Role of Water Resources Research for Sustainable Development of Wadi Systems

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Abstract

Water resources research is considered a milestone for sustainable development of arid and semi-arid regions. About 95% of Egypt's population is located in Nile River Valley and Nile Delta. However, due to the high population density in valley and delta, the successive government of Egypt decided to develop some of the Egyptian desert areas thus the spatial demographic status of Egypt can be changed. Accordingly, many land development projects were proposed allover Egypt, some of these projects are scattered located faraway from the old Nile valley and delta. The main aim of these projects was to reclaim more than 1.5 million Hectares to urge people to be transferred from the old Valley to these new areas. Thus, water is considered the key element for any development plan in Egypt. The any proposed development plan should be accompanied by an intensive research for water resource development. This paper introduces the effort of research and studies that is performed over the Sinai Peninsula as an example of arid-wadi water resources system. The study presents the effort done for data collection, surface and groundwater research and studies that are performed over Sinai for the last 25 years. The paper presents the weather, climate, surface and groundwater data collection system. The use of these data for better management and control of water resource system of Egypt is presented through practical case studies.

Introduction

Since 1981, the Ministry of Water Resources and Irrigation MWRI has been supported the research and development of Sinai Peninsula Water resources system through intensive research program. The research development plans started by building capacity for research through improving the personnel and support the basic research. Also, MWRI supported the research for financial support for field, office and Sinai through giving laboratory research work. Hundreds of missions were sending to Sinai Area for collecting data, installing of weather stations and rainfall recorders allover Sinai. Now, MWRI through the National Water Research Center has a significant database and research capabilities for supporting Sinai area to solve the practical water resources management problems of this area. In the current study a description for the role of research in the sustainable development of a wadi zone represented by Sinai Peninsula in Egypt as an example will be presented.

Role of Research in Sinai Water Resources System

Southern Sinai area is a mountain zone and rises for more than 2500 meter above mean sea level. Heavy storms usually occur over this mountains and results in flash floods in the different wadis networks within Sinai.

The rain occurrences in Southern Sinai are following certain recurrence times that changes from location to another based on the hydrological cycles. The main issue in Southern Sinai is the control of flash floods that usually happens causing catastrophic damages for the infrastructures such as roads, power transmission towers, tourist resorts, etc. The flash floods highest risk locations are in the coastal areas specifically the cities that are located on Aqaba bay and red sea coast. Flash floods is considered one of the main source of risk that threaten highways, roads, power transmission towers, cities, and any infrastructure that may intersect the flash flood pathway.

Accordingly, the MWRI through the National Water Research Center NWRC decided to concentrate on research through which the problem of flash floods allover the wadi system in Sinai and also in other places in Egypt can be well studied for presenting reliable and sustainable solution for protection against flash floods. The Water Resources Research Institute WRRI is the place that has the main role in studying and research the protection against flash floods system allover Egypt. WRRI has been involving in these types of studies since 1980. Several studies has been performed allover Egypt for Studying the Flash Flood systems. The methodology for studying flash floods control started by designing and implementing a database for metrological and climatic data allover the areas that may be exposed to flash floods. Then, scientific researches regarding the drainage basins, floods pathways and stream delineation were performed. The last step was to design and implement flood protection infrastructures. In what follows a brief description with some examples for each of these three items will be presented.

1 Metrological and Rainfall Database

In 1981 a metrological database for Sinai has been established to collect all the required data needed for research on hourly and daily basis. Several stations and telemetry metrological stations were established by WRRI allover Sinai to collect the required data as presented in Figure (1). Each station collects both metrological and hydrographical data. The instruments that are used to measure and collect the data are calibrated on a regular basis. The data logger samples metrological data such as the year, Julian date, time, stationed, air temperature, relative humidity, solar radiation, quantum solar radiation, barometric pressure, wind speed, wind direction, air temperature, also hydrographical data such as the rain fall intensity are also collected. Following the main stations, another set of stations are installed inside each Wadi for obtaining more detailed data regarding rainfall and floods inside the

Wadi itself. Figure (2) presents the weather, rainfall, and runoff station presents within the boundaries of Wadi Wateer in Sinai. On the other hand, rainfall data are collected regularly either by rainfall recorders, telemetry or metrological stations. WRRI is managing and updating the metrological data collecting system by the most updated instruments and equipment for assuring the sustainability of this important section. 80 stations were installed by 1993 allover Sinai and distributed in Northern and Southern parts of Sinai as shown in Table (1), some of these stations now is out of service. For more information reader can return to references [2, 8, 9, 10, 11, 13, and 23].

