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Integrated management of flood water harvesting and groundwater recharge Wadi Zalaga at Wateir region, South Sinai

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ABSTRACT

The present work aims to develop an integrated plan management to utilize the rainwater and floods in Wadi Zalaga at Wateir region, South Sinai that can be applied in other dry and semi-arid desert areas of Egypt. For such reason, we have to build dams and artificial lakes to feed the groundwater aquifers in these areas. The results of this research indicated that planning should not be limited to the establishment of projects only, but needs to consider the possibilities of using the hydrological cycle and the advanced technologies for the development of water resources through studies aimed at exploring all available areas to increase those resources on a good technical and economic basis. The collecting of floodwater is an integral part of flood management and its efficient use is essential for any integrated development project. This also may play an important role in reducing the bleeding of groundwater wells.

In conclusion, the Artificial felling of groundwater aquifer of floodwater during flood periods is one of the most important techniques that save the water resource. Also, the use of floodwater to improve the quality of groundwater currently is available in addition to the protection of water from the possibility of pollution in the case of water surface. Generally, the improvement of both qualities of groundwater and protection from pollution are factors contribute to raising the available water possibilities.

Key words: Wadi Zalaga, Wateir region, Nuweibaa, South Sinai, surface water, groundwater, recharge, artificial facilities, Dams.

INTRODUCTION

Egypt covers one million square kilometers of arid lands and from all this area only 4% is occupied by population concentrated in the delta and valley regions. Arid and semi-arid regions are highly vulnerable to drought and their sensitivity to this phenomenon increase with increasing aridity and it faces serious water shortage and the limited water resources could not meet the population needs. This paper defines characteristics of the water management system in Wadi Zalaga in order to insight the various problems that may occur, and develop a general strategy for sustainable development of Zalaga through management of their water resources. Although rainfall and flood collecting process is linked to some uncontrollable key factors such as prevailing climatic or soil conditions but maximizing the utilization of rainfall and floods using modern technology to apply the related techniques; provides essential water sources in arid and semi-arid regions. The benefit from the collecting of rainfall and floods in these areas, which often rains during the few months of the year, form an important step than collecting thus in wet regions.

A better understanding of the water resources quality and quantity and of how they can be better used in such a way to help their development according to acceptable social and economic norms is very important. This enables the planner and manager to formulate an appropriate management strategy for a given project. Integration of the different operational

strategies confronts system mangers is a difficult task and requires professional knowledge and expertise. So comprehensive re-evaluation of the management of many water resources projects are needed in order to operate these systems in a truly multi-purpose fashion.

Modern technologies such as GIS and satellite imagery should be used in decision-making processes towards choosing the most suitable sites to control floodwaters and achieve inclusive and sustainable development (economically, socially and environmentally). This will be achieved through the optimal utilization of surface and groundwater resources by optimizing the use of floodwater to increase the surface and groundwater storages needed for sustainable development in these areas. In this paper, these objectives have been handled through the analysis of water resources management according to the relative importance and priority of each objective and based on flood water harvesting and groundwater recharge.

Problem Definition

In order to deal with rapid population increase and urbanization, the government of Egypt has been pressed into developing arid areas, which have high potential resources; under these circumstances integrated management of water resources is necessary. Problems facing water deficit have risen rapidly, and new water supplies were needed to meet rising varies demands. In the mid-1980 the government supported policies and practices which increased the efficiency of water use to meet their water deficits. The major reason for the poor predications of water policies arising from analysis based on regional concept social, economic and political entities do not act together in one hand and in research manner and most of the present day problems are the result of poor or mismanagement of the existing resources. Water quantity and quality in Sinai is an example of this practice where management aspects were totally ignored. As a consequence available water resources become not sufficient to satisfy the needs of people. Under these circumstances, important programs have been implemented in Wadi Wateir for management the water resources throughout strategic water plan **(JICA 1999).**

Groundwater aquifer vs. surface reservoirs in priority

When constructing storages, they are carefully selected after studying the climatic, topographic, hydrological, geological and environmental conditions to maximize the utilization of rainfall and floods. In this case, the impact of the severe climatic conditions prevailing in the region or the utilization of the water retained by injection through artificial recharge wells dug inside the excavations. As it is known that, the problem of water storage in surface lakes makes them vulnerable to lose due to evaporation, especially in the summer, where temperature and evaporation rates are much higher than normal filtration rates. So increasing natural filtration rates using artificial recharge will make water flow inside the layers and keep it from being lost due to evaporation.

We know that storing water in unsaturated aquifers in arid and semi-arid areas is economically feasible much better than storing water in surface storage for many reasons, including maintaining it from evaporation as well as the low cost of storing in aquifers.

