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Ministry of Housing, Utilities & Urban Communities

SUPPORTING INNOVATION IN WATER & WASTEWATER IN EGYPT

NATIONAL FEASIBILITY STUDY & ROADMAP FOR RIVERBANK FILTRATION IN EGYPT

CAIRO

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NATIONAL FEASIBILITY STUDY AND ROADMAP FOR RIVER BANK FILTRATION IN EGYPT

FEASIBILITY STUDY REPORT

PARTNERS COORDINATORS

The initial version of this report was produced under Hyat Inclusive and Sustainable Local Economic Development Project in partnership with the Egyptian Ministry for Local Development, the Egyptian Ministry for Housing, Utilities and Urban Communities, the Egyptian Holding Company for Water and Wastewater and the United Nations Human Settlement's Programme (UN Habitat).

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LIST OF ABREVIATIONS AND ACRONYMS

ARE	Arab Republic of Egypt
BD	Bidding Documents
BER	Bid Evaluation Report
BOD	Biological Oxygen Demand / Board of Directors
BOQ	Bill of Quantity
COD	Chemical Oxygen Demand
CSC	Construction Supervision Consultant
CU	Compact Unit
EEAA	Egyptian Environmental Affairs Agency
EGP	Egyptian Pound
EMP	Environmental Management Plan
ERO	Environmental Regional Officer
ESAF	Environmental & Social Assessment Framework
ESIA	Environmental & Social Impact Assessment
ESMMF	Environmental & Social Management & Monitoring Framework
EU	European Union
Fe	Iron
FMS	Financial Management System
g/l	gram per litre
GHWSC	Gharbyia Water and Sanitation Company
GIS	Geographic Information System
GOE	Government of Egypt
GWA	Ground water aquifer
GWP	Groundwater Plant
HCWW	Holding Company for Water and Wastewater
IWRM	Integrated Water Resource Management
K	Soil Permeability Coefficient, Hydraulic Conductivity
LA	Land Acquisition
LAL	Local Area Level
LAU	Local Administrative Unit
LSC	Local Supervision Consultant
LVU	Local Village Unit
Markaz	District
m asl	meters above sea level
m bgl	meters below ground level
M&E	Monitoring and Evaluation
m/s	meter per second
MIS	Management Information System
Mn	Manganese

MOE	Ministry of Environment
MOH	Ministry of Health
MOHUUC	Ministry of Housing, Utilities and Urban Communities
MOIC	Ministry of International Cooperation
MOM	Minutes of Meeting
MWRI	Ministry of Water Resources and Irrigation
NA	Not Applicable
NCB	National Competitive Bidding
NOPWASD	National Organization for Potable Water and Sanitary Drainage
O&M	Operation and Maintenance
OP	Operational Policy
PAD	Project Appraisal Document
PCU	Project Co-ordination Unit
PIU	Project Implementation Unit
PMC	Project Management Consultant
ppm	Parts per million
PS	Pump station
PSL	Potential Site Level
RBF	Riverbank Filtration
RBL	River Basin Level
SSP	Site Selection Procedure
TA	Technical Assistance
TDS	Total Dissolved Solids
TOR	Terms of Reference
UN-HABITAT	United Nation Human Settlement Program
WSC	Water and Sanitation Company
SWTP	Surface Water Treatment Plant
WW	Wastewater
WWTP	Wastewater Treatment Plant

1. UNDERSTANDING AND BACKGROUND OF RBF

1.1 INTRODUCTION

Alluvial aquifers are widely used as a groundwater source in many countries, mainly due to their high production potential, proximity to demand areas, their ease, and economy of extraction. By pumping wells located in an alluvial plain hydraulically connected to a river it is possible to generate a hydraulic gradient so that surface water is forced to flow through the bed and the banks of the river (Figure 1). During this process, known as riverbank filtration (RBF), a reduction in the concentration of pollutants is achieved by physical, chemical, and biological processes that take place, between the surface water and groundwater, and with the substrate [1-3].

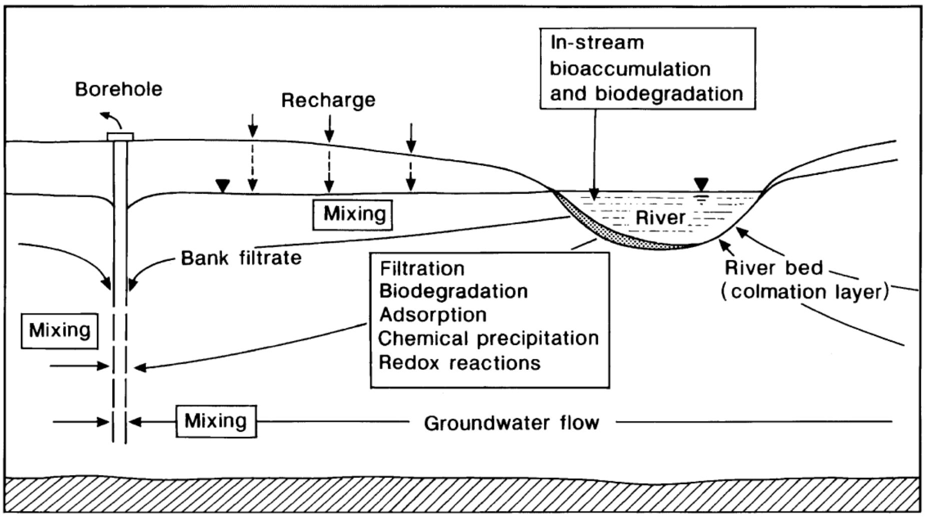


Figure 1: Basic scheme of riverbank filtration and main attenuation processes [1]

The reduction of pollution levels is accomplished by various of processes including physical filtration, microbial degradation, ion exchange, precipitation, sorption, and dilution. Other factors that also contribute to the treatment are: the river water and groundwater quality, the hydraulic conductivity and porosity of the riverbed material and the adjacent aquifer, the flow path lengths and water residence time in the aquifer, temperature, pH and oxygen concentration of river water, and redox conditions in the riverbed and aquifer.

In addition to the removal of pollutants (particles, microorganisms, organic, and inorganic compounds, etc.) there are two additional advantages of RBF. The first is relative to the fact that the flow through the aquifer acts as a barrier against concentration peaks that may result from accidental spills of pollutants or stormwater run-off and floods. The second is the buffering of temperature variations in the river water: during winter, when air temperatures are low, the filtered water is usually warmer than surface water, and in summer it is cooler. Lower variation in temperature improves the quality of the bank filtrate and the operation of post-treatment units.

Riverbank filtration technology has been a common practice in Europe for over 150 years, particularly in countries such as Switzerland where 80 % of drinking water comes from RBF wells, 50 % in France, 48 % in Finland, 40 % in Hungary, 16 % in Germany, and 7 % in the Netherlands [4]. In Germany, for example, 75 % of the city of Berlin depends on RBF, whereas in Düsseldorf RBF has been used since 1870 as the main drinking water supply. In the United States, on the other hand, this technique has been used for nearly half a century, especially in the states of Ohio, Kentucky, Indiana, Illinois, among others. Other countries that have recently started implementing RBF for drinking water supply are India, China, and South Korea [5].

All the aspects mentioned above make RBF a very appealing tool to be implemented in a country like Egypt, especially for areas having no access to good quality drinking [6].

1.2 SITING AND DESIGN

Local factors such as river hydrology, hydrogeological site conditions (i.e., aquifer thickness and hydraulic conductivity), and the aims of water withdrawal determine not only the capacity of the wells, but also the travel time of the bank filtrate, and distance between the river and the well.

Riverbank filtration wells can be designed either vertically (as the most common practice) or horizontally (for high extraction rates). Horizontal wells (commonly with a radial pattern), also known as collector wells, are often directed toward the river and extract water also from beneath the riverbed, whereas vertical wells extract water along the riverbed. Also, RBF wells can be distributed parallel to the riverbank in galleries or groups.

Grischek et al. [5], Ray et al. [7] and Kruc et al. [8] compiled available information from RBF systems in Europe and the United States, and concluded that the most important hydraulic parameters for success during RBF are the flow path length, the thickness of the aquifer, and the infiltration area in the river. Finally, it could be concluded that the siting and design of an RBF system does not only depend on hydrogeological factors, but also on technical, economical, regulatory, and land-use factors [3, 7].