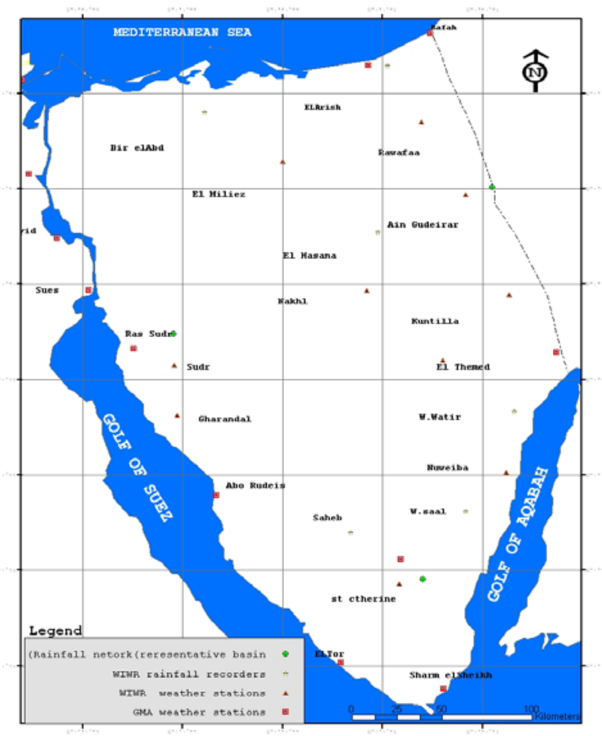

Figure (1) Locations of Metrological stations and Rainfall recorders allover Sinai and Egypt Installed by WRRI [8].

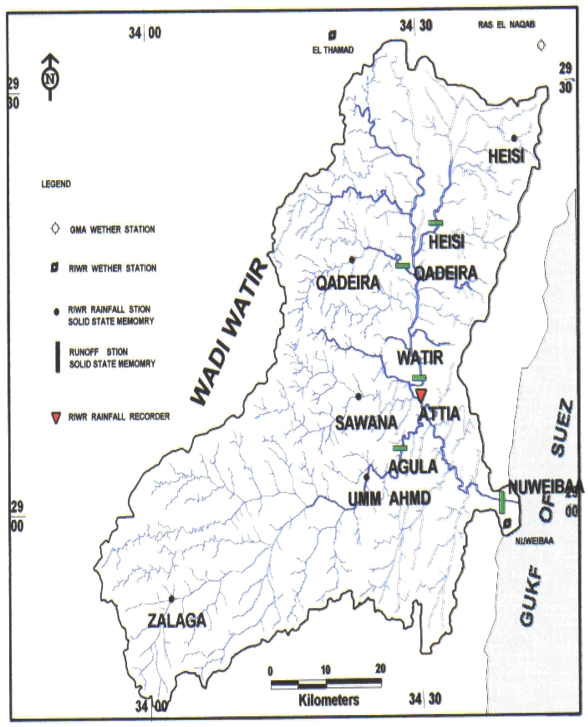

Figure (2) Weather, Rainfall, Runoff And Rainfall Recorders Station within Wadi Watair.

Table (1) Climatic, Rain Recorders and Flash Floods Stations which installed by WRRI in 1993 [11].

Station Type	North Sinai	Southern Sinai	Total Number of Stations
Climatic	6	4	10
Rain Recorder	19	39	58
Flash Floods	1	11	12
Total Number of Stations	26	54	80

2 Sinai Morphology

Sinai is a triangular peninsula, the base points to the north and it's apex to the south North-East of Egypt with a total area of 59,570 sq km. It is 370 km long and 150-240 km wide and extends north into a broad isthmus linking Africa and Asia. The entire Sinai region is deeply dissected by the wadis that eroded at earlier geological periods. These wadis break the surface of the plateau into series of detached massifs with a few oases scattered here and there. Most lowlands slope gently towards the Gulf of Suez, the lowest forms the El-Qaa coast plain. In the southern zone, the mountains come close to the sea forming a bold and rocky coastline that runs into the Gulf of Aqabah. The Sinai coastline is varied alternating high mountains, hills and fine-grain yellow sand beaches.

Figure (3) presents the major drainage basins inside Sinai As shown in this figure Wadi El-Arish is considered the largest Wadi allover Sinai. WRRI is responsible for studying the different Wadis inside Sinai since 1981. The main target of these studies is to study the volume of flash floods water, the optimum use of this water, protection of infrastructure against flash floods and the estimate the volume of percolated water from rains and flash floods to the groundwater aquifers. In what follows some examples for studying wadis watershed management will be presented.