For these reasons, the locations of the lakes in the delta Wadis areas have been chosen; where the thickness of the porous sediment layer (the number of open spaces in the material) and the permeability (ease or difficulty of water movement) is increased and consequently a portion of the flooded water is leaked into the ground to become groundwater Gamal (2004).

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METHDOLOGY

Methods used to utilize floodwater under arid climatic conditions in Sinai

Most of the methods used in such circumstances, especially in flood-prone areas, rely on the construction of dams, artificial lakes and dentation dams, and relies on simple and inexpensive technologies. In order to optimize the utilization of the accumulated water, we can store it in the aquifer through artificial recharge wells or trenches, which greatly decrease evaporation losses. In this case, these works have a major positive role in the dry desert environment.

Collecting floodwater and save it inside the land

At floodwater collecting sites, some water seeps into the soil and rock below the surface. The amount of infiltration depends on the characteristics of the soil and some of this water can leak to deeper distances to feed the aquifers. If this aquifer is shallow or porous enough to allow water to move easily through them; people can dug wells and use water for their own purposes.

Study Area:

Wadi Wateir at Nuweibaa city located on the Gulf of Aqaba, South Sinai (Fig. 1). The vast area of the basin and its many tributaries (basins) requires many industrial works to optimize the utilization of floodwater. We can see that some industrial works (like industrial lakes, dentation dam and storage dams) were implemented on some channels in some sub-Wadis. For example, a group of dams and lakes on Wadi Qadira, which has a storage capacity of about 4 million/m^3, Wadi Zalaga with more than 10 million /m^3. Some of these facilities were built during the period of 2006 until 2018. Currently, rehabilitation and maintenance of a number of these facilities are being made. The new group of facilities is being established starting from 2015 till now. During the floods in 2010 the capacity of the dams was full, which helped decrease the damage on the international tunnel road - Nuweibaa and protect the strategic and vital areas in the region from the dangers of floods.

Wadi Zalaga is considered one of the most active and largest Wadis which increase the rainfall causing floods in the Wateir region. As a result of the acute topographic slops of the Wadi, rainstorms cause devastating floods at the main Wadi exit and thus negatively affect the infrastructure causing severe damage to the people. These floods are characterized by the huge amounts of water loaded with sediments that reach the city of Nuweibaa, causing significant environmental and physical damage to the port of Nuweibaa. On the other hand, Wadi Zalaga suffers from dry seasons with low rainfall which causes low groundwater levels in the wells and the depletion of groundwater aquifer. The scarcity of water in the area leads to the drying of agricultural land and the impact of livestock one of the most important activities of the Bedouin in the region WRRI, (2004).

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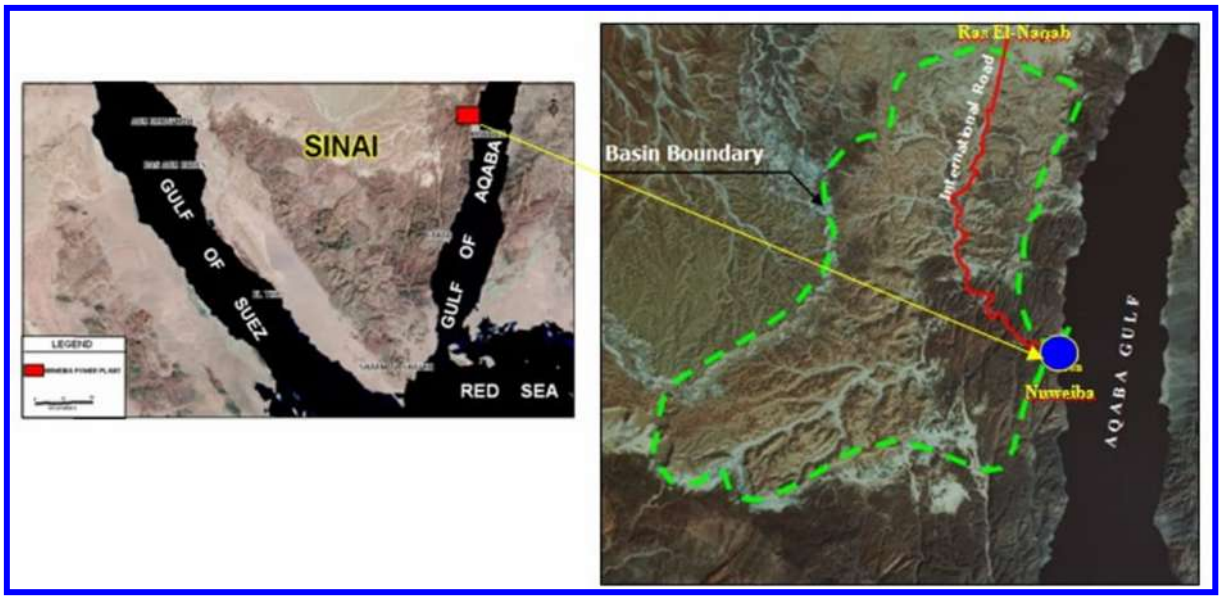


Fig.1. Location map of the study area.