1.3 PROCESSES DURING RBF

Four processes which are involved in RBF: hydrodynamic, mechanical, biological, and physicochemical Hydrodynamic processes include convective-dispersive transport, and mixing. The aquifer acts as a buffer for the temporal variation of pollutants in the river caused by accidental (or intentional) spills. As a result, variations in the surface water quality are reduced in pumped bank filtrate due to different flow paths in the aquifer and mixing of water which has been infiltrating at different times and distances [3].

The most important mechanical process for the improvement of water quality is the natural filtration of fine particles, particulate organic matter, and pathogens, especially in the first centimeters in the riverbed and first few meters of the flow path in the aquifer [3].

The biological processes that occur during RBF are directly dependent on the type of microorganisms that inhabit the aquifer. The metabolic processes of these microorganisms mainly determine the final quality of filtered water.

Finally, physicochemical processes are associated with sorption, precipitation reactions, and flocculation, coagulation, and redox reactions. All these processes govern the removal of dissolved water constituents, affecting the concentration and the behaviour of trace organic compounds, metals and other inorganic compounds, thus having implications for the chemical evolution of water.

All previous studies and applied practices and above specific characteristics support the implementation of RBF as an appropriate alternative to conventional surface water treatment plants in Egypt. The alluvial aquifer which extends alongside the Nile River and the delta makes almost all cities & villages physically and topographically applicable for RBF projects since they are located in close proximity to the main river or branches, if the latter are hydraulically connected with the aquifer and the natural groundwater gradient towards the river or branch is not too high.

Building on the successful implementation of RBF units in Egypt [9], and the recent endorsement of the scale-up plan by the Ministry of Housing, UN-Habitat Egypt Office in cooperation with the Holding Company for Water and Wastewater are planning to conduct a national feasibility study to explore potential implementation sites for RBF in Egypt, which is the purpose of this report [10].

2. APPROACH AND METHODOLOGY

At the beginning of the project the consultant is undertaking a comprehensive documents investigation in cooperation with the concerned governorates and affiliated water companies for initial data collection, and is giving an overview for the collection of additional data and information required for the completion of the study. Documents to be taken into account in elaborating the Project Methodology are: Requirements stated in the ToR, relevant Egyptian laws, and available data resources and references including latest RBF application and similar site studies. In addition, the general requirements set out in related directives and publications will be taken into consideration in preparing the documentation under this assignment. The facts and findings of the different investigations will be used by the project team to understand the project and to prepare the required reports. Major activities as set forth in the ToR will be commenced and progressed in parallel to cope with the project timetable.

Project Assumptions, Risks and Overarching Constraints

At this project stage, it is assumed that the consultant will perform services in accordance with the ToR and guidance given by the concerned stakeholders. Potential risks to the project may be determined as:

Institutional Setup*:* One of the cornerstones of the activities will be the institutional set up and determination of responsibilities between the stakeholders. The consultant requires full support by the client in order to organise the inputs from the stakeholders on schedule in order not to delay the performance of services. The consultant expects full support from HCCWW and affiliated companies in terms of providing the necessary data and following the demand driven approach for the eligible areas for RBF implementation.

Costs against reasonable budget*:* It is the understanding of the consultant that we shall look for a feasible solution respecting financial capability of the potential funding and the authority concerned considering and respecting “lessons learnt”. These lessons learnt from the implemented RBF applications are assumed to be handed over to the consultant whenever being available.

Delay in obtaining approvals and permits: The project preparation will be in accordance with the contract, but nevertheless there might be some overarching constraints to keep on holding with the time schedule foreseen such as: Late comments to reports submitted by the consultant. The schedule of activities and the work program has been established in such a way that the time for review and or approval is not included in the project contract period and as set in the consultant’s works program.

Data Sources and References

A list of available / related documents which might be useful as preliminary source of data, documents and references is prepared upon award to be handed over to the consultant. The list includes, but is not limited to the following documents:

- Summary of water master plan for the potential governorates, to be provided by affiliated water companies including the recently inserted updates.
- Identifying areas suffering from water shortage in terms of availability of service as well as level of services. A water balance for each district and/or water system should be also provided.
- For those areas having shortage in water or having low level of service, the water authority should propose a tentative list of sites which can accommodate RBF facilities.
- Available water quality data should be provided for those identified sites including surface water and groundwater quality.

3. PROPOSED SELECTION METHODOLOGY

3.1 DEVELOPMENT OF SITE SELECTION CRITERIA AND SELECTION PROCEDURE

The development of site selection criteria for RBF was initiated by reviewing and compiling existing RBF case studies worldwide. The various site selection criteria from the available case studies were focused upon the key performance indicators for RBF systems. Essential data clusters and necessary specific parameters were identified and categorized. The site selection data groups reviewed and compiled include hydrogeology, hydrology, water quality, water demand, land use, and infrastructure. The data sets considered in this study include:

- Geology (Quaternary geology/alluvial plains),
- Hydrology,
- Hydrogeology such as conditions of groundwater sources, groundwater quality, and groundwater wells data (if available),
- Land use,
- Water supply demand (Provincial water supply).

3.2 SITE SELECTION PROCEDURE

Based on previous international experiences, the selection procedure could be divided into 3 steps, namely:

Step 1: Potential River Basin Level (RBL), attempts to identify potential RBF areas in the River Nile basin (regional) scale;

Step 2: Potential Local Area Level (LAL), attempts to identify the RBF potential local areas (mainly Governorates) within the potential river basins obtained from step 1;

Step 3: Potential Site Level (PSL), districts and communities, attempts to identify the RBF potential sites and locations within the local areas obtained from step 2.

Then the potential sites and locations obtained from step 3 will be used for more detailed site investigations to determine the RBF key performance parameters for the RBF system design and construction. After a more detailed examination of existing available data was carried out, a new adjustment and arrangement of data groups selection procedure were made as demonstrated in Figure 2.

Considering the site selection procedures, steps and selection criteria in Figure 2, a series of thematic maps was compiled or prepared for each selection step. Overlaying such maps helps to identify the eliminated locations as well as the potential locations.

