of them. The Wadi Ghweiba and Safi wells were very low, with half a meter per year, see figure 4. This depletion warning the occurrence of water salinization in these areas [18].

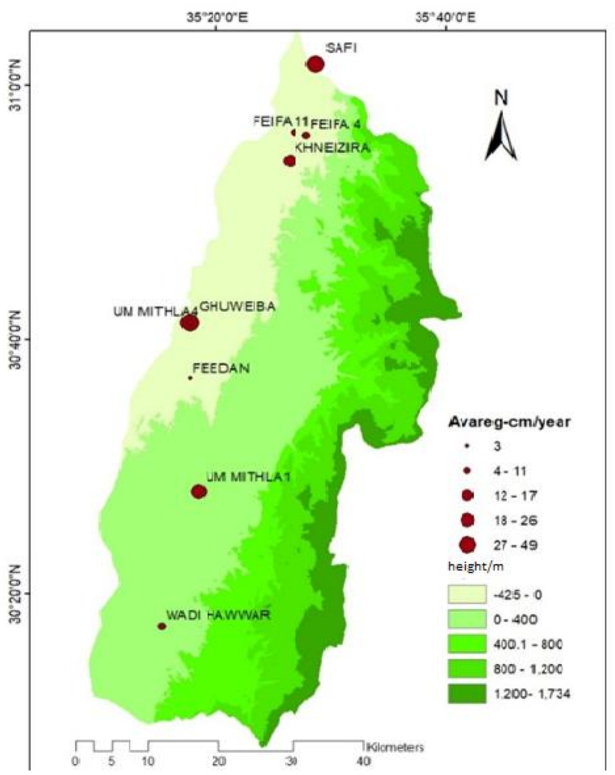

Fig. 4: Rates of Decrease in Groundwater Levels in Some Wells in the Northern Wadi Araba Basin

C. Water budget in the Northern Wadi Araba Basin

Wadi Araba Basin is characterized by its diverse terrain, geographic location, and impacted by four climatic regions and the decline of rainfall rates from approximately 300-100 mm/year by moving from the eastern highlands of the basin to Wadi Araba. The eastern highlands of the Wadi Araba basin, descend from more than 1770 m to 400 m below sea level, through a distance of 25-30 km, see figure 3. Furthermore, the possible evaporation in the western part of the basin reached to about 2500 mm/year [21]-[22]. The following results can be summarized:

1- There was a fluctuation in the amount of precipitation in the basin within the range of 150 million m³ during the years 1999-2001 to about 500 million m³ during the period 2013-2016. This significant difference in the amount of underground recharge is due to the distribution of precipitation during the rainy season. In contrast, the concentration of precipitation during the rainy season 1999/2000 during the warm months resulted in an increase in the rate of evaporation 98.8% and thus decrease the rate of groundwater recharge.

2- Groundwater recharge in the period 1994-2016 ranged from 1 million m³ in 1999/2000 to 28 million m³ in 2014/2015

3 - The flow ranged from 1 million m³ in 1999/2000 to 7.5 million m³ in 2013/2014.

4 - Not only the amount of runoff and groundwater depend on the amount of rainfall, but also on the distribution of it and the quantities during the rainy season.

D. Water usages in the Northern Wadi Araba Basin

There is considerable fluctuation in water usage in the northern Wadi Araba Basin in all sectors. The Wadi Araba region is inhabited by tribes that have been settled in this area, but a part of the population of many of these communities who depend on agriculture and grazing are still leaving annually from April to May. In September 2000, two wells were drilled in order to produce 120,000 m³, and the number of wells and water extracted fluctuated until 2012, and there was a leap in the number of wells and water extracted during the years 2013-2016. To reach 13 wells and the amount of water to 2 million m³/year. As for the industrial sector, the number of wells and quantities of water used decreased from 8 wells in 1994 to 3 wells in 2016. As well as, the amount of water was decreased from 3.24 million m³ to 0.9 million m³ by 73%. In the agricultural sector, the number of wells and the quantity of water used increased significantly during the same period, where the number of wells increased from 4 to 22 wells and the usage amount also grew up from 0.65 million m³ to 3.6 million m³, with significantly increased in the number of wells and the amount of water used which exceeded 450%.