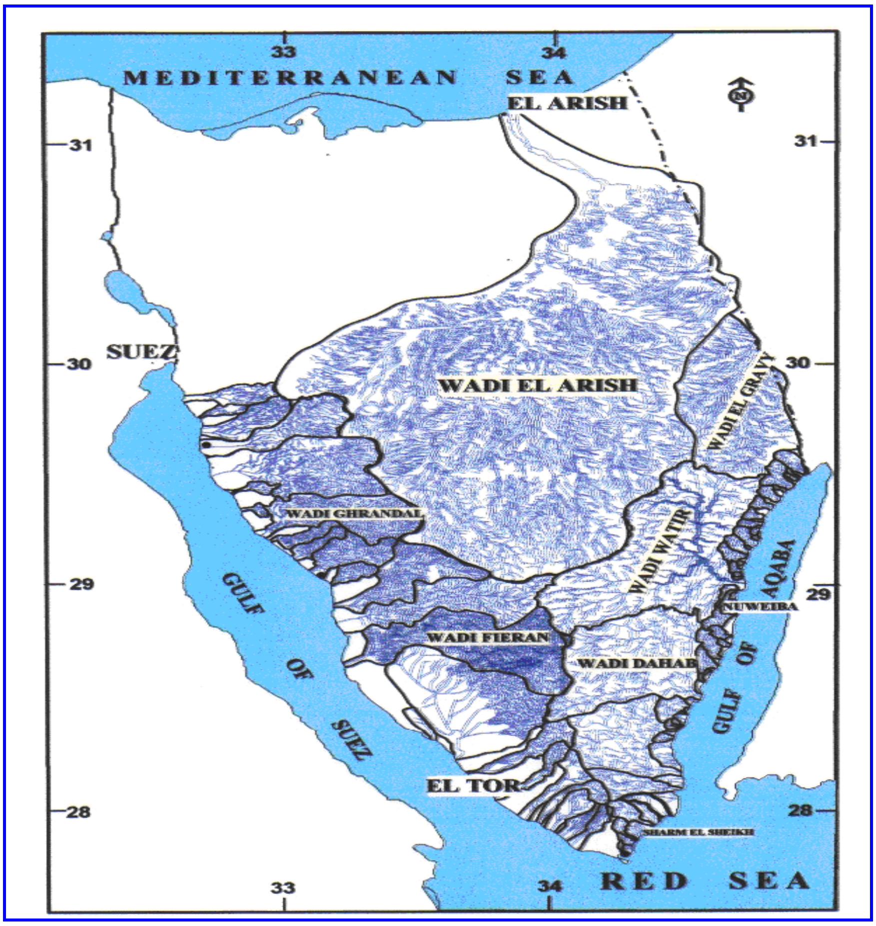

Figure (3): Main Drainage Basins in Sinai [23]

2.3 Sinai Wadi System Practical Studies

The WRRI concentrated since 1981 to study the Sinai Peninsula Morphology. Several studies have been intensively performed for the different wadis inside Sinai. Some studies are concentrating on one Wadi only, while other studies concentrate on group of Wadis. This was depending on the aim and target of the studies. In general, the main aims of these morphological studies can be listed as:

- Protection of cities and tourist resorts from flash flood damage.
- Protection of main and secondary roads from flash floods.
- Design and construct flood dentition dams

In what follows an application example for each aim will be introduced to present how the studies lead the researchers for better management and design of different engineering items related to the flash floods problems.

3.1 Protection of Cities and Resorts from Flash Floods

Many flash floods protection studies have been performed in Sinai since most of the cities and tourist resorts are usually exposed to flash flood problems. The reason is that in each drainage basin water drains directly towards the coastal area as shown in Figure (3) where it is usually a city or resort located. The eastern Wadis are draining into the Gulf of Suez, while The Western Wadis are draining into Gulf of Aqabah, and Only the Wadis that are located at the apex of the Peninsula triangle are draining directly into the Red Sea. Wadi AL-Areesh, which has the largest Wadi area in Sinai, is the only Wadi that drains its water into the Mediterranean Sea as shown in Figure (3). On the other hand, most of the resorts and cities are located on the shore line along with Gulf of Aqabah, Red Sea and Gulf of Suez. In addition there are some cities and resorts that are located inside Sinai and far-off from the coastal line but they are located within the flash flood pathways. Thus, the protection of the cities and resorts in Sinai was an essential target for the decision makers since tourism sector in Sinai is responsible for an important share of tourism income to the Egyptian economy. WRRI shared in many studies that are listed in Table (2). More information can be found in references [7, 10, 11, 13, 15, 20, 22, 23, and 24]

Table (2) Some of WRRI studies for Protection of Cities from Flash Floods.

Study	Location	Target
Nemaa Bay Protection	Sharm El-Sheikh, South Sinai	Flash Flood Protection
Kersh Bay Protection	Sharm El-Sheikh, South Sinai	Flash Flood Protection
Hammamat Mosa Torism Area	El-Tor City, Southern Sinai	Flash Flood Protection
AL-Maleha Torism Center	Newabaa City, Southern Sinai	Flash Flood Protection
Dahab city Protection	Dahab City, Southern Sinai	Flash Flood Protection
El-Areesh City Protection	AL-Areesh City, North Sinai	Flash Flood Protection

To perform a flash flood protection study several steps are taken aas follows:

- *Field Survey*: a special mission for the area under study is performed through a team from the WRRI using the GPS and most advanced techniques for surveying.
- *Collecting of metrological data:* historical data for the different metrological stations in the vicinity of the study area is collected, analyzed and filtered.
- *Collecting of Hydrologic Data:* These data includes the stream flow data which were measured by the flow measuring devices that were mounted on the hydraulic structure at the main stream of each wadi if it is existed.
- *Collecting of spatial data:* thematic coverage (soil type, vegetation cover, rainfall, evaporation, etc) are collected for the whole basin. In Sinai, the geology and soils are the most dominant factors in the estimation of the resulting runoff. It is also known that in such regions, evaporation rate is very high and there is neither land-use nor vegetation cover.
- *Calculating the runoff*: runoff from each wadi is calculated through developing arating curve for stage and flooding discharge.
- *Performing the Study*: runoff hydrographs together with the causative rainfall hyetographs are evaluated. Many different hydrologic parameters were also determined such as rainfall intensity; lag-time; rainfall duration; loss by infiltration and evaporation; peak flow and the runoff coefficient.
- *Using of Flood Delineation Software*: Following the up-to-date technology, WRRI is performing the wadi analysis through the water shed management software. WMS is applying to study the wadi system. Example of this type of studies is presented by Sonbol et. al. (2005). Figure (4) presents an example of wadi stream lines delineation applying WMS (2004) software.
- *Design the Protection Structures*: After performing the entire study requirement, the final stage will be the design and implementing a proposed protecting system and evaluate it, and then different proposals can be performed until a satisfied design is obtained. An outline for infrastructure for protecting Dahab city, which is located on the outlet of Wadi-Dahab flood way. As shown in this Figure design of Wadi-Dahab flood protection system include detention dams, rechargeable dams, Irish Crossings, Culverts, Dikes and underground tanks.
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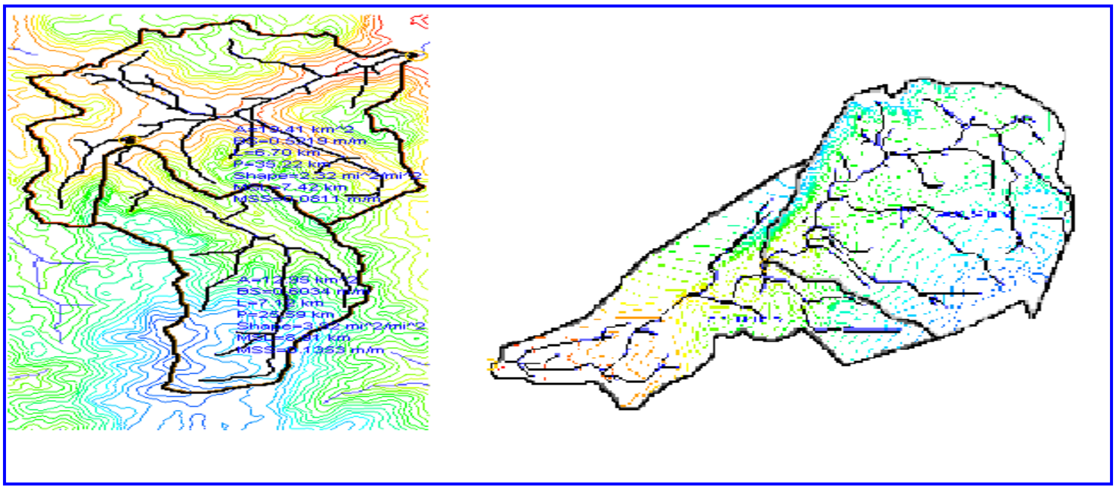

Figure (4): Analysis of Wadi System Using Watershed Management Software [26].

3.2 Protection of Highways and Roads from Flash Floods

Another major target for the flood protection study is to control and protect the roads from the flash floods. Several studies were performed through WRRI to protect roads and highways in Wade Systems. The studies are not limited to Sinai Wade System only but extend to Upper Egypt where there are many Wadis that are intersected with highways, railroads and roads. Table (3) presents summary of these studies. A clear example for road protection from flash floods is presented in Nekhel Road Protection Project. A research study has been performed for study the protection of a road network that intersected at Nekhel city at the Middle of Sinai passing across different wadis that are wadi Al-Areesh, Abu-Olykana and Wadi Abu-Terafya as shown in Figure (5). As shown about five roads are intersected with two wadis and it was required to design a protection system for these roads against flash floods. The arrows show the flash floods flow directions while the red lines show the road direction. To perform this study several research steps were taken following the previous 5 steps. The studies were based on metrological data, field data, geomorphologic maps, and geological maps. From the study it was concluded that there are three wadis that are responsible for the flash floods that come across the road network in this area. The wadi drainage area is 3400 km^2 and through the analysis of the available information in table (4) was developed.

Table (3): Road Network Flash Floods Protection Studies performed by WRRI [11, 12, 15, 20, 22, 24].

No.	Study	Target	Location
1	Newabaa City Road Network	Protection of Roads from Flash Flood	Southern Sinai, Newabaa City
2	Dahab City Road Network	Protection of Roads from Flash Floods	Southern Sinai, Dahab City
3	Sharm El-Sheikh Road Network	Protection of Roads from Flash Floods	Southern Sinai, Sharm El-Sheikh City
4	El-Saada Road	Protection of Roads from Flash Floods	Southern Sinai Governorate
5	Wadi Wateer International Road	Protection of Roads from Flash Floods	Southern Sinai Governorate
6	Petroleum Pipe network	Protection of Roads from Flash Floods	Assuit Governorate
7	Rail Road at El-Gaafraa	Protection of Roads from Flash Floods	Aswan Governorate
8	Qena-Safaga Rail road	Protection of Roads from Flash Floods	Red Sea Governorate
9	Nekhel Road Network	Protection of Roads from Flash Floods	North Sinai