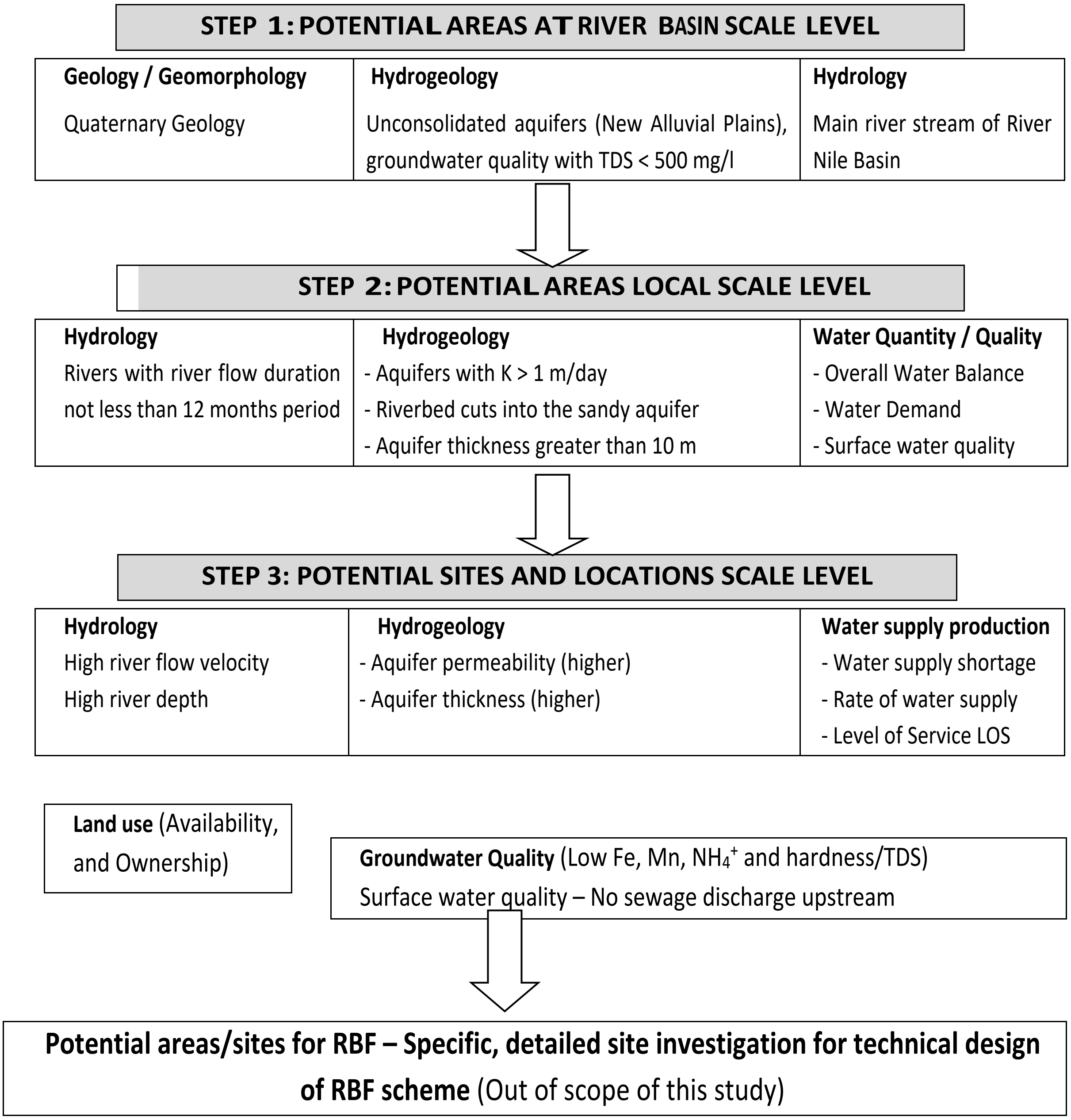


Figure 2: Overall procedures for the RBF site selection

Initially, the **Quaternary geologic map** of Nile Valley regions was obtained. The map sheets were combined to obtain the distribution of Quaternary deposits focusing on the alluvial plain deposits.

Groundwater quality map using total dissolved solids (TDS), chlorides, and sulphates was obtained from the existing provincial groundwater availability maps published by the Department of Groundwater Resources, included in the handbook of Description of Egyptian Soils, produced by Cairo University.

The thematic map from hydrogeology was overlaid on the groundwater quality map to obtain the RBF geologic and hydrogeologic suitability areas to identify the RBF potential areas at the river basin scale level.

River hydrographs were examined to get the river flow duration. The river hydrograph information showed that the river flow of the main river stream is 12 months flow duration over the year, which makes this criterion equal for the potential areas driven from other criteria.

River water quality is considered nearly consistent along the main river stream, however, apart from high level turbidity in seasonal precipitation periods, better quality is assumed for Upper Egypt governorates.

The aquifer thickness and aquifer permeability were reviewed and compiled from the existing literature and range of practical aquifer thickness and eligibility of aquifer permeability were investigated in different regions along the main river stream. To prove the hydraulic connection between the river and the alluvial aquifer was more difficult because this requires the normalized level of the river bottom and geologic information about the location/level of the clay layer covering the aquifer.

The expected main water user from the RBF system is the Provincial Water Supply Authority. Water demand for provincial water supply is, therefore, considered as one of the important parameters for RBF site selection. The demand driven approach has been followed in obtaining the water demand and water balance for provincial water supply in order to be compiled and assessed.

3.3 SCORING AND WEIGHTING OF SELECTION CRITERIA

At the local and site suitability scale level, the considered site selection criteria include 5 components, namely, hydrology, hydrogeology, water quality, land use, and provincial water supply production capacity as categorized, scored and weighted in Table 1.

Based on the scoring and weighting of the selection criteria illustrated in Table 1, the potential areas at the site and location scale level can be identified and ranked to define priorities. The results from the application of Table 1 should only be used as indicators for site selection, because there is no proven scoring and weighting system available yet applicable to all types of potential RBF sites. Indicators such aquifer permeability may have higher weight if the pumping rates should be high. The hydraulic gradient of the groundwater towards the river is not yet included but has an impact. Furthermore, operational aspects raised by the water companies are not yet included. Thus, Table 1 should be seen as a decision support tool but does not replace meetings of experts and local staff.

The identified potential sites will be used for further detailed site investigations to determine the RBF system key performance parameters for preliminary RBF system design and construction.

The site investigation data determined from this stage of data acquisition will be used for final site selection screening which will be carried out in a similar manner so as to obtain the sites for the RBF pilot and full project development. It should be noted that scoring and weighting need detailed site information and measurements which is not within the scope of this study. Accordingly, at this stage the selection will be based on the elimination of areas which are not complying with the requirements stated in Figure 2 based on macro scale data and information. The specific site conditions will be assessed based on the available data and knowledge. No site measurements will be performed during this study.

Table 1: Proposed scoring and weighting of selection criteria – Detailed site investigation and prioritization level

Type	Selection Criteria	Unit	Score			Weight
			1	5	10	100
1	**Hydrology**					
1.1	River flow velocity	m/s	0.5 - 1	1-1.5	>1.5	10
1.2	River flow duration	months	9	>9 - <12	12	15
2	**Hydrogeology**					
2.1	Aquifer thickness	m	10 - 15	>15 - 20	>20	20
2.2	Aquifer permeability	m/day	1 - 10	>10 - 50	>50	10
3	**Water Quality**					
3.1	Surface water	type	poor	good	high	5
3.2	Groundwater (TDS)	g/l	1 - 1.5	0.5 - 1	<0.5	5
3.3	Others (chlorides, sulphates, Fe, Mn)					5
4	**RBF Construction Site**		Com/Industry	Agricultural	Public	5
5	**Water Supply Production**					
5.1	Raw water shortage	months	<1	1 - 3	>3	5
5.2	Rate of water supply production	LPCD	>100	50 - 100	<50	20

Max Score = 100 points

4. POTENTIAL ZONING FOR RBF POTENTIAL APPLICATION

4.1 RIVER BASIN LEVEL – MAIN STREAM

Based on the national zoning, Nile river valley can be geographically divided into three main zones as the following:

- Nile Delta Zone
  - Greater Cairo Zone
  - North of Cairo Zone
- Nile Valley Zone
  - Northern part of Upper Egypt Zone
  - Middle part of Upper Egypt Zone
  - Southern part of Upper Egypt Zone
- Fayoum Depression Zone

4.2 DESCRIPTION AND LOCATION

Delta area starts at 23 km north to Cairo as reversed triangle with its base at North extending from Rosetta at west to Damietta at the East for @ 220 km. The height of this triangle is @ 170 km. Therefore, the total area of the Nile Delta zone is @ 22000 km^2 representing almost double of the Nile valley from Upper Egypt to Cairo. In other words, the Nile Delta area is almost two third of the total Nile alluvial lands.

The Nile Valley extends from 7 km south of Aswan until Cairo with a total length of 965 km. The length between southern borders with Sudan to Aswan is @ 320 km [11].

4.3 TOPOGRAPHY

The overall slope of the Nile valley is 1/12000 steeping from South to North. The width of alluvial plains is very narrow at Aswan @ 2.8 km while in Beni Suif is 17.2 km with an overall average of @ 10 km. Two edges identifying the valley; eastern edge at 200 m level which is almost directly parallel to the valley. The western edge also at level 200 m but moving little bit far from the Nile stream representing the plains with average width of 10 km. The average levels of the valley from South to North is illustrated in Table 2. Table 3 illustrates the Nile valley width in different governorates along the Nile main stream.

As for Delta area levels starts at 16 m asl from Cairo and sloping to the North to the sea level with an overall slope of 1:10000 [11].

Table 2: Land topography of Nile valley governorates

No.	Governorate	Ground Level at South in m asl	Ground Level at North in m asl
1	Aswan	+ 120	+ 85
2	Qena	+ 87	+ 69
3	Suhag	+ 65	+ 56
4	Assiut	+ 54	+ 44
5	Minya	+ 44	+ 32
6	Beni Suif	+ 31	+ 26
7	Giza and Cairo	+ 23	+ 16

Table 3: Width of Nile Valley (alluvial plain) in Nile valley governorates

No.	Governorate	Alluvial Plain Width in m		
		Max	Min	Average
1	Aswan	7500	200	2800
2	Qena	18000	2500	5800
3	Suhag	19000	9500	15000
4	Assiut	20000	9000	14700
5	Minya	20000	11000	15300
6	Beni Suif	22000	10000	17200
7	Giza	12000	5000	8300

4.4 GEOLOGY AND MORPHOLOGY

A corner stone for RBF feasibility is to define the areas having alluvial plains which is somewhat, comparatively, young and not consolidated. The following Figures 3 to 6 illustrate the alluvial plain along the River Nile for different zones. It can be concluded that the Nile Delta Zone is reach zone in terms of alluvial plain and extends form Rosetta Branch at west side until Damietta branch at east side. The rest of Nile valley is comparatively narrow with narrowest part at Aswan. Major cross-sections are presented in Figures 7 & 8 in order to indicate the aquifer layers and formations along the valley and Delta branches indicating the type of soil as well as the depth of aquifers [11].

