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CLIMATE CHANGE EFFECTS ON WATER RESOURCES IN AMMAN ZARQA BASIN – JORDAN

Eng. Bassam Mohammed Al-Qaisi

Ministry of Water and Irrigation –Water Authority of Jordan – Jordan

Amman -11131

Phone +962 799074380**, Fax +962 65813661**

E-mail Qaisi960@yahoo.com

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Abstract

The Amman Zarqa Basin (AZB) area which extended northen to the Syrian boarders, the Azraq basin to the east, Yarmouk basin to the northwest, and Amman area to the southwest. The total area of the basin 4120km^{2}where around 95% of the area is within Jordan and 5% is in Syria. The basin represents a transitional zone between the semi arid highlands in the west to the arid desert in the east. The main populated centers are the cities of Amman, Zarqa, Jaresh and Russaifeh. Groundwater is the main source of water supply in the basin, whereas extracted from Basalt and B2/A7 aquifers through a huge number of wells.

Unjust and wrongful groundwater extracting generate depletion in water level and deterioration in the water quality where engendering narrowly use. Climate Change Effects extra challenge squeeze on the water budget in the basin and cause intimidation on the water resources. (AZB) has been taken as case study to demonstrate the climate change effect on precipitation distribution and water resources availability. In additional to, observe the metrological parameters variations.
The methodology of this study is to analysis precipitation distribution and rainfall variability and intensity, observe evaporation and temperature changes, gauging the runoff volume, and explored the groundwater recharge variability. The second part of this study is to suggest climate change mitigation and adaptation methods.

This study deduce that the mean annual precipitation over the area is reducingfrom 300mm in previous studies to 267.92mm, which is defined out of 58 rainfall station and for 58 years monitoring records, and this study is designated that increase in the minimum value and the potential evaporation value (2436) mm has unsystematically fluctuation. The runoff coefficients in the basin vary from 2,45 to 3 % where generate runoff average volume 26MCM yearly.
The groundwater recharge where seemes to be observed around (5-5.75)% according to water budget method which used to calculate the infiltration volume where found around 60MCM/y
The water quality deteriorates to critical limits. The study suggests the water harvesting methods, artificial recharge to take as agent to mitigate climate change effects.

Keywords: Climate change, rainfall, infiltration, artificial recharge, metrology, retention dams

1. Introduction

Jordan is a Mediterranean country that depends mostly on rain as its main water resource. Recent years have witnessed shortage in the rainfall in different partsof the country. As a result, numerous streams have dried out, ground water level has fallen to critical levels and most water aquifers are experiencing highsalinity. In addition, extreme weather conditions such as flash floods during winter and heat waves during summer are becoming more frequent in the region.

Jordan has one of the lowest levels of water resource availability, per capita, in the world. Water scarcity will become an even greater problem over the next two decades as the population doubles and climate change potentially makes precipitation uncertain and variable. Management of water resources is therefore a key issue facing national government authorities. Increasing overall water extraction to meet demand carries a high cost.
Groundwater the main source in Jordan due to the limitation of surface water resources. The groundwater resources have been exploited since 1950s by government and private sectors with few wells to reach more than 4000 wells nowadays.

These conditions are in additionally to consequences of global climatic changes that have recently been affecting several locations, which are dramatically impacting wide ranges of ecosystems. Decreases in the amount of precipitation and other extreme climate events, including hot extremes, heat waves are very likely to become more frequent in multitudes and subtropical land regions.

Jordan is now accessing non-renewable water resources from fossilized deep-water aquifers. Water quantity and quality also have major health and environmental impacts. Assessing those impacts against alternative water management and efficiency strategies, and in the light of policy costs and economic development issues, can optimize the use of a scarce resource.

2. Background

Countries in the Arab region are confronted with various water problems due to both climatic conditions and socio-economic factors. From an eco-climatic point of view, most of the region extends across semi-arid, arid and hyper-arid zones. The semi-arid belts have been particularly affected by cycles of drought and desertification in the past. Socio-economically, the region is characterized by a fast increasing population, which has resulted in a sharp decline of the per capita availability of water, from about 2200 m3/capita/year to less than 1000 m3/capita/year over the past 25 years (IHP, 2005).
In response to these concerns, many countries have adopted policies for thesustainable management, development and efficient utilization of their waterresources. However, due to increasing water scarcity and reduced per capitaavailability, many countries have recognized the urgent need to secure and utilize new supplies of water in order to sustain a minimum resource base. For many countries, the development and efficient utilization of the renewable sources of water in wadis is an important aspect when addressing water shortage problems. (IHP, 2005).
Water resources development through various techniques has to be introduced for the improvement of both quantity and quality of water. Natural recharge of aquifer from precipitation and surface water runoff helps to maintain the water level of producing aquifers, control contamination of existing water supply by waste water and lessen or entirely avoid the

degradation of fresh water resources due to mixing with adjacent or underlying brackish/saline waters. As ground water is of fundamental importance to meet rapidly expanding urban, industrial and agricultural water requirements in arid and semi-arid areas, the artificial recharge technique has become a standard practice in the development and management of groundwater resources (Kruseman, 1997).

Among the various artificial recharge methods, one of the methods is to retain surface water by constructing dams across the surface channel and let storage water to percolate into depleting groundwater aquifer. It refers to the movement of water through man-made systems from surface to underground water bearing strata where it may be stored for future use. In areas where groundwater is an important component of the water supply and rainfall variability does not allow for a sufficient level of aquifer recharge by natural means, this technology provides for the artificial enhancement of the natural recharge.

Jordan is known for its scarce water resources. Throughout history, the people in Jordan have suffered from water shortages due to the semi-arid climate that is associated with limited annual rainfall. Over the past few decades, the problem was enormous due to high natural population growth, rural to urban migration and major influxes of population in response to political and economic crises in the Middle East. These trends have resulted in increased demand from domestic and industrial users.

The main water resources in Jordan are groundwater sources, surface water resources and treated wastewater effluent. The variability in the surface water resources left no choice but the use of groundwater resources to cover part of the shortage. The total renewable safe yield of the groundwater resources in the whole of Jordan is 277 MCM/year, which does not include the Disi aquifer as this is a non-renewable source. Although extraction from these sources exceeded this safe yield by more than 200 MCM/year in recent years, Water Authority of Jordan (WAJ) was unable to meet the substantially increasing demand. The declining per capita water availability in Jordan.

The water resources strategy included existing and potential sources. Investment programs were developed to implement new projects such as water harvesting, dams and rehabilitation and restructuring water systems to minimize the unaccounted for water (UFW). Concentration was made on demand management and public awareness programmes. New sources were identified to relief the existing groundwater source and allow the natural recharge of these sources and to restore their water quality which shall relief part of water shortage in Greater Amman area. This situation is deteriorating each year by the increase of demand and therefore, MWI had to consider the option of implementing the Disi Project by conveying water from the southern part of Jordan to Amman.

3. Case Study

Amman Zarqa Basin (AZB) has been taken as case study to demonstrate the climate change effect on precipitation distribution and water resources availability.The (AZB) is one of the largest developed areas in Jordan. It is also the fastest growing region both industrially and in terms of population. New industries and irrigation projects are being implemented in the area. Groundwater represents the main source of water supply in the basin. Most of the groundwater exists and is being abstracted from the Basalt and B2/A7 layers within an area enclosed by the saturated limit of the B2/A7. This area includes the highest concentration of wells where depletion and deterioration in water quality has reached to critical stages. Abstraction in Amman-Zarqa basin started in mid sixties (8.46MCM) and increased continuously through the nineties (119MCM).The estimated annual recharge is approximately 70.0MCM.