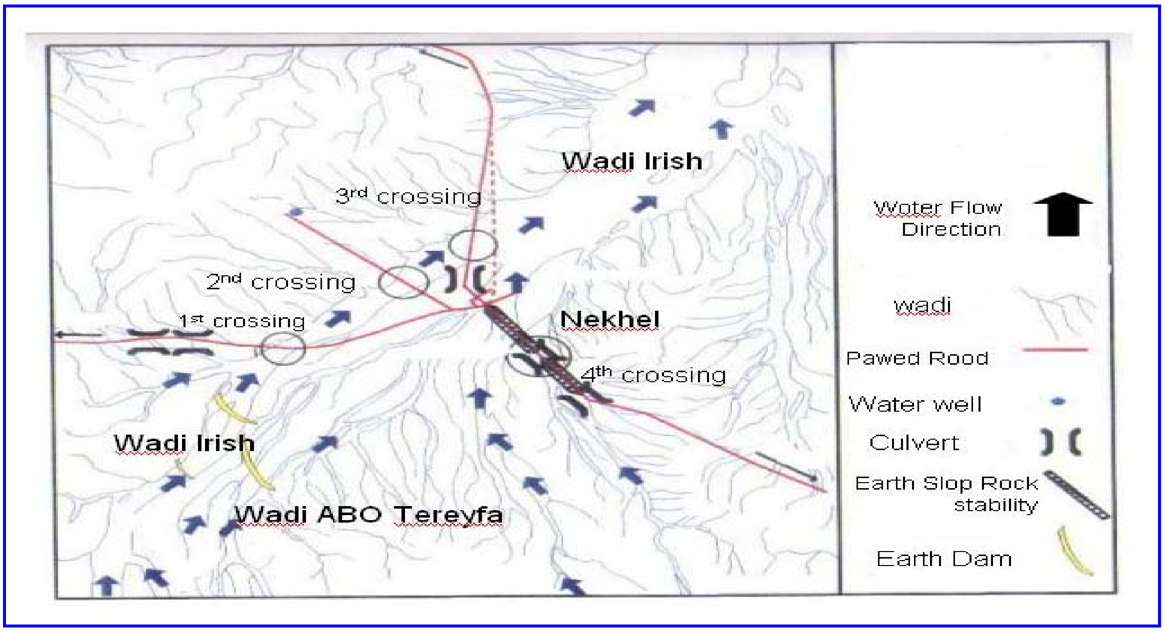

Figure (5): Proposed Protection Infrastructure for Nekhl City Road Protection System [22].

Table (4): Results of Hydrological, Morphological and Geological Research for Design a Flash Flood Protection System for Nekhel Roads in Sinai [22].

Wade ID	Area (km^2)	Length (km)	Time of Concentration (hour)	Lag Time (hour)	25 year Discharge (m^3/sec)	50 Year Discharge (m^3/sec)	Runoff Time (hour)
Abu-Terifa	835	90	3.7	6.5	100	280	16
Abu-Olaykana	301	40	2.4	4.1	32	124	18
Al-Areesh	2130	115	4.6	7.6	415	922	34

Using the research results, a complete design for flood protection system, the type and location of some infrastructure that have to built constructed within the area under study. These structures are presented in Figure (6) and can be listed as:

- A detention dam along wadi Al-Areesh with a capacity of 0.50 million m^3.
- A protection dike on wadi Abu-Terifya to divert flood water to Wadi Al-Areesh.
- An Irish Crossing for two intersections.

3.3 Design and construct flood dentition dams

In some locations in Sinai flood detention dams can collect a significant volume of water that can be used for a relatively long period after flood occurrence. A good example of this type of dams is El-Rawaafaa dam in Northern Sinai. This dam has been constructed in 1946 to protect Al-Areesh city that locates on the Mediterranean shore in North-East Sinai. The dam was constructed 52 km south of Al-Areesh city with a storage capacity of 2.0 million m^3 with a length of 70 meters and height of 12 meters. In 1986, the dam crest was raised two meters high than the original crest and this increases the storage to be 6.8 million m^3. In 1989, a pump station and a pipeline were constructed to irrigate an area of about 170 Hectares downstream of the dam. However, the problem will be the sustainability of using such stored water in detention dams due to the highly uncertainty in the hydrological cycles and rain fall intensity allover Sinai Peninsula. Also, the runoff coefficient in most of Sinai Wade is considered very low, foe example in Al-Areesh Wade the runoff coefficient is about 0.01 which is considered very low and most of the rainfalls water volume is lost through percolation, seepage and evaporation. Table (5) presents integrated morphological and hydrological information regarding the different Wadis in Sinai, Northern and Southern. It can be concluded that the largest average rainfall annual volume allover the basin is that of Al-Areesh basin with an average value of 1.1 billion m^3. The other basins having an average annual values range from 10 to 129 million m^3.

Groundwater Research and Development in Sinai

As shown in the previous sections water resources of Sinai is considered a very limited resources. Groundwater in Sinai can be divided into two major section the deep aquifers and shallow aquifers. The Water Resources Research Institute has been studied the groundwater resources system of Northern and Southern Sinai since 1981. Several research studies were performed. The main target of these studies was to explore and evaluate the groundwater system either in the shallow or deep aquifers. Hundreds of studies were performed to study the hydraulic characteristics, water quality, and optimum volume of groundwater withdrawing, groundwater well locations, groundwater recharge system, groundwater observation, and integrated groundwater management system in Sinai. In what follows brief description of some efforts that has been performed with the WRRI for studying the groundwater system of Sinai will be introduced.