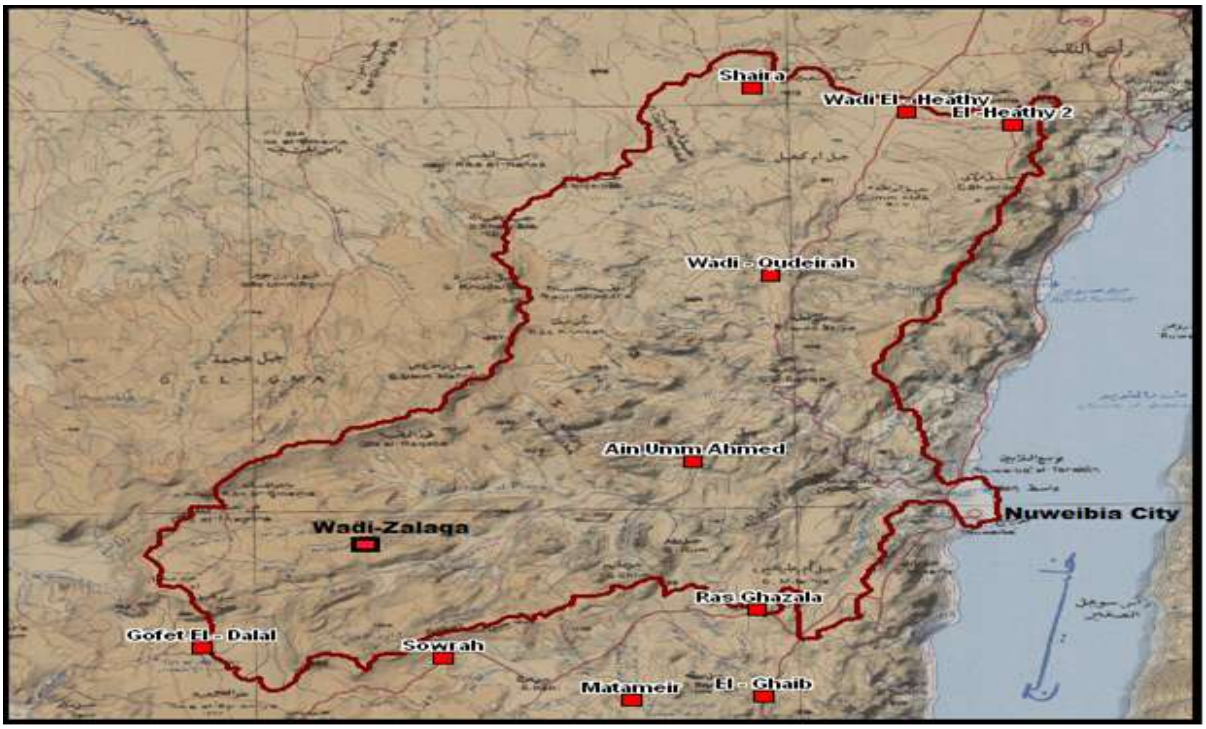


Fig. 2. Wadi Wateir sub-basin (After WRRI, 1996)

This depends on the use and application of the latest scientific methods available in the analysis of topographic, geomorphological, geological, meteorological and hydrological data to estimate the expected quantities and flow rates. Besides, determine the types and locations of industrial works needed to protect the Wadis from the dangers of floods and Recharge the groundwater storages and use them for future development in the region. Moreover, to calculate the amounts of flowing water flow and speeds and maximum actions as a result of a rainstorm with a recurring time of 5, 10, 25, 50 and 100 years. In addition, calculate the amount of waters runoff that contributes to the recharge the surface of the aquifers in the study area. We can use this calculation to meet the needs of drinking water and

grazing or for agricultural development purposes in addition to future use in various aspects of development.

Topographic and Geomorphological studies

The results of topographical studies showed that Wadi Zalaga is one of the main branches of Wadi wateir in South Sinai. The Wadi Zalaga drainage basin is the largest sub-basin of Wadi Wateirin terms of area with an approximate space of 1500 km². The first tributaries of Wadi Zalagastart from the South Sinai Mountains, the most important of which are Jannah Mountain, Abu-Raqba Mountain, and Glim Mountain from 1500 m.

The Wadi Zalagais separated by Wadi Al-Arish from the northeast by the water division line represented at the southern edge of the Al-Ajmah plateau, which occupies most of central Sinai. From the east, Wadi Zalagaand the Wadi Ferain are separated by the water division line at Alwa Al-Ajramiyah and from the south by Wadi Dahab.