4. Objectives of the study

This study objected to identify the effect of climate change in water level and water quality on the Amman Zarqa Basin (AZB) by the following:-

1. Determination the fluctuations in weather parameters in the study area and study the impacts of climate change on the land cover and land use

2. Engagement of water depletion and water quality deterioration with Climate Change in the Region.

3. Encourage the Ministry of water and irrigation (MWI) and Water Authority of Jordan (WAJ) to mitigate and adapt the impacts of Climate Change.

4. Submitted the Artificial Recharge as one of the suitable solution against water resources scarce circumstances in Jordan.

5. Methodology

The methodologies adopted for this study included items such as the study of the weather and atmospherically parameters simultaneously with the assessment of the hydro-geology and geo-hydrology of the area, the analyses of time series, the classification of the groundwater quality, the development of water balances , and possibly the execution of groundwater modelling to assess the impacts of climate change. The detailed elements of the methodology are:

1.Study and analyses the fluctuation of the annual precipitation data, and the cumulative annual evaporation.

2.Study and analyses the annual average temperature records, the prevailing winds and the heat waves in the region, and the land cover and land use that impacted by the climate change.

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3.Analyses of the geo-hydrology of the groundwater system available for the analyses are: spreadsheets with time series of groundwater level data and the field-collected regional groundwater level data. An analysis of the interaction between rainfall, the surface water hydrology (floods) and groundwater level behavior.

4.Evaluation of groundwater quality analyses of water samples within the area to evaluate the groundwater types in the study area, and evaluate the water quality against standards, along with evaluation of the surface water quality (floods).

5.Positioning and evaluate using Artificial Recharge methods and structures within the study area as mitigation and adaptation activities against climate change and water scarcity effects.

6. Problem description

This study drive to carry out a pilot project aimed to detect trend in weather parameters and valuate the influence of climate change on the water resources in Amman zarqa basin . The AmmanZarqaBasin has been designated for this study because of the importance of this area as a groundwater supply area for Amman city, and because of the depletion of the aquifers and water quality deterioration in the last few decades. In addition the geological formations there directly effected with precipitation fluctuations.

7. Available data

A wide rengeof data is available including geological maps, groundwater level measurements, infiltration data, pumping test analysis, groundwater samples for water quality analysis, meteorological stations data available and rainfall, runoff data, and climate data including potential evaporation.

8. Fieldwork

The fieldwork within the study area included visits to the regional meteorological stations, Ground water monitoring wells ,surface water and floods stations and the springs in the Regan as well , visits should cover serving and investigation the land cover and land use in the study area , the top soil classification should carried out. Well visits included the checking of water levels, taking the water quality (EC measurement).
This study has to be carry outcooperatively with the Ministry of water and irrigation (MWI) and Water Authority of Jordan (WAJ) whereas they has to provide the studywith all of the groundwater and surface water data and records in addition to water quality results that they have, maps, facilities for fields investigation.

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9. Amman Zarqa Basin (AZB)

Physical Characteristics

9.1 Location

The study area extends north to the Syrian boarders, the Azraq basin to the east, Yarmouk basin to the northwest, and Amman area to the southwest. The total area of the basin 4120km^{2}where about 95% of its area is within Jordan and only 5% is in Syria. The basin extends from the Syrian city of Salkhad in Jebal al-Arab with an elevation of 1460 m to south of Amman and then westward to discharges its water at its confluence with River Jordan at an elevation of -350 m.The basin represents a transitional area between the semi arid highlands in the west to the arid desert in the east.

About 2.72 million people (2004) are living in the basin representing about 50% of the total population in Jordan. The main populated centers are the cities of Amman, Zarqa, Jaresh and Russaifeh.(Fig. 9.1).

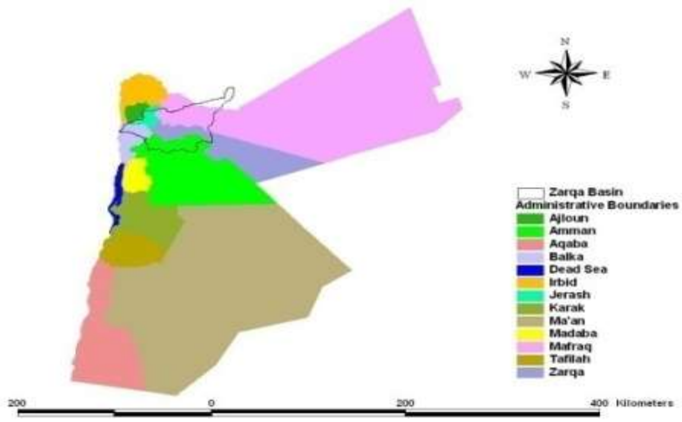

Figure 9.1: Location map of the study area

9.2Topography

A sloping terrain from 950m near the ArabMountain to 620m near the Sukhna area and 735m southwest of Amman characterizes the study area. The topography reflects the geology consisting mainly of a basaltic mount that slopes down to a central, gently rolling plateau bounded from north and south by rugged and dissected limestone hills. The stream flow of the Zarqa River is impounded by King Talal Dam at an elevation of 120 m and a capacity of 82 MCM. The area behind the river is about 3100 km^2 producing an average runoff of about 60 MCM. (Fig. 9.2).

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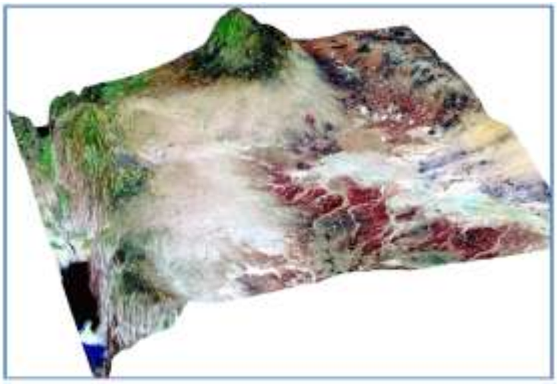

Figure 9.2: Topographic map of the study area

9.3 Climate

Jordan lies in the eastern side of the Mediterranean. The climate is semi-arid and characterized by cold humid winter with lower temperatures including moderate frosts during the nights and warm dry summer. According to the 50-years mean annual rainfall map, rainfall ranges between 100-500mm. The mean monthly surplus volumes are in December, January, February and March. Average evaporation constitutes approximately 90% of the total rainfall (WAJ, 1989). Average estimated infiltration rate is approximately 4-10% (WAJ, 1989; Mahamid, 1994). The eastern highlands of Jordan and its climate is characterised by hot summers and mild winters. Low amounts of precipitation occur during the relatively wet months from October to May and they are normally associated with the inland vapour transport from the Mediterranean Sea.

The annual average temperature is 17.3 °C. The daily average temperature ranges from approximately 8 °C in the winter to 25°C in the summer . Prevailing winds at Amman Airport are from the southwest in the winter shifting to the northwest in the summer. The available data for the water years from 1965-66 through to 1989-90 indicate that the cumulative annual evaporation, based on Class A pan data, is in the order of at least 2000 millimetres. Monthly evaporation rates range from approximately 85 up to 90 millimetres in December and January to 210 millimetres in April, and up to 300 millimetres in May (Chehata and Livant, 1997).

9.4 Geology

The rock outcropping in the study area ranges in age from Creteaceous (Ajlun) to recent (Macdonald & Partners, 1964).

As below:-

1- Wadi Sir Formation A7 (Turonian)

It is the upper most unit of the Ajlun group. It outcrops extensively both in the north, central and south parts of the area. The massive crystalline limestone is karstic and weathered in the top 20m of the formation. Below them there is a general increase in the marl chalky limestone and thin marl beds occur, indicating a transition into the underlying Shueib formation. The formation ranges in thickness between 50-250m dipping to the east and northeast.