1 Investigations and Studies of Groundwater Aquifers in Sinai

WRRI has been involved in many studies that deal with investigation of the different groundwater aquifers in Sinai. Since 1981 WRRI was performed several field investigations through intensive research plans to evaluate and estimate the groundwater potentiality and availability allover the different aquifers in Sinai. WRRI started the research studies by developing a database for the hydro-geological and hydro-chemical through intensive field investigations of the different groundwater aquifers, especially that before 1981 the scientific information regarding the groundwater system and different aquifers in Sinai was very limited. The major field work in Sinai shows that there are three main groundwater aquifers that are:

- Fractured Limestone and
- Lower Cretaceous sandstone;
- Quaternary aquifer.

In what follows brief description of the different of the research results for the investigations of the different aquifers in Sinai.

Table (5): Average annual rainfalls and average annual rainfall water volumes allover Sinai Wadis [1, 2, 4].

Region	Basin Name	No. of Wadis inside the Basin	Basin Area (km^2)	Wadi's Length (km)	Average Annual Rainfall (mm)	Average Annual Water Volume (million m^3)
Al-Areesh	Al-Areesh	444	19500	630	56.46	1101
Al-Graafy	AL-Graafy	82	2250	526	25.00	59
Gulf of Aqaba	Waset	261	2512	1149	26.63	129
Gulf of Aqaba	Dahab	155	2025	672	45.66	92
Gulf of Aqaba	Keddah	71	1025	324	22.01	23
Gulf of Aqaba	Om-Adwaa	22	250	127	25.00	8.8
Gulf of Suez	Al-Tor	63	1463	264	23.51	48
Gulf of Suez	Feeran	109	1075	512	40.85	68
Gulf of Suez	Sodri	94	1025	272	25.33	26
Gulf of Suez	Baboa	41	712	205	29.00	31
Gulf of Suez	Teebah	41	425	158	26.00	11
Gulf of Suez	Grondol	33	800	195	25.00	20
Gulf of Suez	Wardan	58	1288	328	25.00	22
Gulf of Suez	Sedr	31	625	167	25.00	16
Gulf of Suez	Lehyatah	10	550	89	25.00	15
Gulf of Suez	Al-Rahaa	16	725	129	25.00	18
Northern Coast	Al-Haji	12	512	94	25.00	12
Northern Coast	Al-Gedy	5	325	48	25.00	8.2
Northern Coast	Om-Khoshiba	17	350	93	20.00	10.5
Northern Coast	Al-Hagayeb	20	912	161	20.00	27
Northern Coast	Al-Hassana	21	1250	345	44.25	59

1.1 Fractured Limestone Aquifer

The fractured Limestone aquifer is present at different localities in Sinai Peninsula. It is composed of limestone; dolomite and dolomitic limestone intercalated with some strikes of clay contents. The strata-graphic succession of this aquifer deposited from the Eocene to Jurassic age. The thickness of water-bearing formations has different values that changes significantly, for example in some zones it is in the range of 15 to 30 meters, while in some other places it is in the range of 2000 meters. Thus, strategic research plan was performed to study the aquifer continuity in Sinai Peninsula through geologic and geophysics science. Also, field investigations through well logging and open hole tests were performed in many locations allover Sinai. The output of the different WRRI studies ended up with a hydro-geological map for the carbonate aquifer. Figure (6) presents a hydro-geological map for the fracture limestone aquifer. The groundwater salinity of this aquifer ranges from 1500 ppm in southern to 10000 ppm in Northern parts. The salinity variation of the aquifer depends on the location of recharge area in addition to the rock type and the water bearing rocks. On the other hand, WRRI performed another set of studies to estimate the aquifer potentiality. The results of these studies shows that the groundwater in this aquifer is basically a renewable, but the volume of water actually in storage may vary greatly from place to place in carbonate aquifer. The total exposed area of the fracture limestone is estimated at 16670 km^2 and the total annual recharge from Sinai rainfalls is estimated to be in the range of 76 million m^3. The central and northern areas in Sinai Peninsula are the best locations of groundwater exploitation from this aquifer where the well production rate ranges from 50 to 70m^3/hr while the productivity in the southern part ranges from 3 to 5 3m^3/hr.

1.2 Lower Cretaceous sandstone (Nubian) aquifer:

WRRI has performed several studies to estimate and evaluate the potentiality of this aquifer. The Lower Cretaceous sandstone aquifer underlies an Upper Cretaceous Formations and overlies a Jurassic Formations, this aquifer is composed mainly of sandstone intercalated with shale in the upper most part, where the shale decreases gradually downward, and the facials are changing from sandstone to limestone in Northern Sinai, the total thickness of this aquifer has been obtained from different field studies and it is found to be different from region to another. The average thickness of this aquifer ranges from 150 to 300 meters. It is considered the most prospective aquifer in Sinai due to its high storage capacity of 250 billion m^3 El-Bihery (1998) with a suitable salinity for different usages that ranges from 1000 to 5000 ppm. This aquifer covers most of central Sinai in addition to scattered blocks in some wadis in south Sinai. The recharge to the Lower Cretaceous sandstone aquifer has been studied through several researchers within the WRRI. The recharge values are varied among the different studies, for example Dames and Moore (1985) estimated the recharge to be in the range of 8.39 million m^3/year. Farid et. al. (1995), estimated the recharge value to be in the range of 4.86 million m^3/year. On the other hand, the average abstraction from the aquifer was found to be 3.94 million m^3/year based on some investigations by WRRI (2001). Figure (7) presents a general schematic diagram for the Cretaceous sandstone aquifer.