Above the surface of the drainage basin near the exit of the Wadi of Ain Umm Ahmed, there is a slope that generally severe on the drainage basin, where the slope starts from the level of 1500 m and ends at the exit of the valley at the level of 400 m approximately. This helped to stabilize the population and agricultural development in the region, especially in the area of Wadi Al Ain.

Geological Study

Geological maps of the research area indicated that the drainage basin of Wadi Zalaga consists of four main geological units:

1. Sediments of the modern era (5%)
2. Cretaceous (70%)
3. Jurassic (20%)
4. Pre-Cambrian in two areas is at the first tributaries and at the estuary in the main Wadis (Wadi Wateir), as shown in the geological map (Fig. 3).

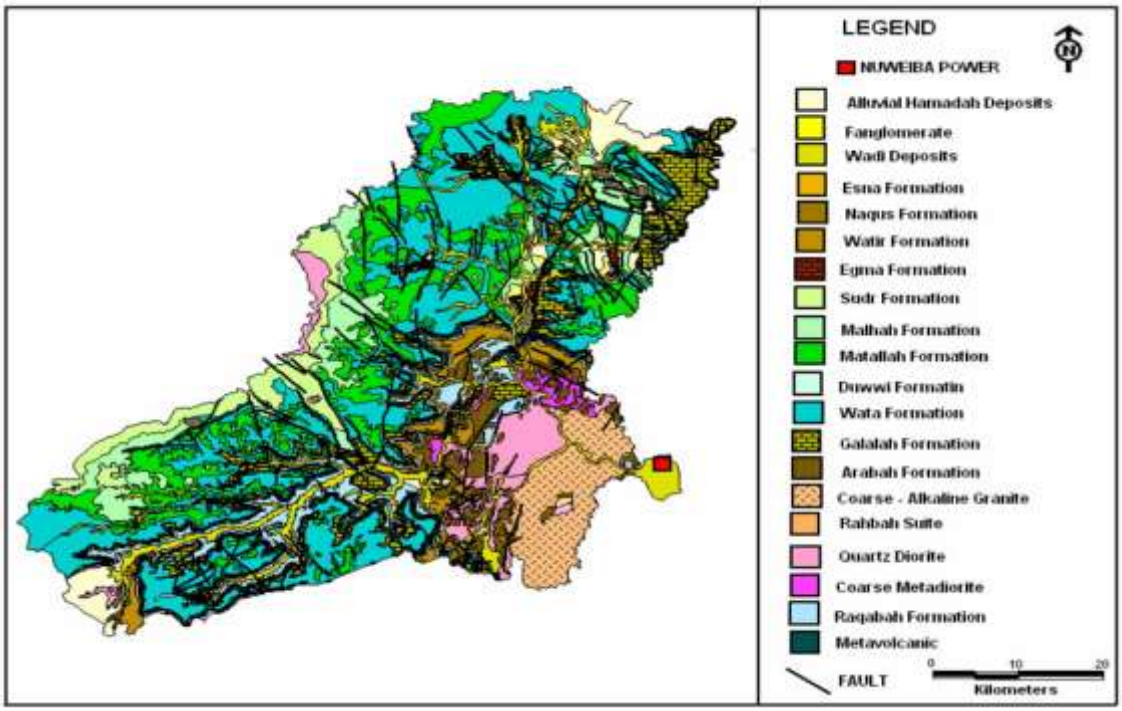


Fig. 3. Geological map of Wadi Wateir (After WRRI, 1995).

Determine the most suitable sites for saving water in the groundwater aquifer.

One of the most important methods to study and select the most suitable sites for saving floodwater is the use of GIS programs, remote sensing, satellites and hydrological models to estimate the quantities of surface runoff and quantities of water leaked into the groundwater. As well, geophysical probes to determine the sequence of soil and rocks in the region with the determination of the water-bearing layer. It's recommended that, to drill a well on site that can be used as a monitoring well for the movement of water inside the ground before and after the flood as follows:

Digital Elevation Model (DEM)

The digital elevation model of the research area is prepared to derive the characteristics of the surface drainage network of the floodwater, drainage basins and determining the level of layers, slopes and contour lines, so as to know the shape of the basin and trends of water flow, using some programs such as Arc WMS or Arc Hydro and ArcGIS.