2- Amman Formation B2 (Santonian_Campanian)

It is a cyclic deposit of chalk, phosphate, silicified phosphate, limestone and Chert. Its thickness ranges reaches 47m in the study area.

3- The Plateau Basalt (Oligocene-Pleistocene)

Basalt outcrops in the northeastern part of the basin. Six major flows have been identified in the study area. Thin layers of clay and gravel consisting of limestone and Chert pebbles have been encountered between the successive flows. The basalt thickness in the northeastern part is 400m and wedges to the west towards the periphery of the flows.

4- Younger Alluvium Formation

The younger alluvial consists of thin deposits overlying the basalt in the cemented out-wash and the old river terraces.

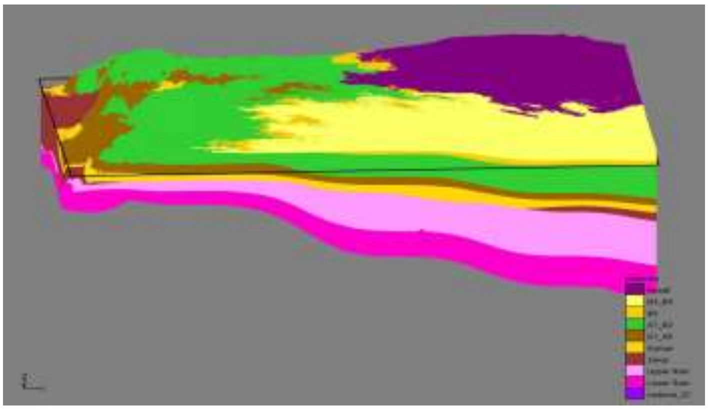

Figure (9.3) Outcropping and formations in the study area

9.5 Structure

Generally low dips and gentle folding except for the abrupt flexures and associated faults characterize the study area. Such features mark the limits of the important synclines of Wadi Sayih and Muasher in the south and south-central parts. North of the Muasher syncline there appears to be another turndown of fault. The limestone north of the basalt formation is affected also by a flexure downloading the strata to the south. In the central part of the area

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the structures are covered by the basalt flow where the basalt filled a major synclinal structure having a pitch to southeast (Macdonald & Partners, 1965).

10. Hydrogeology

Based on the geologic and structural features descried in the pervious section, three main aquifers were identified:

- The B2/A7 limestone aquifer

Most of this limestone formation is wholly within the limit of saturation. In areas where the formation is below the water level and fissures and joints exist, it was recorded as a potential aquifer. Also the degree of fracturing and secondary porosity controls the yield and availability of water.

- The Basalt and the Older Alluvial aquifer.

Both are considered one of the main aquifer system in the study area and extend to the north and northeast. The alluvial deposits lie below the basalt, in the drainage channels and depressions of the former land surface and within the basalt sequence. They are considered as the major conduits carrying recharge water from the high rainfall areas into the Dhuliel and other groundwater provinces.

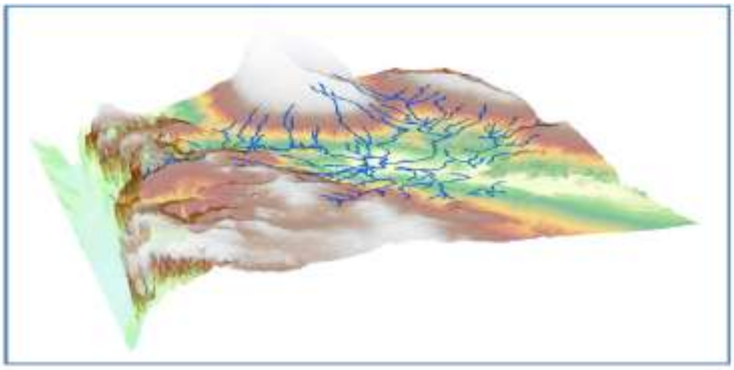

Figure (10.1) hydraulics streams in the study area(adopted from dar alhandasah)

Apart from the interflow alluvial within the basalt, scoriaceous and jointed basalt in the east and central part is considered a very good aquifer.Both formations are considered in hydraulic connection. Thus, they are considered as one unconfined aquifer system.

10.1Hydraulic Parameters

Transmissivity

Structures are considered the main control factor for the location of high yield aquifers (100m^3/hr). Wells that were drilled by Macdonald & partners (1964) showed that the main synclinal structures are considered as potential aquifers.Several wells were drilled in the B2/A7 aquifer and showed that the highest yield aquifers are located in the Muasher syncline. This formation has poor ability to transmit water and wells should be restricted to areas of the major structural deformations where high secondary permeability exists.

Limited number of wells that were drilled in this aquifer has transmissivity data. In order to calculate the transmissivity (T) for the remaining wells.(Fig.10.2). The correlation equation for the Wadi Sir formation is illustrated by the following equation: $T = 48.27S^{0.88}$

Figure (10.2) transmissivity and specific drawdown for the B2/A7 formation.

The main synclinal features are the Muasher in central part of the study area, the East-Abdalliah in the southwest, and the Hallabat in the northeast. As a result, a zone of scoriaceous basalt reaching to a thickness of 45m is considered to be the primary aquifer in basalt flows where the transmissivity values are considered very high. Away from the high yield areas, the basalt is made up of a series of semi-interdependent channels or pipes lying side-by-side giving the possibility to pump from one well without affecting the next. The correlation equation for the basalt formation is illustrated by the following equation:

$$T=223.55S^{0.64}$$

10.2 Specific-yield

Lack of observation wells in the study area prevented the obtaining of specific-yield values. Also the nature of basalt and the semi-interdependent channels make it very difficult to estimate the specific-yield for a large area. Nevertheless it is obvious that the few specific-yield values that were measured indicate that the system is under water-table conditions. Estimated values for specific-yield range between 0.05 and 0.40 and are shown in Figure (19.3).

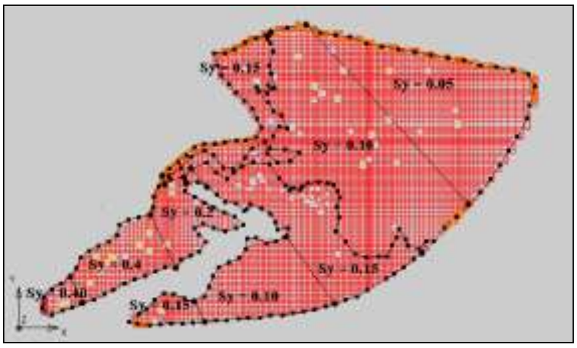

Figure 10.3: Specific yield distribution over the study area

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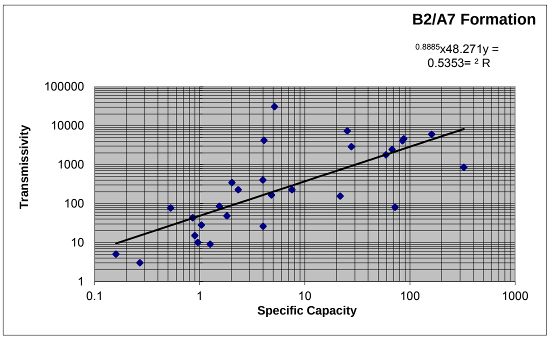

10.3 Flow-Net

Static-water level readings were obtained from more than 200 wells prior to 1980 when the system was in equilibrium. For the central and Hallabat areas, the year 1965 was the initial water level.(ARD).

The groundwater flows from the northeast from Arab Mountain in Syria towards the west and northwest into the Yarmouk basin Figure (10.4) and toward the east to the Azraq basin. The configuration of contour lines indicates the aquifer characteristics. The groundwater velocity varies through the study area considerably according to permeability.