1.3 Quaternary Aquifer

This aquifer is considered the main water supply in the coastal strip of Sinai along the Mediterranean Sea in Northern Sinai and at El-Qaa plain the Southern Sinai. The Quaternary aquifer in Northern area is shown in Figure (8). The Northern part aquifer can be classified into three major aquifer zones that are: the upper zone which is stabilized sand dunes with total dissolved solids ranging from 1,500 to 2,500 ppm; the middle zone is alluvial deposits with TDS value varies from 2,500 to 3500 ppm; the lower zone is the calcareous sandstone with TDS ranging from 3,500 to 5,000 ppm. The recharge from rainfall was estimated to be 18.5 million m^3/year. The Southern part is El Qaa Plain that is located in the Southwestern part of the Peninsula, it forms the most representative Quaternary sedimentary basin in South Sinai, and covers an area of about 1930 km^2, it is bounded in the east by the uplifted Pre-Cambrian basement rocks, A number of main wadis are flowing into the basin with a total area of about 3900 km^2. The lithic features of the Quaternary sediments are composed mainly of sand, gravel, clay, and weathered basement. The water resources in El Qaa plain is consumed for municipal water of the Southern Sinai cities. The groundwater extraction was found to be 2.92 million m^3/year in

1984, increased to 3.44 million m^3/year in 1997, while the outflow to the sea was found to be 2.46 $x10^6$ m^3/year JICA (1999). The annual average precipitation was estimated to be in the range of a 5.9 million m^3/year

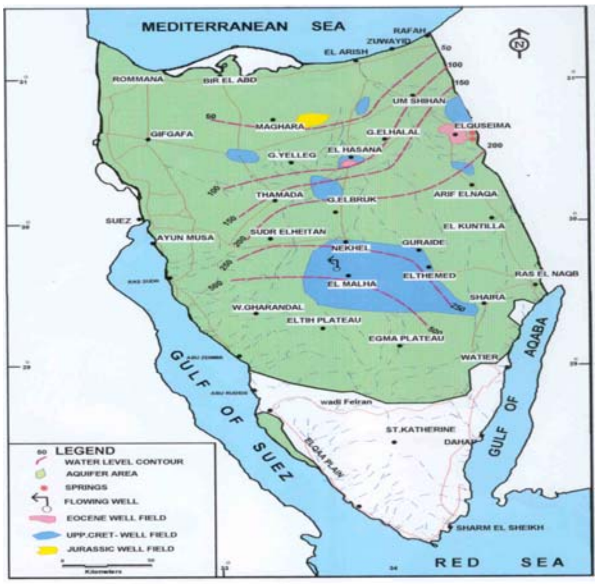

Figure (7): Fracture Limestone Aquifer in Sinai [27]

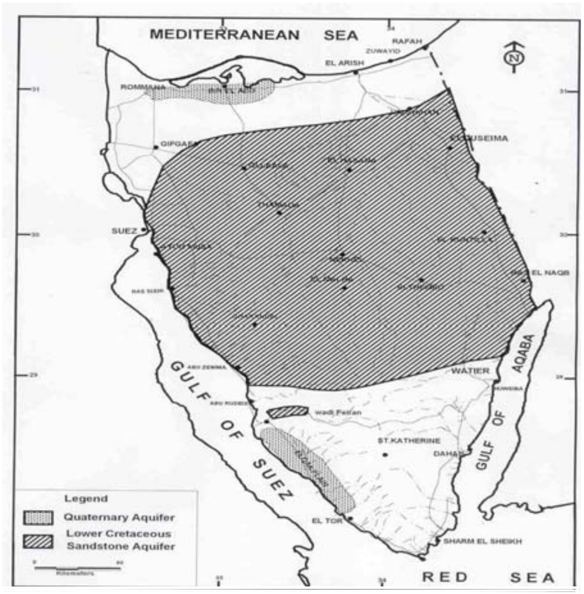

Figure (8): A Map presenting Quaternary and Lower Cretaceous Aquifers in Sinai [28].Sandstone

Integration of Water Resources Research and Sinai Sustainable Development

As presented in the previous sections, it can be concluded that there was a great effort was done in the field of water resources research within Sinai Peninsula which was considered a black box area till 1981 for the area of water resources. WRRI started since 1990's to establish a strong practical base, thus researches can cope with the reality. Thus, many studies have been performed to apply the research and getting use of it, among those studies are:

- Feeding of Sinai Cement Factory that locates in Mountain Lobna in Northern Sinai with groundwater with an abstraction of 2500 m3/day.
- Use of Groundwater for Abu-Oagelia Area for cultivation and domestic usage in Northern Sinai.
- Study of the use of groundwater in Wade Okaaba in Central Sinai.
- Abstracting water for heavy industrial areas in Maghara, Northern Sinai.
- Groundwater Potentiality in Taba area for domestic use.