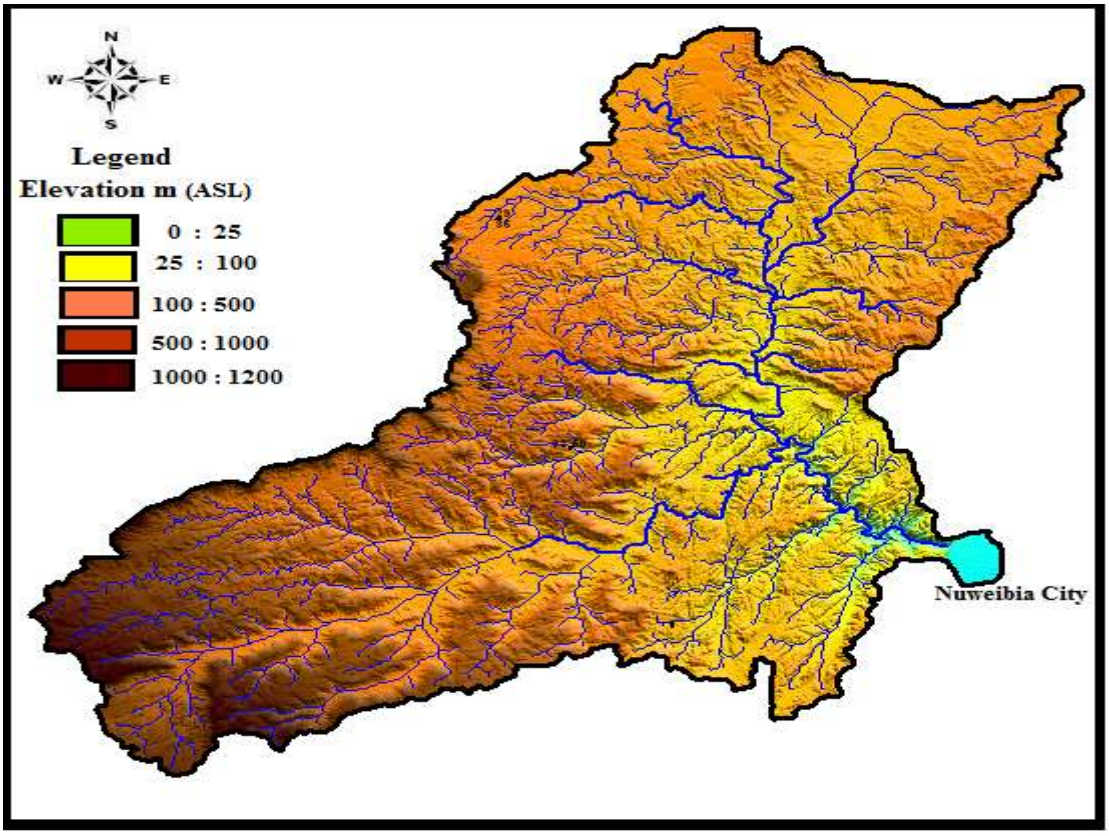


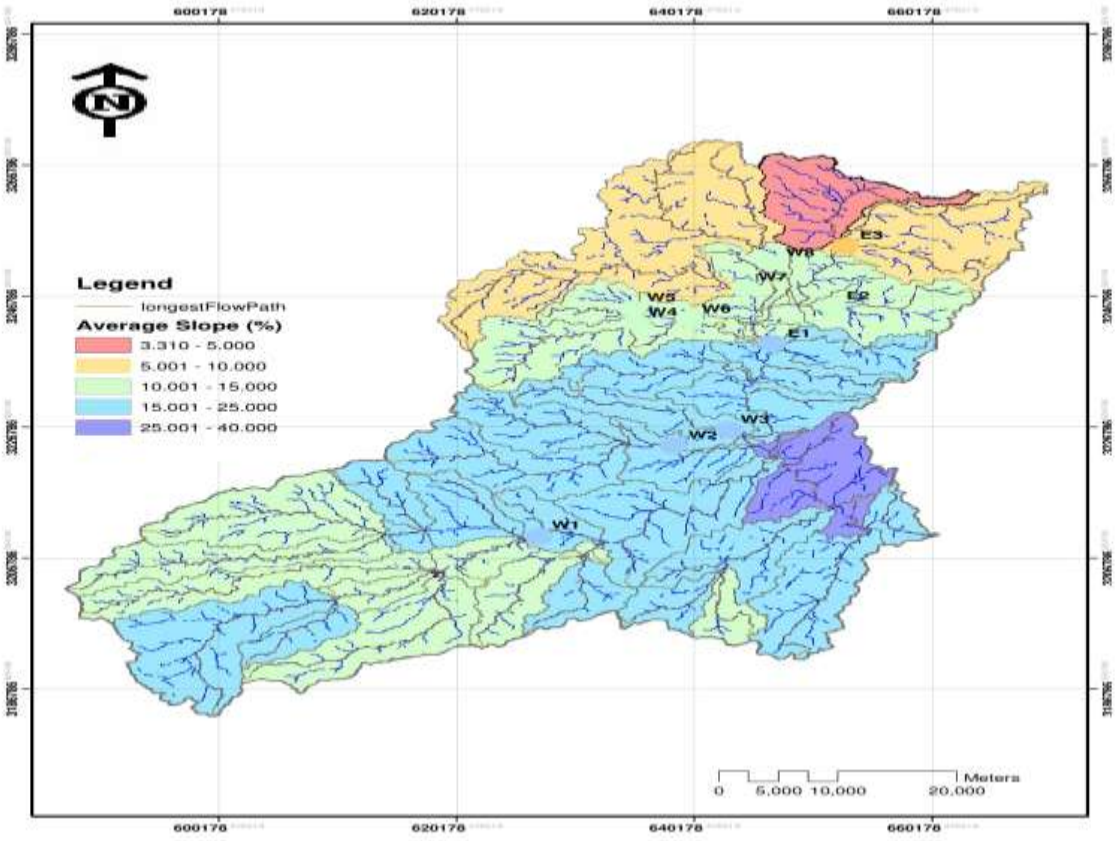
Fig. 4. Dem and Topographic area.