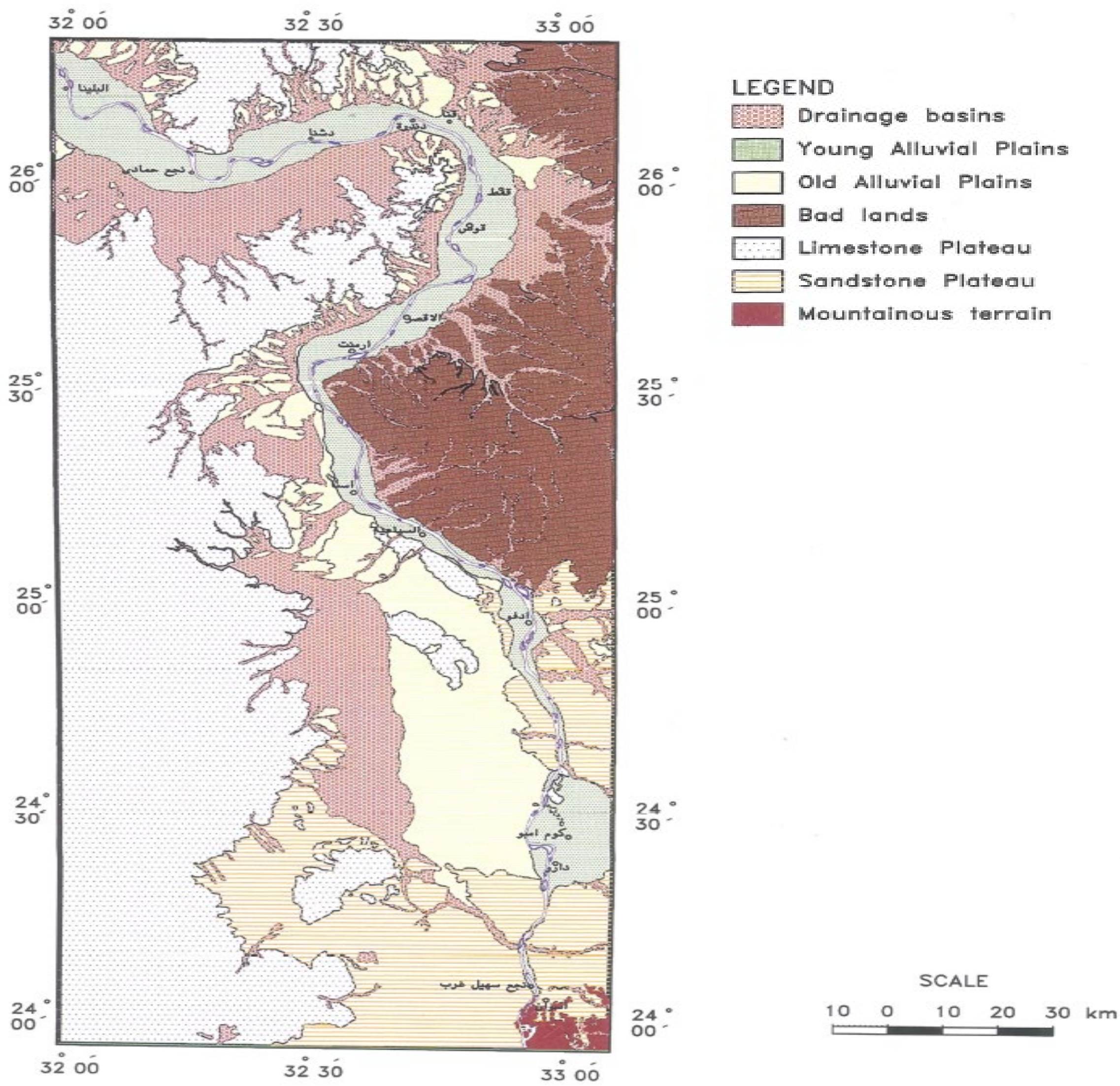


Figure 3: Alluvial Plain along Nile River valley - from Southern Upper Egypt (Aswan – Qena) [11]

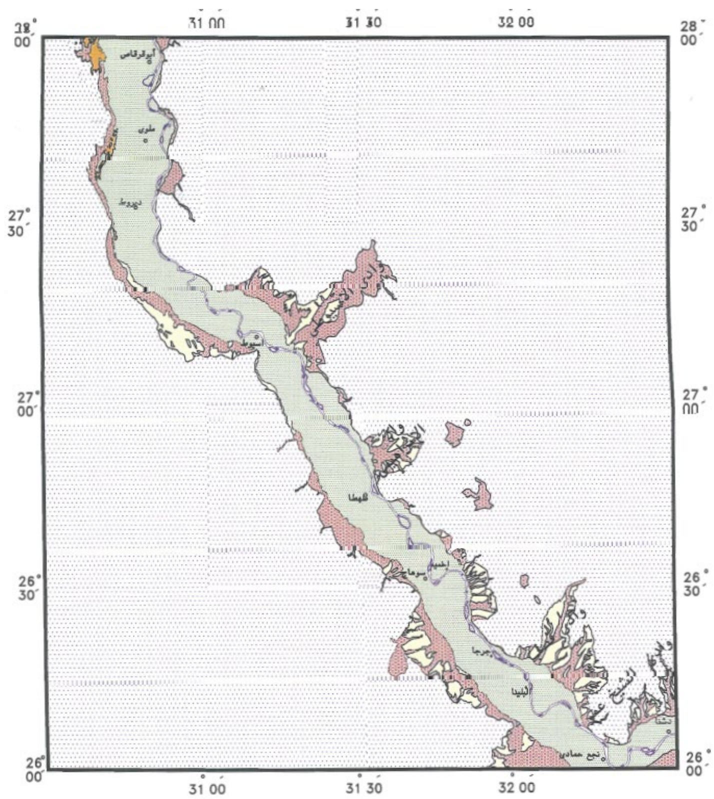


Figure 4: Alluvial Plain along Nile River valley - Middle Upper Egypt (Sohag – Assiut) [11]

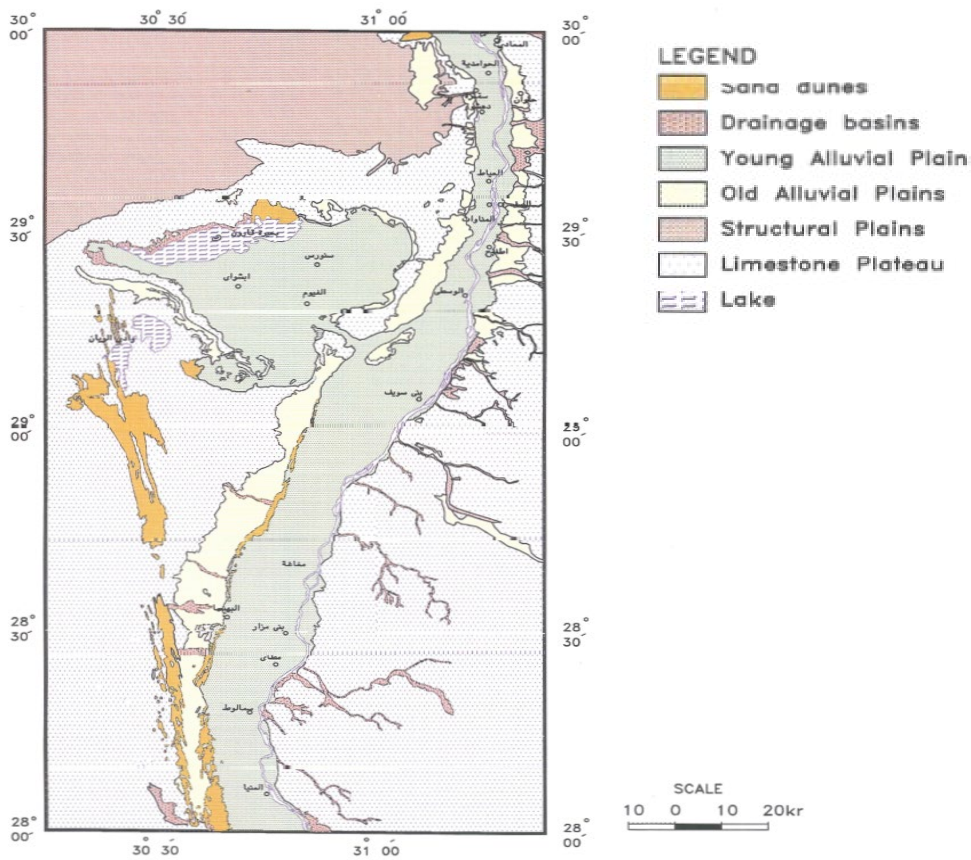


Figure 5: Alluvial Plain along Nile River valley - North Upper Egypt (Minya – B. Suif – Fayoum) [11]