1 Example for Integrating of Water Resources Research for Sustainable Development: A Case Study Bedouin Settlement Project

Methodology

A special project has been performed to study the Bedouin settlement in Northern Sinai as a result of integration for the previous and current researches to end up with concrete application that can be useful for sustainable development of Sinai community. The area under consideration is characterized by a little number of residences except the coastal area of Mediterranean Sea. The methodology for obtaining the project targets can be listed as:

- Collection and analysis of the available data since 1982 until now on the study area.
- Field investigations of all the water points such as wells and cisterns.
- Topographic and geomorphic studies.
- Hydrologic study to quantify surface water within the surrounding wadis and propose surface water control structures.
- Geological study to recognize the litho-geological unites and the nature of the water bearing formations in addition to the effect of different geological structures on groundwater.
- Geophysical study to delineate the extension and depths of different aquifers.
- Hydro-geological and hydro-chemical studies to perform extension, potentiality, flow direction and storage of different groundwater aquifers
- Social study to identify the behavior and demographic characteristics of Bedouin residence.

Analysis of Results

A huge number of well are existing and under us in the far North-East part. The numerical study shows that there is a significant depletion for groundwater reservoir in this location. However, the geological and hydro-geological studies show that there are some other promising areas for groundwater aquifer usage. These areas locate in the middle and south of the study area. On the other hand, the social studies have been performed for the different areas of Bedouins settlements as shown in Figure (9). The social studies dealt with many social and demographic issues such as standard of living, educational level, family characteristics, gender issue, etc. The study ends up with the different characteristics of Bedouins and the optimum methodology for dealing with them and how to convince them with new rules and ideas. Also, the project dealt with the watershed management system within the area. Different wadis within the study area and the main wadi, Al-Areesh were classified, where its flow towards the North into AL-Rawaafaa Dam. Accordingly, for sustainable development of this area control structures and diverters of flash floods water should be constructed to collect and make use of the flash floods.

Project Conclusions

The integration of research within the study area has been performed by merging the results from field, social, groundwater exploration, numerical modeling for groundwater, watershed management system and demographic studies. The integration of these studies shows that for sustainable development within the area under investigation it is not allowed to get extension expressed by drilling more new wells in the Northern part. However, it is allowed to get extension and more use of the groundwater aquifer in other areas. Accordingly, for sustainable development of this area a management system should be performed for not allowing drilling more water in the far Northern Eastern part of the study area.

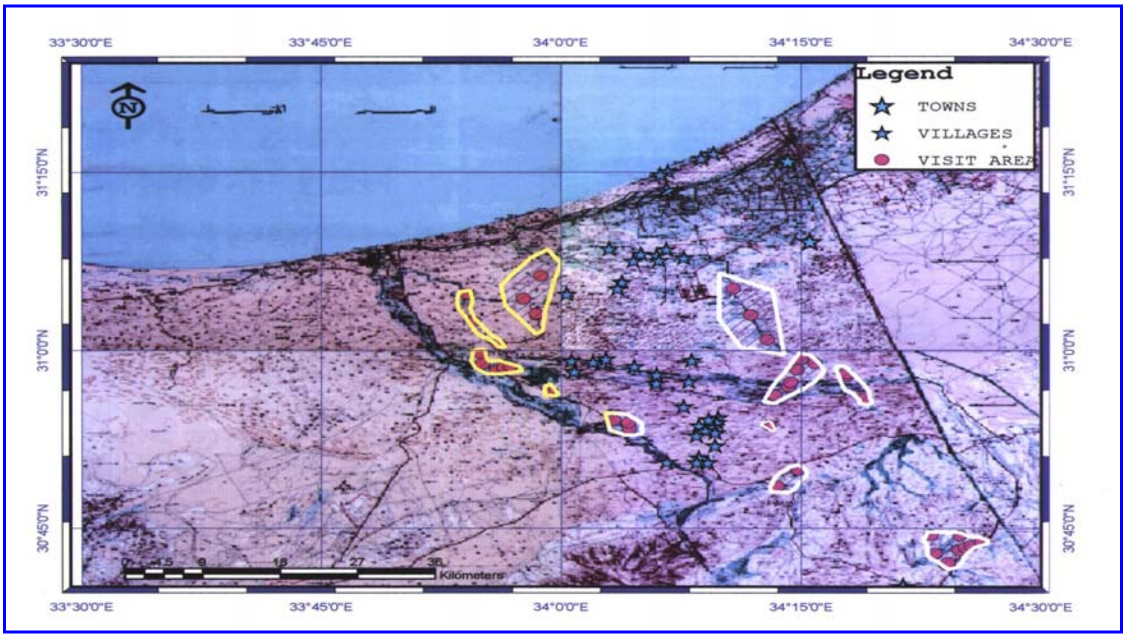

Figure (9): Current Settlement Areas for Bedouin within the Boundary of the Project Study Area [25].

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