Satellite Image

Different satellite images (land sat, aster, spot) are dealt with to determine the areas of land use within the drainage basin, whether residential, agricultural, industrial or uses. Determining land uses is useful in identifying areas where floodwaters should be stored, exploited and optimized.

Slope Maps

WRRI (2004) developed the slopes of the main and secondary Wadis to set out the hydraulic characteristics of the Wadi, the intensity of the flood, the degree of hazard and the most suitable sites to save the floodwater.



(Fig. 5) Basin Slope aspects

Metrology studies

Daily available rainfall data were collected and maximum storm values were detected on stations affecting the drainage basin of each sub-Wadi. As a result of the large area of the basin, it's affected by Saint Catherine Station, while the other part is affected by Nuweibaa Station. Therefore, the data was relied on to identify the floods that occurred in the region and to predict their quantities for different recurring times (Table 1)

Table (1) the maximum depth of rain tense iterative meteorological stations

The maximum depth of the rain					
Station Name	The times iterative				
	5 year	10 year	25 year	50 year	100 year
Nuweibaa	8.8	14.4	26.5	39.3	55.9
Saint Katharine	16.9	28.3	49.7	72.1	101.4

Hydrological study

The results of meteorological studies indicated the abundance of rainfall for large repetitive times 50 and 100 years, where the average of rainfall in the region between 70 and 100 mm. Consequently, the amount of potential runoff amounts reaches 33.45 million cubic meters and 59.82 million cubic meters for the same cyclic times when rain occurs over the

entire area of the Wadi drainage basin. The accumulation of rainfall and flooding at very high costs will be implemented in a long time (Kotb, 1998).

Concerning the small frequency periods 5, 10 and 25 years, the results indicate the small amounts of rainwater, where the average of rainfall in the region is about 8, 14 and 26 mm. Consequently, there is a small amount of surface runoff. The volume of floodwater is about 522,546 thousand /m³, 3,904 million /m³ and 16,091 million /m³ for the same repetitive times.

This water is being used to feed the surface aquifer in the region at great rates and meet the needs of drinking water and grazing for the people of the region or for the purposes of limited agricultural development. Infiltration experiments were conducted on the sub-Wadis of Wateir Wadi as shown in Table (2).

Table 2. Soil analysis data showing the results of infiltration test and D50 for Wadi wateir (WRRI, 2004).

Name	Castor of the Wadi			Sediment of the Wadi			Soil type
	Infiltration rate (mm/hr)	D		Infiltration rate (mm/hr	D		
		At depth 30 cm	At depth 60mm		At depth 30 cm	At depth 60mm	
Zalaga	12156	6	5.5	1928	5.75	130	**Gravely sand to sandy gravel**
El Shafalla	2483	2.8	0.9	526	0.7	850	
Sawana	9952	1.95	9	1000	4.5	300	
El Meretba	48031	5.8	230	1099	4.5	550	**Sandy gravel**
Qadera 1	4141	0.59	2	658	7.5	1850	**Gravely sand to sandy gravel**
El Heithy	14689	5.25	7	1184	1.4	120	
El Butum	8775	8	215	668	2	250	
El-Hagney	5025	2.8	540	3654	5.25	160	
Abu el Thalam	22229	6.6	4	473	6	700	**Sandy gravel**
Al Shfalla	2629	8.25	6	1080	3.8	800	
Qadera 2	13929	2.15	875	836	5.5	500	**Sandy gravel (10%slit)**
Butum Sortoba	2082	4.65	6	1755	4.3	730	**Gravely sand to sandy gravel**