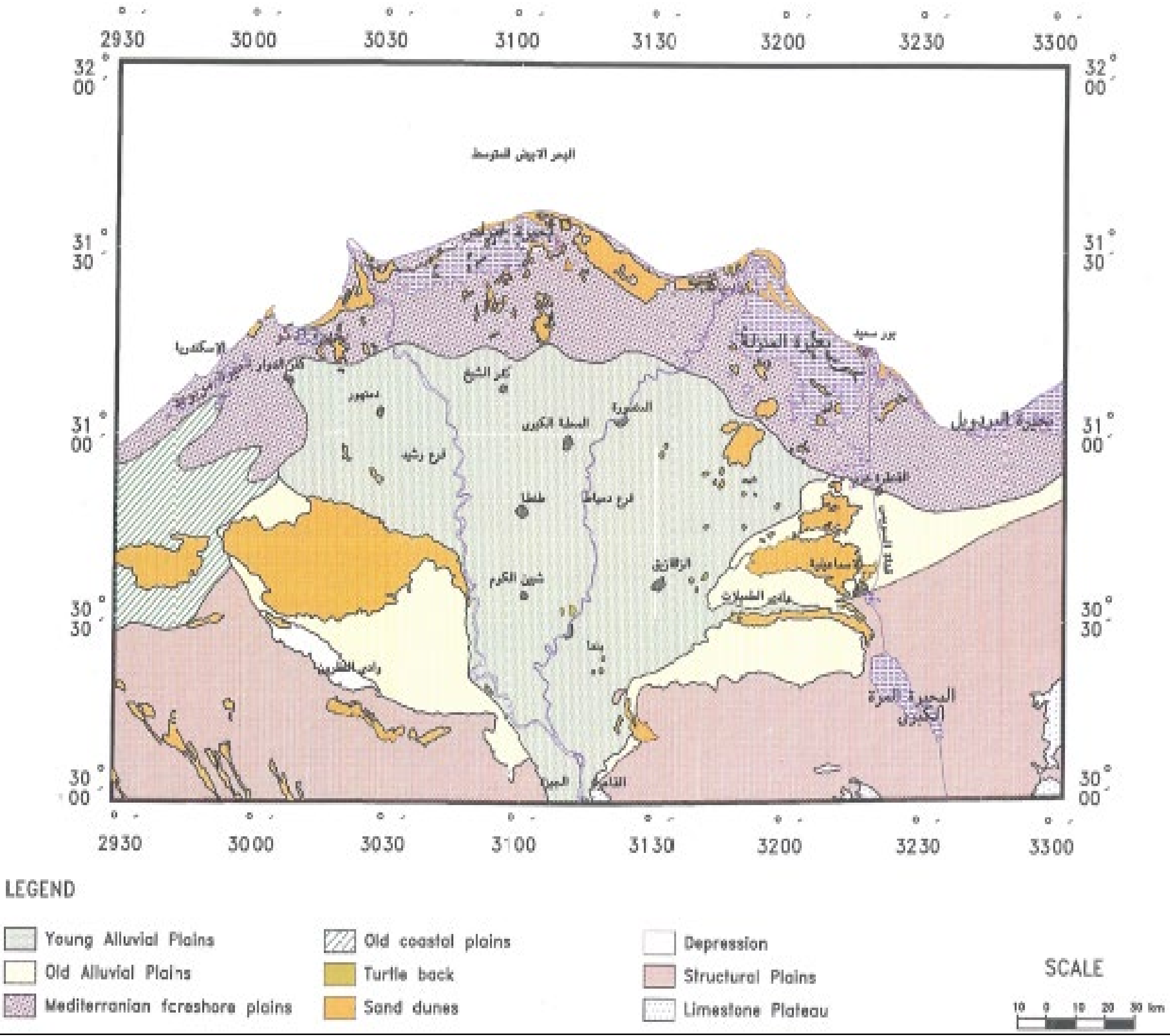


Figure 6: Alluvial Plains of the Nile Delta Zone [11]

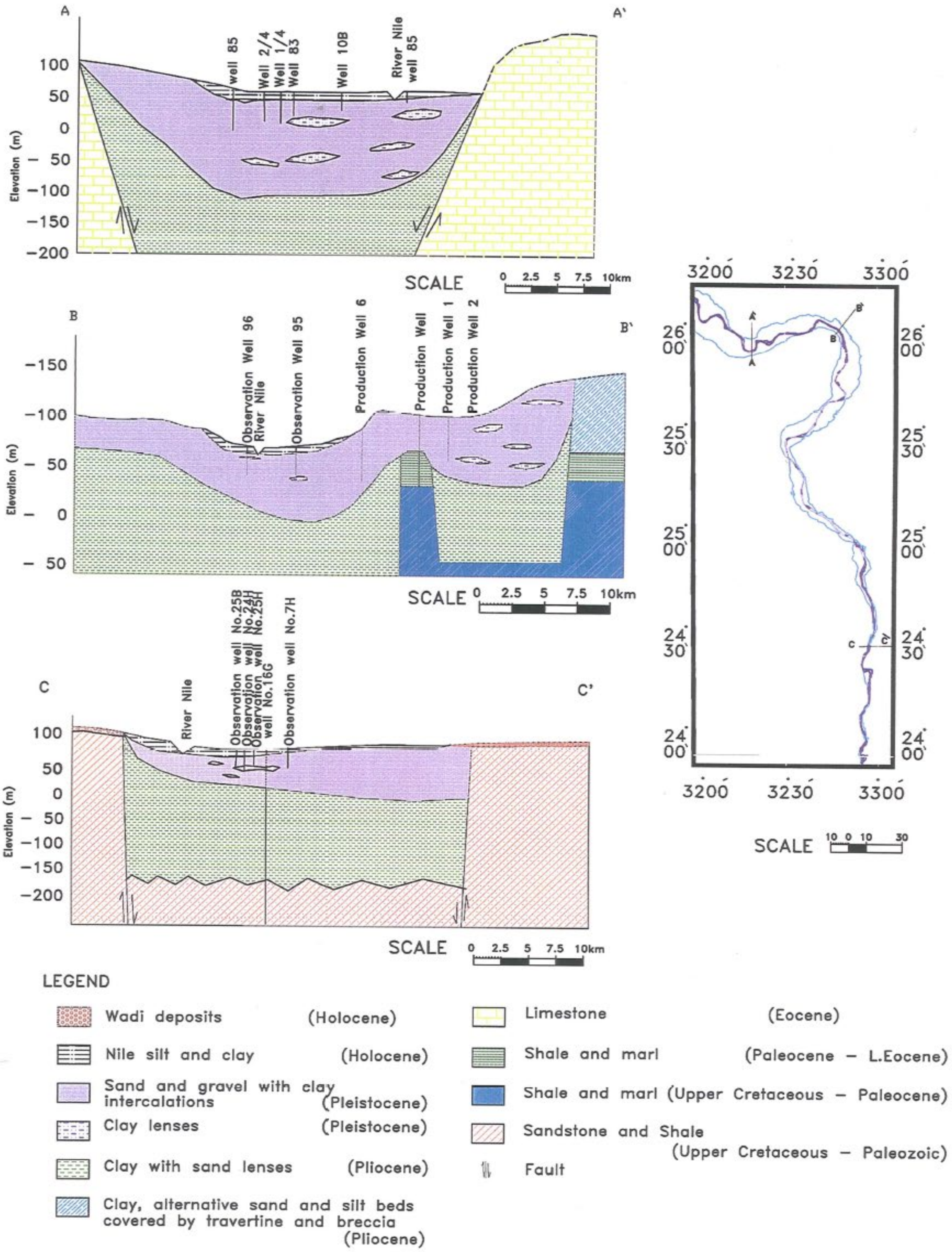


Figure 7: Geological formations / sections under Quaternary Zone - South Valley [11]