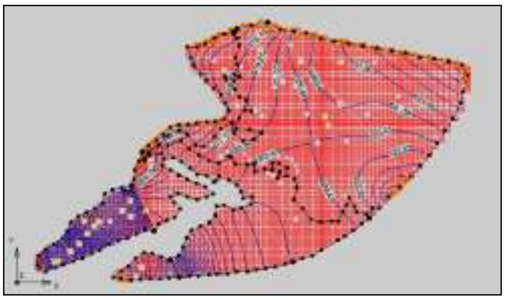

Figure 10.4: Measured steady state water-level map of the study area

10.4 Recharge

Recharge occurs through direct and indirect recharge in the study area. Direct recharge is due to direct rainfall infiltration on the study area. Indirect recharge consists of lateral flow from the high rainfall areas in the Arab Mountain.

Direct recharge within the study area was calculated by multiplying the 50-years average annual rainfall by the infiltration ratio. Previous studies have calculated the average infiltration rate based on the water budget method. In the Amman-Zarqa basin water

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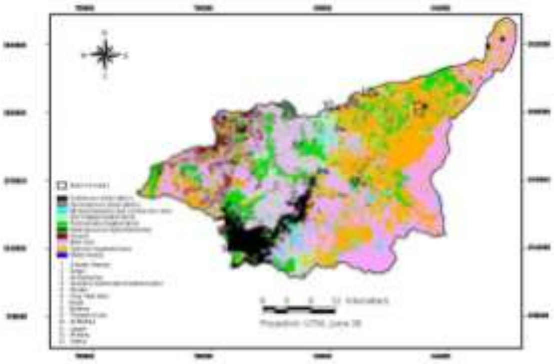
resources study (1989), the calculated infiltration rate was 7.0%-10.0% of the total rainfall amount. Recent study by Mahamid (1998) showed that the infiltration rate ranges between 3%-6%. And ARD study an infiltration rate of 6% was used to calculate recharge. The annual rainfall in the study varies between 100 – 500mm. Estimated mean annual direct recharge in the study area totals to around 32MCM.



Indirect recharge or lateral flow via the basalt and associated gravel was calculated according to Darcy's law in the model. Model Results showed that annual lateral recharge from the north is approximately 46.5 MCM. Total annual recharge to the study area was estimated to be 80MCM.(ARD)

10.5 Abstraction

Development in the study area started in the early sixties. Abstraction increased gradually from 8.46 MCM in 1965 to 123.4MCM in 1998.The increase in abstraction from 1965-1975 was concentrated in the Dhuliel-Hallabat area where the abstraction reached to approximately 37 MCM/yr. Starting from 1980, a gradual expansion of the wells took place in the north and northeast. By the year 1995, another expansion to the east was noticed leading to increase in abstraction to 123.4MCM by 1998. Total domestic and industrial abstraction is around 48.8MCM, representing 40% of the total production in the study area.

10.6 Land cover

The soils of the basin differ widely according to rainfall and relieves. In the most humid west, reddish to brownish clay and clay loams prevail. Toward the east, the soil become more immature with silty loam to loamy in texture, yellowish brown to strong brown with very high carbonate content. Soil erosion on the steeper slope is main cause of colluvial processes where sheet erosion is more pronounced in the eastern part. Different types of soil erosion are causing serious problem threatening the storage capacity of King Talal Dam. Soil depth is function of slope where deep colluvial soils have been accumulated in the valleys and lower slopes. The upper slopes are affected by soil erosion and degradation, leaving behind shallow and stony soil.

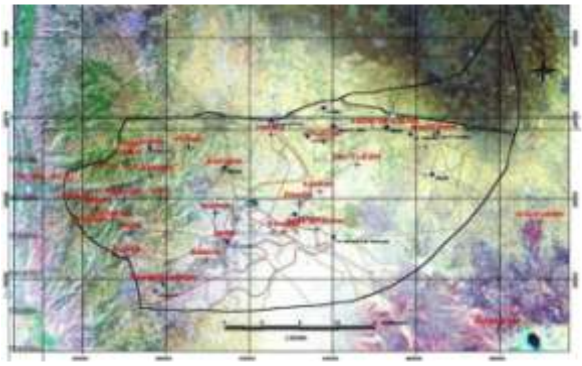


Figure (10.5) AZB land cover (adopted from Shatanawy)

The basin is subdivided into two main catchments;(shatanawy,2002). Wadi Dhuliel sub-basin representing the arid conditions and flat land and Seil al-Zarqa sub-basin which represent the most populated mountainous area. Below the basin, Amman-Zarqa aquifer system is located and is considered one of the most important basins with respect to its role in development.

10.7 Landuse

During the last 20 years, the basin has undergone considerable land use changes. The expansion of Amman and other towns has been enormous, where before large areas of grazing land and fertile agricultural land could be found between Amman and other towns, it has now developed into one large urban conglomerate.(Shatanawy,2002).
ZarqaRiver basin is capable of supporting forests and agricultural activities. Natural forests occurring in the mountainous part are composed of oak, pine, juniper, wild olive and cypress. Agricultural activities and their associated weeds have supplanted the indigenous flora communities. Agriculture is scattered with the basin from rainfed orchards, olive and field crops to irrigated agriculture on the river banks and

10.8 Rainfall

The hydrological network in and in the vicinity of the study area consists of 94 rainfall stations 58 of them within the (AZB) area others are in surrounded where they distributed as some of them shows in figure (11.1).thirty five stations according to the data accuracy and geographical distribution was selected to establish the water contour map .

Farther more there is three from seven evaporation stations are located within the basin area. Among to the stations there are 8 wadis as in figure (11.3) drain in the study area. The location and long term average annual rainfall are listed in table (11.1) where the most stations recording was started in the fourth decade of the last century. Two stream gauging stations are recognizing in the study area. For groundwater recharge many water wells in the basin has been observed.

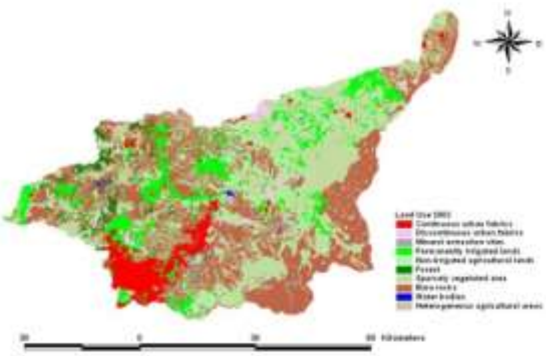


Figure (10.6) rainfall station location

11. Precipitation Distribution

The amount of rainfall is mainly governed by the topographic elevation of a location. Precipitation analysis shows that the rainfalldistributions can be divide into four zones within (AZB), the Highlands, Plateaus and Terrain flat, Desert area and Lowlands (Gours) where these divided represents the Jordan topography. In the highlands the rainfall stations, Jarash, kitta, Dibbin, Aluk, Sweilih and Husain collage are represent this area with rainfall ranged from 543.35 mm/y in kitta to 319.32mm/y in aluk station.