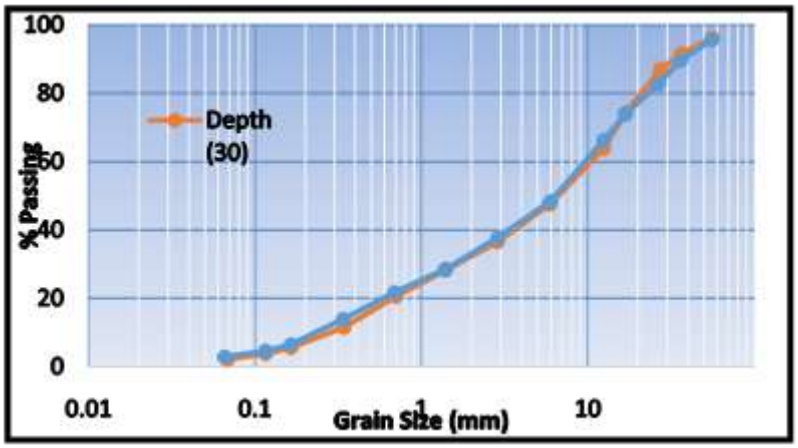


Fig. 6. analysis of soil at study area.

Proposed Industrial Works

A group of industrial works have been proposed in Wadi Zalaga, which are artificial dams and lakes with large storage capacities. The lakes are beneficial in saving the floodwaters, recharging the groundwater aquifer, developing the area and protecting the

infrastructure from the dangers of the floods. In order to increase the storage capacity of the lakes, it is recommended to place the drilling output regularly behind the lakes to serve as a protection bridge to increase the storage capacity of the lake.

The specifications of the artificial lake which has been established in the Delta of Wadi Zalaga areas are:

- Construction date 2018.
- Dimensions of the lake 850 x 250 meters and the average depth are 7 meters.
- Storage 6 million cubic meters.
- Construction costs = 50 million EGP.

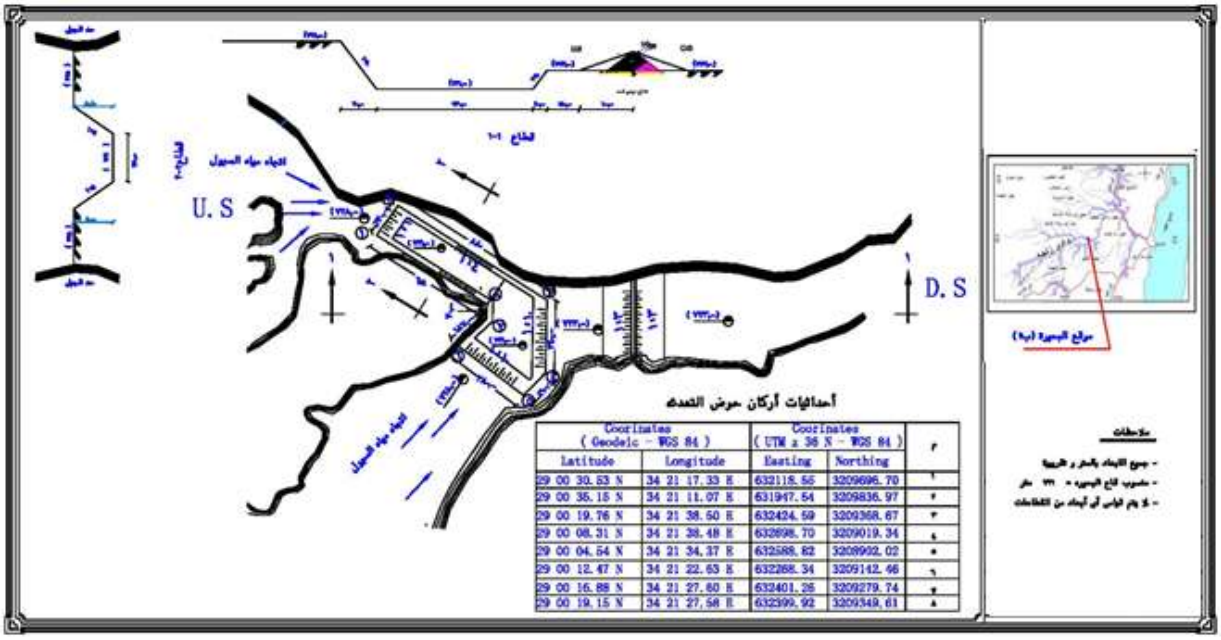


Fig.7. Zalaga Lake

Drilling control wells inside the industrial storage lake:

Monitoring wells shall be drilled inside the industrial storage lake in the valley to monitor the movement of groundwater levels before and after the occurrence of floods (Figs. 8 & 9) and also to protect them from destruction.

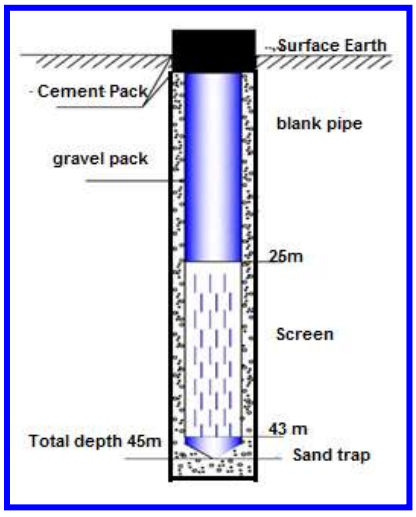


Fig. 8. Image of the sector of the surface well.