E. Water Situation in the Northern Wadi Araba Basin

By tracking the water situation in the Northern Wadi Araba Basin and the relationship between the amount of use and extraction of water from the basin and the number of wells used can be summarized through the following observations

1 - Inconsistency between the production quantities of water wells and their number.

2 - There is an increase in the quantities of water consumption during the period 1994-2012 by 50%.

3- The amount of water consumption in 1994 was about 4 million m³ and the number of operating wells was 17 wells, then the amount of water consumption decreased in 1999 and 2000 to 3.5 and 3.7 million m³ respectively, while the number of wells increased during the two years to become 27. In spite of the increasing number of operating wells decreased the amount of consumption and water extraction.

4 - There is an increase in the number of working wells by almost 100% during the period 1994-2012 offset by an increase in the amount of water extraction by 50%.

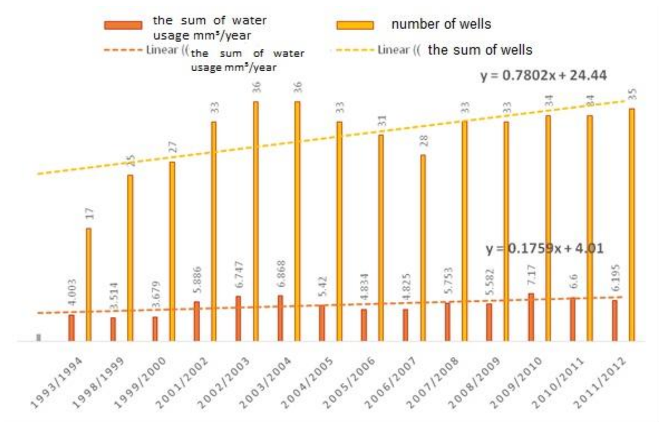

Fig. 5: Water Situation in the Northern Wadi Araba Basin

5- Water is depleted relatively large in the Northern Wadi Araba Basin, Figure 5 shows that in some years water extraction is twice the amount of safe extraction from the basin. as we see that the percentage usage of water in the agricultural sector is increasing steadily it has been alarming the water supplies.

V. Conclusion

This study, many observations can be seen:

The general trend of precipitation in Jordan and in the Northern Wadi Araba Basin, in particular, shows a decrease, which has negative effects on groundwater in terms of low recharge rates. Furthermore, the increase in the number of working wells, particularly in the agricultural sector, does not reflect the logical amount of pumping and usage, which may be due to the absence of real control over the wells and the meters that show the amount of the extracted water. Also, the presence of significant fluctuation in the amounts of rainfall during the period from 1994-2016 reflected on the elements of water balance, runoff, evaporation, and groundwater recharge.

A large part of this water is wasted, without utilizing it in agriculture after storing it in dams or feeding groundwater, as shown by the readings of the ground wells in the basin, which indicates a general decline in the levels of these wells up to more than 0.5 m/year and this is a bad indicator of the groundwater situation in this basin particularly, and in Jordan generally, if we know that the largest percentage of water consumption goes to the agricultural sector, where the decrease in the efficiency of water use by comparing the quantities and percentages of water used with the economic return of cultivated varieties in this region. However, Inconsistent the proportions and numbers of wells drilled and used in the agricultural sector is not consistent with the proportions and quantities of increase in water pumped and used from these wells, where the increase in the number of wells according to the equation $Y = 64.186 * X \quad 2307$ where Y: number of wells and X: Year Number.

The increase in water use by $Y = 6.4396 * X \quad 463.73$ where Y: quantity of use and X: year number. And this is illogical and the reason for this might attribute to the presence of wells pumping water out of control the absence of meters that give real values and therefore this distortion appears in the readings.

There must be real control over the pumping wells, especially for agricultural uses because an increase in the number of wells and the pumping quantities recorded is not logical. Moreover, It is imperative to make optimal use of the rainfall in a country scarce water resources such as Jordan through the expansion of the construction of dams and earthen pits and to minimize a high water consumption agriculture and low economic feasibility.

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