The Plateaus and Terrain flat covered by stations Miduar, Baalama, Sukhna, Khaldiah, Nuasif, Um El-jimal, Zarqa and Rusaifah with annual rainfall range from220.74mm/y in Miduar station to 119.76mm/y in Um-El jemal station. While in Desert area the Annual rainfall ranged from 112.86mm/y in Um Qaiteen station to 66.48 in wadi Salaheb station and by incursion out of the basin to eastern south to al Emary stationwhere the annual reainfall about 41.24mm/y. The fourth part of the basin is the lowlands where stations Dair all and Subaihi located there with annual rainfall ranged from 277.44mm/y to 391.75mm/y respectively. Nearly all of the precipitation occurs during the months from October to May. Snowfall is not uncommon in the highlands during the coder winter months. A comparison of data from adjacent stations reveals that rain storms are often very local events in Jordan. Figure (11.3) illustrates that the highest rainfall in recorded in the northern highlands around Ajlun and Swaleh

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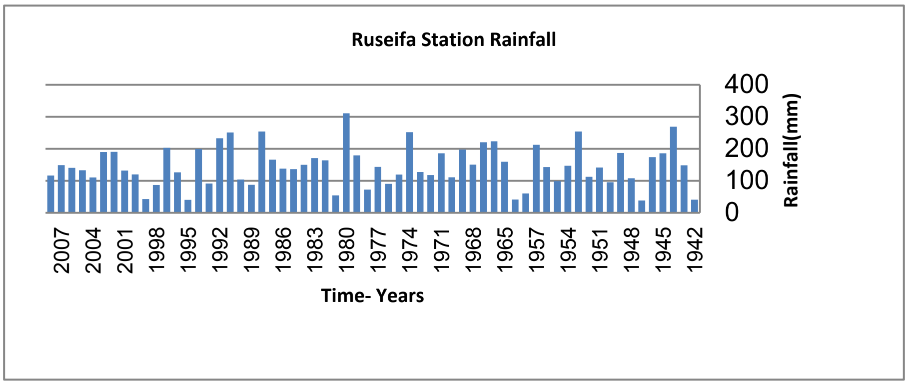

Figure (11.2) Annual Rainfall for Ruseifa Station

Based into above data the precipitation distribution in the (AZB) started with 543.35mm/y in the Northern-eastern part of the basin with progressive decreasing within unify topographical zone, while decreasing dramatically with moving toward Eastern-southern from highlands to plateaus farther to the desert to reach 66.48mm/y in wadi salaheb station. The thirty five stations that selected to establish the long term annual rainfall map shows in figure (11.3) for the basin has records from 1950 to 2008 and the other station has been excluded because of messing and clouds data.

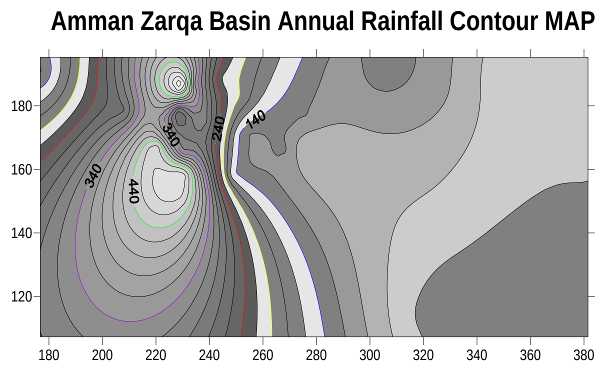

Figure (11.3) Annual Rainfall contour map for (AZB)

By using Thiessen method the annual mean value has been calculated for the 58years for each station as tabulated in table (11.1). As well the stations fragmented areas have been computed by Plano meter and polygone methods. **While the maximum annual rainfall was** pointed in (1991/1992), the absolute minimum rainfallwas at (1959/1960) but in the last two decades the minimum rainfall year was (1998/1999). The average annual rainfall for the Amman Zarqa Basin is 267.92 mm.

Thiessen Polygons and Isohyatal maps are used to select 1998/1999 as dry year, while the year 2003/2004as normal rainfall year and 1991/1992as wet year.According to dry year the rainfall distributed over the basin with ranges from 277.4 mm in the Northern-western parts to less than 54mm in the Eastern-southern parts of the Basin. Whereas, the rainfall was ranged from 86 mm in the Eastern-southern parts to862.5 mm in the Western-northern parts for wet year.

11.1 Precipitation Variations

By using Findgraph Software the leaner trend was calculated for most of the 35 rainfall stations overall the 58 years, out of the trend it is clear that absolute annual rainfall in the majority of station heading down as shown in figure (11.4) for the Kitta station.

Moreover the Annual rainfall data has been computed for each station decidedly for changing determination in the rainfall amount where figure (11.6) shows the inclination in rainfall with time rising. In the1940s the rainfall was by 40-50% higher than the long term average .until the late 1960s the average annual rainfall dropped to between 20 to 30 % below the long term average.

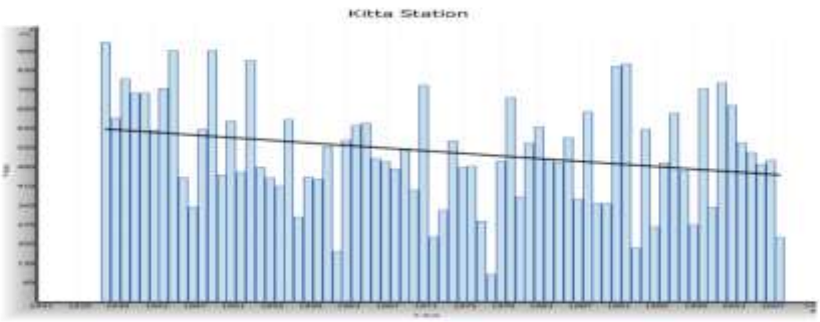

Figure (11.4) Rainfall trend in Kitta station

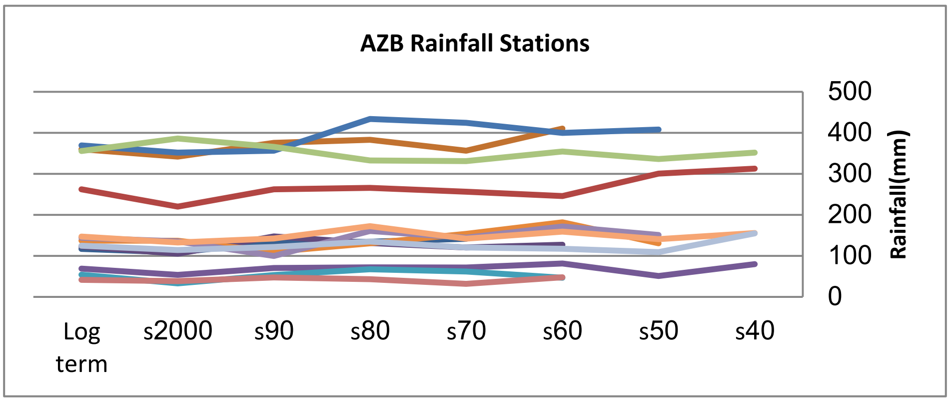

Figure (11.5) Rainfall dropping down in(AZB) decidedly

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Around 1963/1965 it rose again to a level of 10 to 15% above the long term average. In the following years the average sharply dropped again, reaching a low of up to 20% below average around 1978/1979. Thereafter, the situation differs for the different station. At some station in the north the average rainfall seems to have increased until to day, whereas most other stations as shown in Kitta station Figure (11.6) averages decreasing below the long term average.

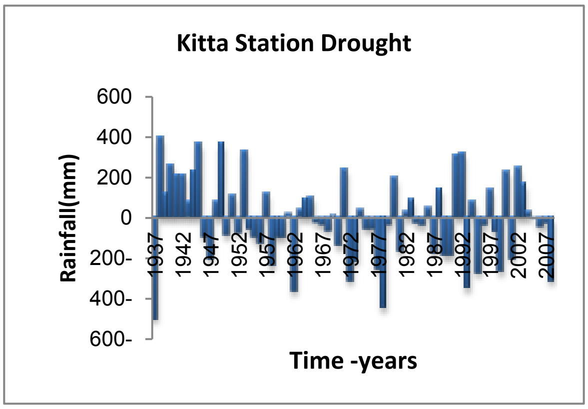

Figure (11.6) Rainfall drought in Kitta station

Whereas in the mid , south and Southern-Eastern of Amman Zarqa Basin as well in Jordan the rainfall mean trending down by 10-15% in the last two decades, where in the desert stations the reducing in rainfall much more than the others areas in Jordan as H5 station as present below.