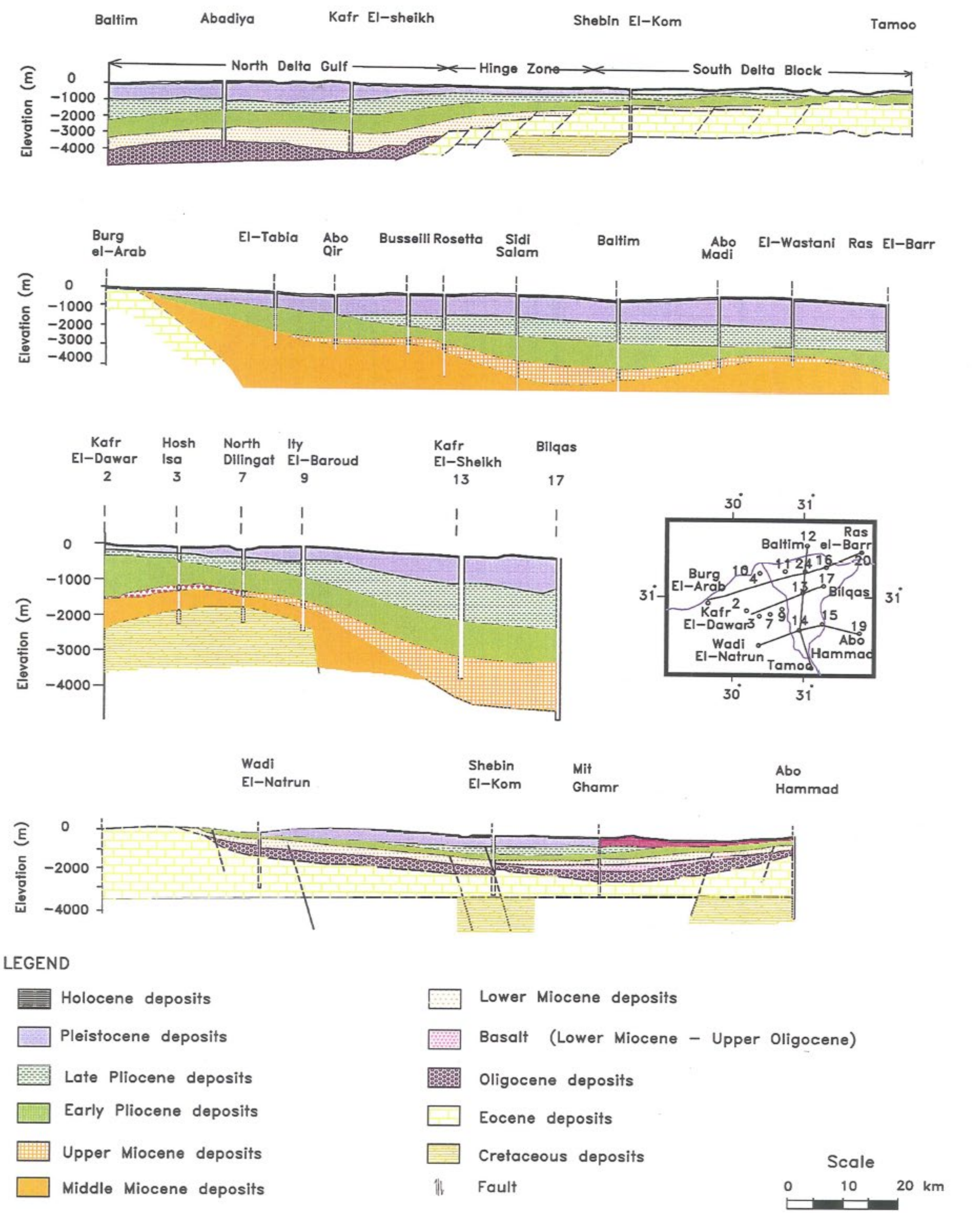


Figure 8:Geological formations / sections under Quaternary Zone - Nile Delta [11]

4.5 HYDROGEOLOGY AND HYDROLOGY

The Nile valley is hydrogeologically characterized by the existence of a quaternary reservoir. This reservoir is the most productive groundwater reservoir in the valley. Semi-permeable layers with a thickness varying from 1 to 15 m appear along the Nile main stream, compared to 1 - 30 m at the South and Middle Delta and up to 60 m at the North Delta. This layer is followed by a permeable layer which is suitable for high RBF well yield. Thickness of such sand/gravel layer differs from South to North as shown in Table 4. Thus, aquifer thickness is not a limiting factor for RBF along the Nile river. According to Table 1, all areas would gain the highest score for aquifer thickness.

Table 4: Thickness of sand/gravel aquifer in the Nile valley [11]

Location	Aswan (Kom-Ombo)	Qena	Sohag	Assiut/ Miya	Beni Suif	South Cairo	Delta
Range of sand/gravel layer depth (m)	25-100	25-150	50-250	50-300	25-200	50-100	100-1000

Figures 9 to 12 illustrate examples of hydrogeological and hydrological characteristics of some areas.

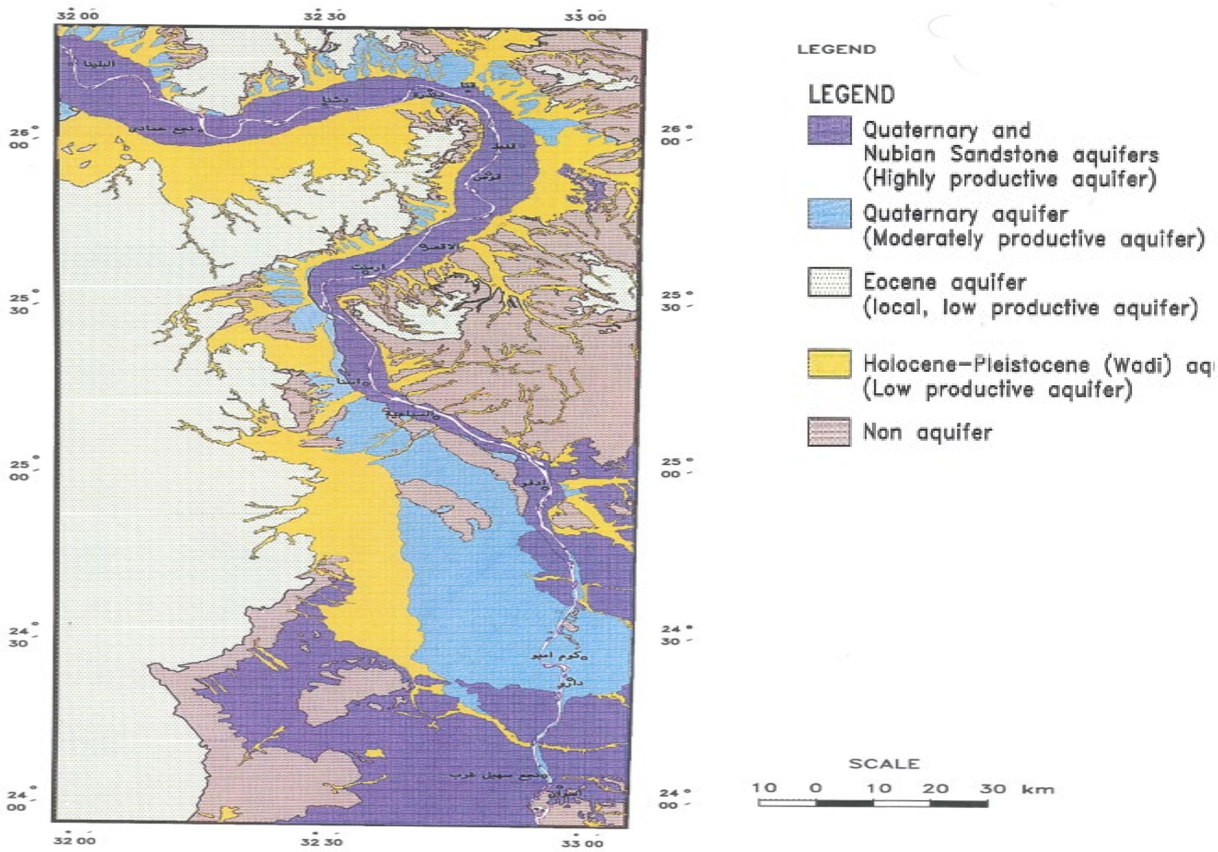


Figure 9: Groundwater reservoir productivity – Quaternary reservoir (Aswan – Qena) [11]