Conclusions :

1. The reason behind this paper was to find factors that contribute to the sustainability of water resources, which are regarded as a long standing water management, and should look into the wider consequences of water resources development options, and emphasize the importance of water management at basin level.
2. It is evident that there is a growing recognition of the importance of artificial recharge as a tool for improved groundwater management where it considered a valuable tool for groundwater protection in terms of quantity and quality, and could be used effectively for the storage of floodwater, and consequently the conjunctive use of surface and groundwater, and considered as a mean of achieving efficient integrated water resources management.
3. The water users can play an important role in the control of water and following the master plan in different stages. And it is expected that the applicable strategy will not be respected by all the water users. The use of a flood water harvesting and groundwater recharge can guarantee a desired reduction of water consumption, but it is costly to implement.
4. The amount of water leaked to the ground can be increased by expanding the implementation of a range of common technical techniques such as the construction of storage dams, mountain lakes and industrial lakes with large storage capacities and drilling of injection wells.
5. Economic Benefits: recharge surface aquifers decrease water transport or the need for desalination of high-cost seawater.
6. Social Benefits: Social stability and sustainability of Bedouin resettlement policy through the development of pastoral activities based on the use of floods and surface groundwater within the Wadi.
7. Environmental Benefits: lower the environmental impact of desalination plant waste - decrease the severity of disasters caused by floods due to climate change.

Recommendations:

1. It is recommended to promote an integrated development of spate and aquifers to encourage the conjunctive use of Wadi flow and aquifers by utilizing artificial recharge techniques which is considered as important water resources management methods in Wadi Zalaga;
2. Attention has been drawn to put strategies for water policies in all Wadi Wateir, it is strongly recommend that the governorate should face water shortage by understanding of the global supply and demand, and to improve water productive and allocate efficiency in using water.
3. As a result of the climate changes experienced by Egypt in general and the study area in particular, it is recommended to further expand the industrial works that storage water and prevent wastage.
4. Coordinating with all relevant authorities to benefit directly and indirectly from saving the water after each flood season to help in the social and economic development of the people living in these areas.

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الادارة المتكاملة لحصاد مياه السيول وتغذية الخزانات الجوفية بوادى زلجه بوادى وتير جنوب سيناء

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المستخلص

تهدف هذه الدراسة لوضع خطة ادارة متكاملة للاستفادة من مياه الأمطار والفيضانات في منطقة وادى زجلا والتى يمكن تطبيقها فى المناطق الصحراوية الاخرى الجافة وشبه الجافه. وقد أوضحت نتائج الدراسة انه يتعين بناء السدود والبحيرات الاصطناعية لتغذية طبقات المياه الجوفية في منطقة الدراسة والمناطق الصحراوية الاخرى المعرضة للسيول والامطار الشديدة. كما يجب ان لا يقتصر التخطيط على إقامة المشاريع فحسب، بل يتطلب الأمر النظر فى إمكانيات استغلال كل ما تمنحه الدورة الهيدرولوجية وكل ما تتيحه التقنيات المتطورة لتنمية الموارد المائية من خلال الدراسات الهادفة لاستقصاء كافة المجالات المتاحة لزيادة تلك الموارد على أسس فنية واقتصادية وتقنية سليمة.

وقد توصلت الدراسة الى ان حصاد مياه السيول وشحنه جوفيا" يعتبر جزءاً لا يتجزأ من إدارة الفيضانات، واستخدامه بكفاءة ويعتبر هذا أمراً أساسياً بالنسبة لأي مشروع متكامل للتنمية ويمكن أن يلعب دوراً مهماً في الحد من إستنزاف الخزنات الجوفية. الى جانب ان الشحن الاصطناعي للخزانات الجوفية من مياه السيول في فترات الفيضان يعتبر من أهم التقنيات التي تحقق الحفاظ علي المورد المائي لأنه يحقق العديد من المزايا ومنها تقليل فقد المياه بالبخر في التخزين السطحي ، كما يؤدي الشحن الاصطناعي بمياه السيول الي زيادة تغذية الخزان الجوفي وبالتالي رفع امكانات المياه الجوفية بسيناء. وأيضا يؤدي الشحن باستخدام مياه السيول الي تحسين نوعية المياه الجوفية المتاحة حاليا اضافة الي حماية المياه المشحونة من احتمالات التلوث في حالة كونها سطحية. ويعتبر كل من تحسين نوعية المياه الجوفية والحماية من التلوث عاملين يسهمان في رفع الامكانات المائية المتاحة .