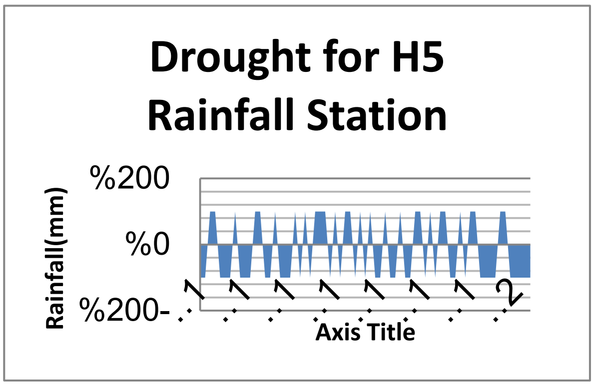

Figure (11.7) Rainfall drought in H5 station

According to the long term average, the total volume rainfall over all AZB equal 87MCM. Thus the reduction in rainfall by 12% means to loss yearly more than 14MCM as Precipitation.

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12.Temperature and Evaporation

The recent researches that executed and published about climate change in Jordan, temperature and wave heat end speed variations gesticulated to no cleared changes that take place in these parameters in last two decades.
This study has been reorganise the five evaporation station that located within AZB with yearly evaporation data based on class A pan method for more 25 years according to The table (12.1) below show.

The evaporation data for stations (AL0019, AL0035, AL0059, and AL0066) has divided for two decadal (1988-1998, 1998-2008), and thiessen Polygons and Isohyatal maps are used to calculate the evaporation value, where found the potential evaporation value for period (1988-1998) is about 2452 mm but for period (1998-2008) it is about 2502 mm.

The evaporation data indicated that AL0035 station in Baqa near Amman city has clear variation from 2292mm in the first decade to 2995 mm in the second. Other stations has limited variation as shown in AL0059 data in figure (12.1) below.

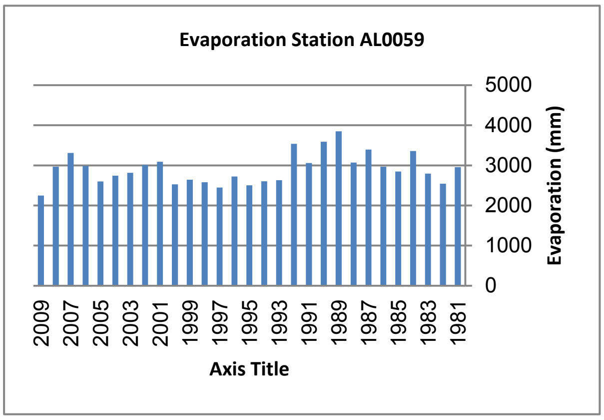

Figure (12.1) evaporation Value in AL0059 station

The research Climate Change in Jordan that executed by (Moshrik R. Hamdi,Mahmoud Abu-Allaban, and others) from Department of Land Management and Environment, Hashemite University,Jordan and Consortium Consultants for Safety and Environment, Abu-Dhabi, UAE gesticulated to that there are no visible trends indicating an increase or decrease in the annual precipitation and maximum temperature. However, there are good to strong trends indicating that annual minimum temperature has increased in the last decade while annual temperature range has decreased. Conclusion: Decreasing temperature range proved that the
Earth's atmosphere is becoming more efficient in trapping terrestrial infrared radiation, which is accountable for the global warming.

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Another study by Dr Ali El_ Naqa from Hashemite University attain results says that maximum temperature has no change while the minimum value has increase whereof the temperature log term average increase.

This study has attain the same results which says that there is seems to change in temperature long term average whereof could cause the increase in the poetical evaporation long term value. Whereas changing about one to two percentage in evaporation need historical data to sanction the change in the evaporation value. **Whereof the previous studies approve the value 90% as evaporation factor for AZB while this study slanting to 1% increase in the potential evaporation value.But with notices that the rainfall storms shifted in time toward summer time so the effect of evaporation became more. As a result this study seems to see the evaporation value for AZB to be 92%.**

13. Runoff

Rainfall-runoff relationships are used primarily for design, forecasting, andevaluation. If a strong relationship between rainfall and runoff can be developed for acatchment of interest, combination of the rainfall-runoff relationship and the rainfalldata may be helpful to estimate runoff volume, peak discharge.

Amman zarqa basin was divided for fourteen sub catchment areas each one contains main streams as shown in figure (13.1) , and all the streams bump into major main stream called Zarqa river and spilling downward west lower territory (Gaur) where retain by king Tallal dam.

Jarash bridgestation(AL0060) one of the eight runoff gauging stations that located on Zarqa river and other streams in the basin , this station has taken to calculate the amman zarqa basin runoff volume .

Figure (13.1)Main streams in AZB –(adopted from Shatanawy)

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Runoff gauging stations are shown in figure (13.2) below , whereas all the surface runoff of AZB pass AL0060 Runoff station (Jarash Bridge Station) it became the reference to calculate runoff volume .

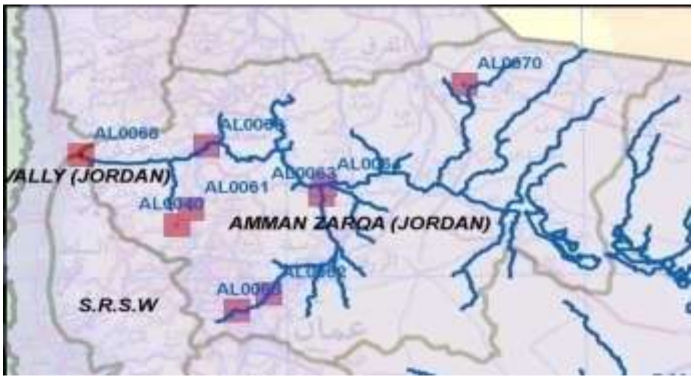

Figure (13.2) AZB runoff stations

The runoff data from all the stations was screened and evaluated, this stations recorded runoff base flow and flood flow. At station AL0060 the recorded found from year 1980 to 2008 and the data was divided to three decadal sections for comparison purpose.

Table (131) base and flood flow at AL0060 station

Years	Base Flow (MCM)	Flood Flow (MCM)	Total Flow (MCM)
80-89	41.7	27	68.7
90-99	68.4	28	96.4
2000-2008	64.5	21.2	85.7

The base flow articulate increase because of outflow of al-Sammra sewage treatment plant . Where the outflow as recorded in 2009 to be 161032 m^3/ day (54MCM/Y) about 30MCM pass station AL0060 this plant start at 1988.In figure (13.3) below where the red columns represent the historical flood flow at station AL0060 and the blue columns represent the base flow. The figure clarify the increase in base flow since 1988 according to outflow of Sammra station and its clarify the decrease in flood flow average since last two decades, except the year 1992 where there unreasonable rainfall and flood flow at that year.

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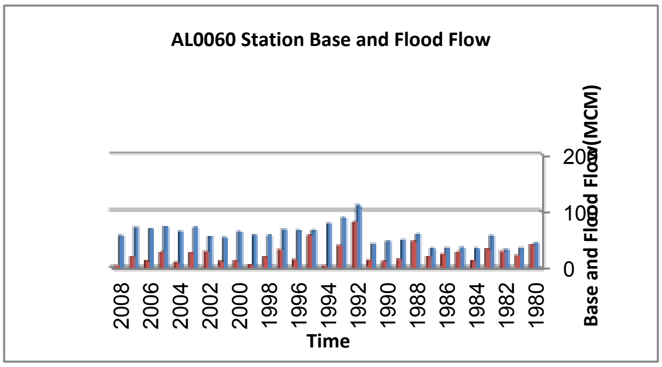

Figure (13.3) Base flow and Flood flow at AL0060 station

The factors that affect the rainfall-runoff relationship in a specific catchment can be divided into two main categories or characteristics, namely those related to the rainfall and those related to the watershed. The history of rainfall prior to an event will determine antecedent conditions and may have a strong influence on runoff production.