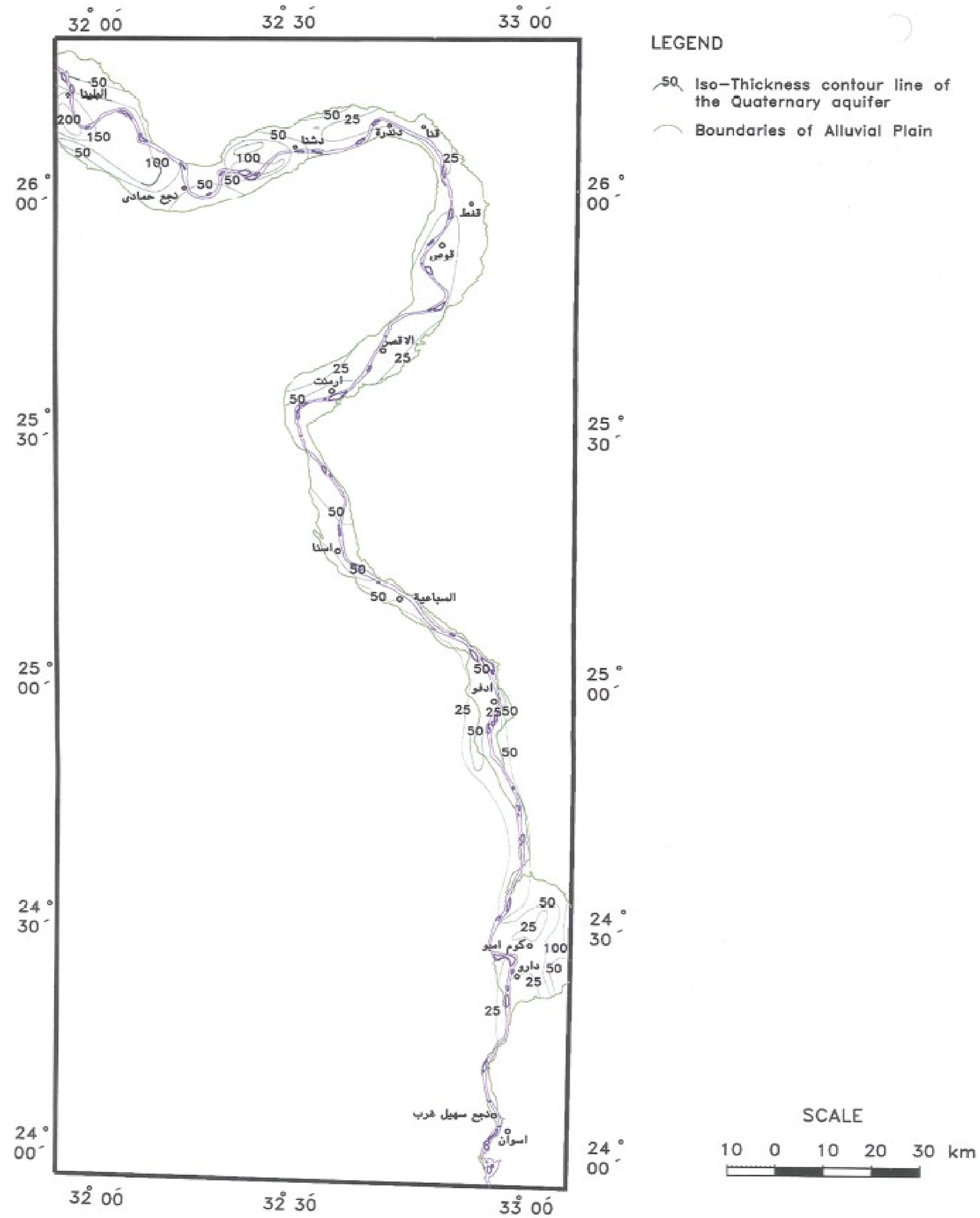


Figure 10: Aquifer depth' contour lines - Upper Egypt [11]

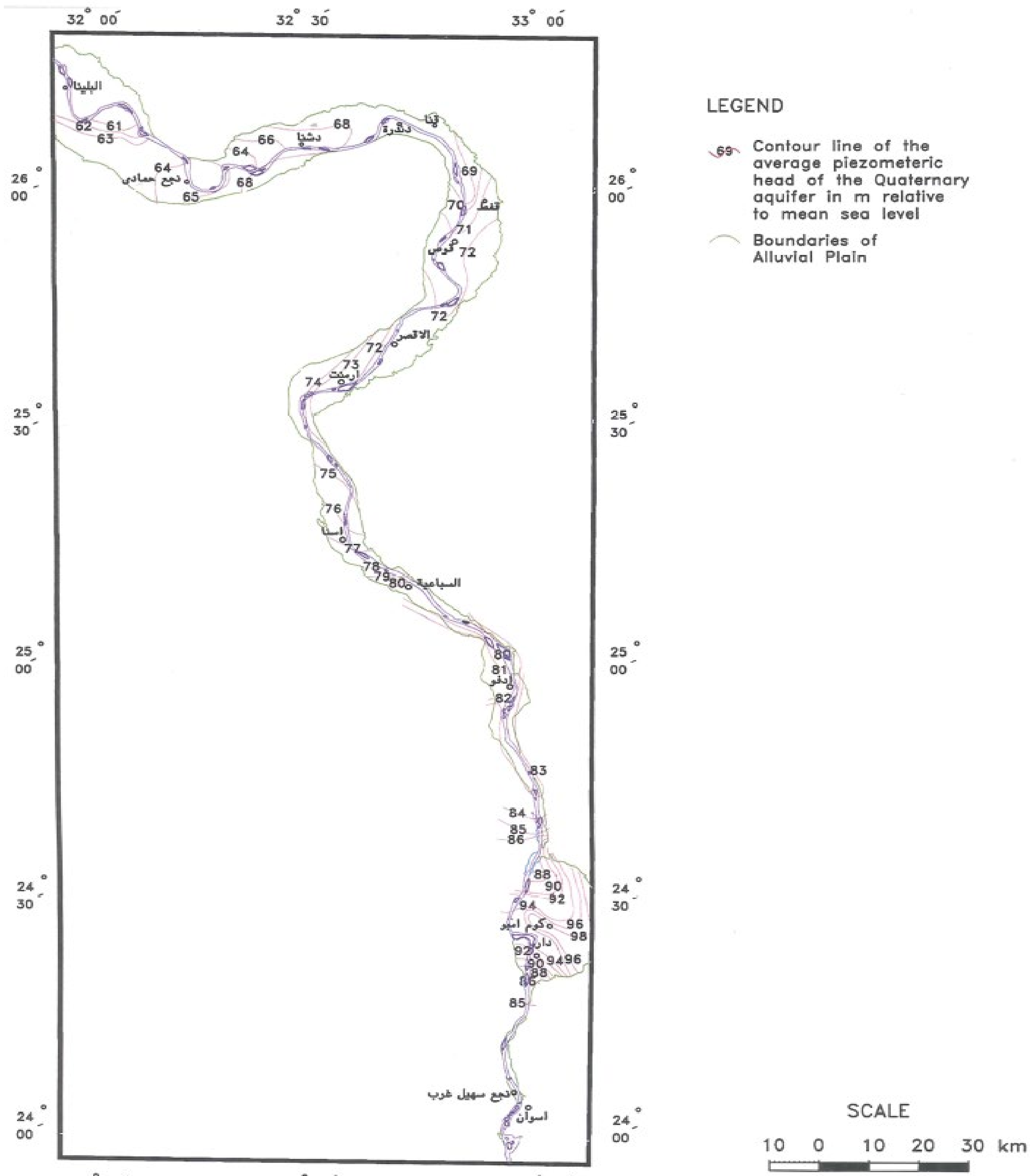


Figure 11: Aquifer piezometric contour lines - Upper Egypt [11]