The available date for rainfall-runoff events in Amman Zarqa Basin in period from 1950 to 2008 analyzed and derive the runoff coefficient. Analyzing the rainfall data recorded by rain gauges, it was foundthat there are eight major rainfall events resulting in floods within the catchment. Allthe rainfall that may have contributed to producing runoff is plotted with thedischarges for each storm. It can be seen that there is a quickresponse of runoff upon the rainfall. The rainfall intensity and runoffcoefficient was calculated in an attempt to establish a relation between two. Thecorrelation was not found to be very high (R2= 0.123). When considering all therainfall, the average runoff coefficient was found to be (3-5) %.

In a second attempt not all of therainfall or runoff of some of the eight storms was taken into consideration. Rainfallnot producing runoff or runoff without apparent rainfall. The value of R2 was now found to be0.6824. The rainfall that has been taken into consideration to develop the relationshipbetween the runoff coefficient and rainfall intensity is plotted with runoff . The runoff coefficients for each storm event were calculated based on the rainfall and runoff considered. The runoff coefficient was not found to bethe same for every storm because it depends upon the antecedent conditions, rainfallintensity, duration of rainfall and distribution over the basin. Therefore an averagerunoff coefficient was calculated to be (2-5) %.

According to above the total Runoff volume seems to be around 26MCM/Yearly in additional to 50MCM/yearly flooded from Al-SAmmra treatment staion.

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14. Infiltration

The previous studies that carried out on Amman Zarqa Basin such as ARD study where it interested in the eastern part of the basin, extend to the recharge value to be 32 MCM /year. Whereas the Mahammed in his PHDresearch that establish in (1996) and cover the Dhulail area (400km^2) as a part of AZB, estimate the recharge to be 58 MCM/year. And he estimate the yearly drawdown in groundwater level is about 0.5 m as in figure (14.1) below.

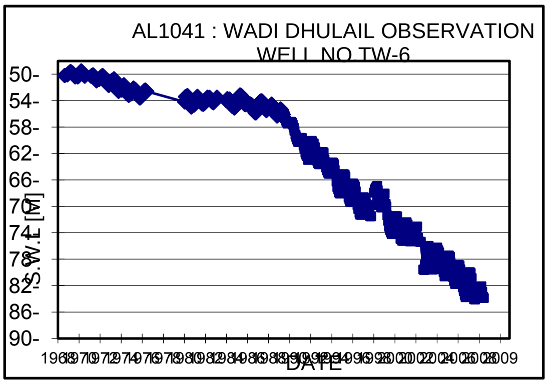

Figure (14.1) Drawdown in water level

In 2010 Dar Alhansah carried out 3D modeling that determined the domain area (10000km^2) to be cover Amman zarqa basin and Azraq basin (Zarqa Governorate) in this beta version of this model the infiltration rate estimated to be within range from 80mm/year in the western-northern part to 4mm/year in the eastern-southern part of the basin as shown in figure (14.2)

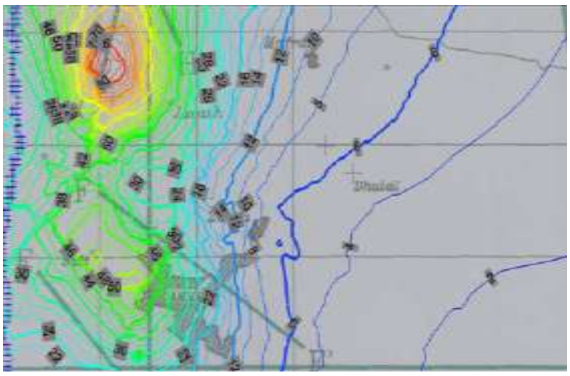

Figure (14.2) infiltration range within AZB (adopted from Dar alhandash molding)

Out of this model the infiltration volume estimated to be around 60MCM while the extraction from the basin aquifer is around 130 MCM. And the model show in figure (14.3) the extraction areas where the most drawdown has taken place.

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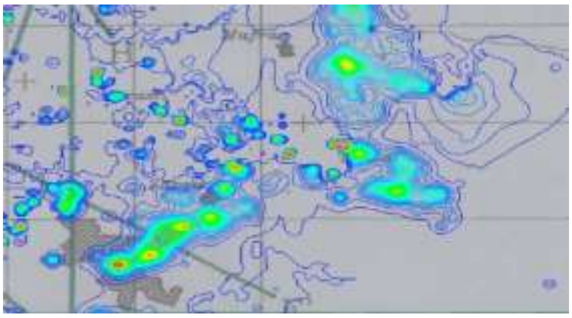

Figure (14.3) drawdown areas within AZB (adopted from Dar alhandash modeling)

In this study groundwater level data has been collected and analysis for77 observation wells just 43 of them drilled to extract water from B2/A7 others drilled to penetrate the lower aquifers such as kurop. The effect of this wells depend upon the correlation between the well and the aquifer whereas found some of this wells drilled throw the aquifer partially and some of the observation wells drilled for production but because of limited capacity it used for observation.
Observation wells show that there is yearly drawdown as seen in Zatari well in figure (14.4) where drawdown equal 22m in 40 years to the amount of 0.55m/year

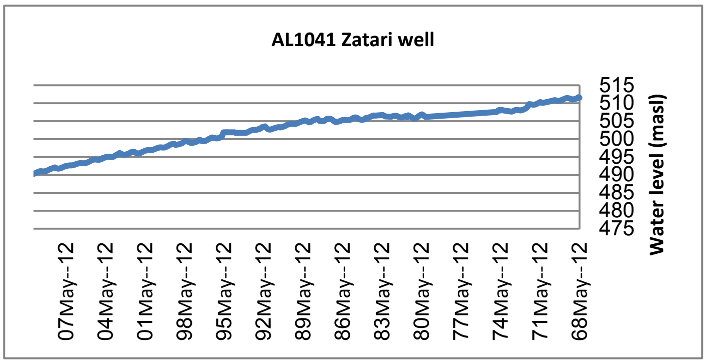

Figure (14.4) groundwater level in AL1041 zatari well

Most the drawdown concentrated in the Amman Zarqa, Dhulail and Hlabat areas where the most production wells located.
It is difficult to calculate the recharge volume specifically while the lateral flow that recharge the basin from Jabal Al Arab undefined but it is presumed around 48 MCM/y (ARD).
Whereas the average annualrainfall in Amman Zarqa basin is 267.9mm out of 58 years records as in section 11 of this study, and the runoff volume identify to be 26MCM as average of 28 years gagging as in section 13 of this study additional to 36 MCM became out the basin according to initialextracting.

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However the water budget approach has applied to identify the infiltration volume as following:-

$$\Delta S=P-R-I-E \qquad (14.1)$$

WhereΔS=Groundwater Recharge volume m3
P = Precipitation volume m^3
R = Runoff volume m^3
I = Initial Extraction volume m^3
E = Evaporation volume m^3

Extracting out of the water budget above it is clarify that the total Rainfall over AZB according to 4100km2 as an area and 267.9mm average annual rainfall equal **1billion CM/y**.
whereas the evapotrasperation value in the basin around **92%**, the net rainfall volume seems to be **87MCM/y**.
while the total surface runoff equal **28MCM/y** and the volume of infiltration that restriction feed B2/A7 equal **36MCM/y**
while there is around 10-12 MCM percolated to recharge the deep aquifer Kurnub formation whereas there is some water wells extracting from this formation in Jarash and Baq'a with more than 20 MCM/y . in additional to the lateral flow where **48MCM/y.**
Summing up the net recharge that feed the AZB (B2/A7)90MCM/y while the total Extracting from the basin (B2/A7) reach 130 MCM.

15.Water Quality

Unjust and wrongful groundwater extracting from Amman Zarqa basin generate depletion in water level as clear in data gatheringand this depletion coincide the deterioration in the water quality where engendering narrowly use.
Salinity Climate Change Effects extra challenge squeeze on the water budget in the basin and cause intimidation on the water resources. As result of depletion in water level in most of groundwater observation wells that distributed over all of AZ basin, and outcome the According to

Based on the collected data from the WAJ central labs, the maximum, minimum and average values for the Ec, NO3, NH4 and E.coli parameters of the Ruseifa well field are presented in Tablebelow.

Table (15.1) Ec, NO3, E.coli and NH4 Values For the Ruseifa Groundwater Wells

Table (15.1) adopted from water authority lab. Report 2010

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Based on the listed data in table-3, the following can be concluded regarding the status of the Awajan wells water quality.

- The average EC values vary from 635µs/cm for well R-17 to 2146 µs/cm for well R-11 (TDS: 400 mg/l – 1351 mg/l), that is within the JS286/2008.
- For the Ruseifa field wells, the average NO_3 concentration ranges from 13.4 mg/l for well R-3 to 63.6 mg/l for well NR-5. The maximum recorded NO_3 concentration for the majority of the field wells exceeds the JS286-2008, indicating clear pollution incidences affecting the water quality of most of the wells.

16. Results

This study carried out to identify the effect of climate change on the water resources in Amman zarqa basin and clarify the evaluation in weather parameters. Starting with precipitation distribution **this study achieve to the long term average rainfall amount is 267.92 mm /y where it was 300 mm/y in the previous which means that there is reducing in the rainfall amount with around 12% in the last decade. Farther more in 2010 the rainfall** amount was 70% from the long term annual average and 1n 2011 till med of March the amount is around 50%. The second result says that the rainfall distribution is retreat toward the spring season. Most the rainfall in the previous time was occur in December and January but in the present time most the rainfall occur in February and March were the day time is increase and the temperature raise association with increasing of evaporation.
Drought circulation in the region out of comparison between the med of twentieth century and the end of the century the circulation expanded from three or four years to be come around five to seven years which intimidate the water resources durability, land cover stability, eco-system and the environmental stabilization.
The rainfall intensity seems to be increase not just regionally but around the word identification.
In the temperature and the evaporation parameters, this study relay on the researches that carried out by some of specialist in Jordan who's interested in Amman Zarqa and other areas in Jordan where they agree each other that the lower limit of the long term average temperature is increase while the upper limit long term temperature remain at the same edge. According the limit increase in average temperature in additional to retreated in rainfall distribution, this study tend to approbate that **evaporation ratio in Amman Zarqa basin increase from 90% to 92%.**

The runoff records that take in consideration is cover the period from 1980 to 2009, for comparison the records was divided for three decadal, out of this study the precipitation in AZB produce flood flow 28 MCM /y as an average, with take in considering that the base flow which recorded in the same station Jarash bridge station is include the out flow of the sewage treatment plant (AL-SAMMRA) where it start in 1989.**The runoff volume formalizes2.45% from the long term average precipitation.Water budget used to calculate the filtration volume wherein found to be around 60MCM/y.**

17. Discussion

Climate change phenomena which lead the international environmental scientists, organizations and economists as well, should take in considering to inure us to initiation the precautionary actions starting with evaluates the bearable effects on various activities such as water resources. Whereofthis study carried out, to demonstrate the hazards on that menace water resources in Jordan.
The data bank in ministry of water and irrigation of Jordan has provided this study with all of surface water hydrology and groundwater hydrology data as well, where this data use to fulfilment the target of this study.
The most atmospheric parameter that definitely change, is the Carbon oxide concentration witch nonstop raising, causative earth temperature ascent whereof the climate change regard. However in Jordan out of this study can notice acuteness weather parameters more than climate change, where this study in precipitation distribution section define 12% reducing in rainfall in the last decade however the previous studies beckon that the precipitation in Jordan was reduce with 20 to 40 percentage in fiftieths and sixtieths of the last century, where at that time the shortage in rainfall not concert with heat waves.
Increase in temperature and reduce in rainfall will duplicate the effect on water budget, farther more climate change phenomena around the word gesture to increase in rainfall intensity which clear in roaring floods as in Pakistan last year where the flood cover the one third of the Pakistan land. Out of the intensity increasing the percentage distribution between infiltration and flood will change toward increasing in flood flow percentage and this again overstrain the groundwater budget, and the surface water constructions such as Dams has to mitigate the floods expansions in additional to corrosion and increase in sedimentation volume.
In AZB with 12% reducing in rainfall and rising in evaporation correlated with rainfall intensity increase going to duplicate the tension on the groundwater budget specifically, where the effects on surface water going to be less tension.
Water harvesting constructions one of the methods that can against the unbalance situation which going to occur according to climate change phenomena, where this constructions can restrain some of the flood water or retard the flood flow to allow to this water to percolate to groundwater budget, and with this action most of climate change dangers will eliminate in additional to alienation the scarcity hazards on groundwater quality.

18. Conclusions

According to this study, the climate change phenomena can be classified as witnessing recording or seems to be phenomena where it is early to fixing the trend in rainfall

distribution. Although precautionary actions should be taken to mitigate depletion in water level and water quality deterioration in additional to climate change. While the more suitable action is water harvesting projects which fulfilment against water shortage and climate variations effects.
Whereas,this study agree the reducing in rainfall about 12% yearly. and seems to otherness increase decrease in evaporation amount with 1%. In additional to rainfall decreasing the hotheadedness weather parameters phenomena going to redistribute the percentage between groundwater and surface water, whereof the infiltration percentage from thunder storms is very less than infiltration from inert rainfall.
So the effect of the climate change going to be more on groundwater, with take conceding 12% reducing in rainfall should generate 15-20% shortage in ground water recharge. By anther hand the surface water according to climate change going to be reduce in absolute amount but going to be in increasing regarding to rainfall percentage. And this could make stress on surface water hydrological constructions.

Regarding to the above this study deeply recommended to worth the water harvesting and artificial recharge constructions as a mitigation and adaptation actions to face both of water resources shortage which has taken place in Jordan and to face the possible effects coming from climate change. With respect to limit cost of these constructions and the ability to funded and implemented locally.

19.The way forward

Based on the results of this study, the amman zarqa basin situation is very critical and precaution actions should taken place to protect the water resources. Artificial Recharge projects or water harvesting projects could be the suitable solution.
The big dams constriction show that each cubic meter from the dam capacity cost one Jordan dinar and the each meter that collected from by harvesting project cost one Jordan dinar either, while the harvesting project can implemented by local employees and by local funding. So according to the above and by economical value the Water harvesting is much benefit.

20.List of used definitions and abbreviations

MWI	Ministry of Water and Irrigation of Jordan
WAJ	Water Authority of Jordan
AZB	Amman Zarqa Basin
UFC	Uncounted of Cost
B2/A7	The second layer of balqa /the seventh layer of ajloun group
MCM/Y	Million Cubic Meter /Year
EC	Electrical Conductivity
T	Trasmissivity

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ARD	Associates in Rural Development
H5	Safawy station
MASL	Meter Above Sea Level
P	Precipitation volume
R	Runoff volume
I	Initial Extraction volume
E	Evaporation volume
AZ	Azraq basin
TDS	Total dissolves solid

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