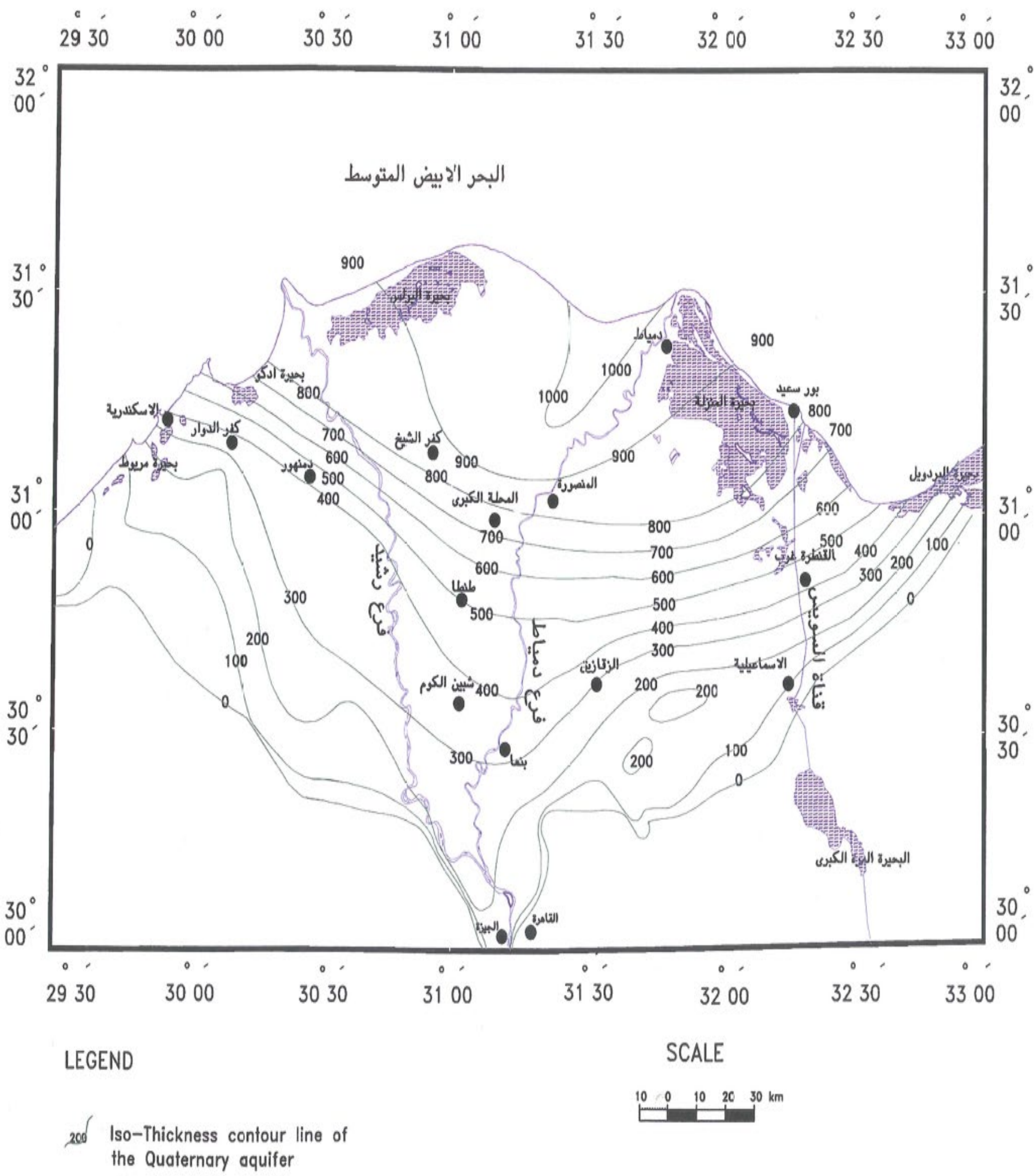


Figure 12: Thickness of Quaternary reservoir in Delta [11]

4.6 HYDROCHEMICAL CHARACTERISTICS

Water quality of the Quaternary reservoir is considered as good especially in areas closer to the River Nile stream. The following chemical characteristics are extracted from previous studies [11]:

- TDS Valley 500-3000 ppm Delta 500 ppm at South to 10000 at North
- Chlorides Valley 100-400 ppm Delta 100 ppm at South to 5000 at North
- Sulphates Valley 25-150 ppm Delta 25 ppm at South to 1000 at North

Other important parameters would be iron and manganese as well as organic compounds which should be identified during the detailed site investigation which is out of the scope of this study. Figures 13 and 14 show the TDS levels in the valley and Delta zones.

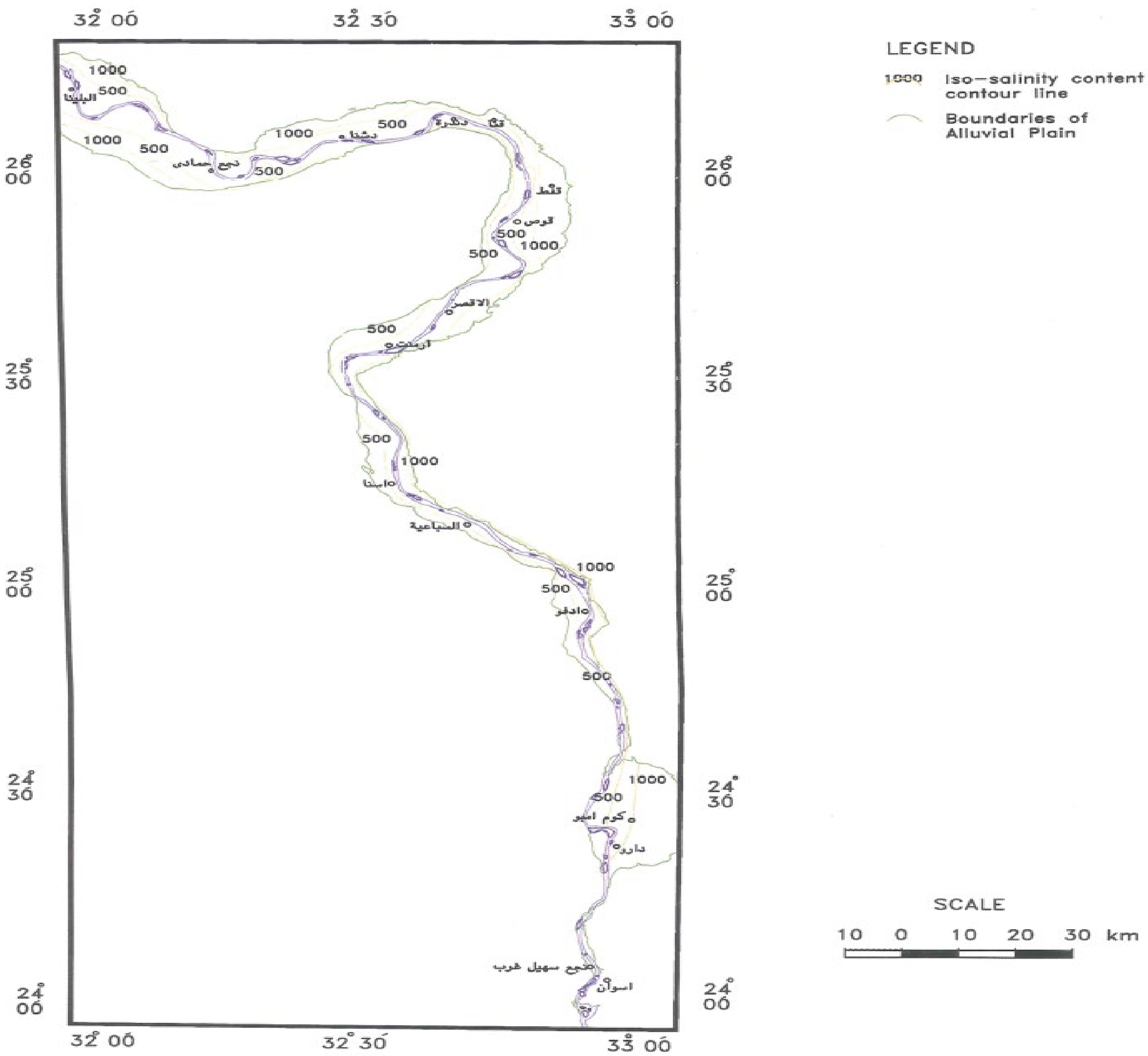


Figure 13: TDS in ppm in Upper Egypt - South (Aswan – Qena) [11]

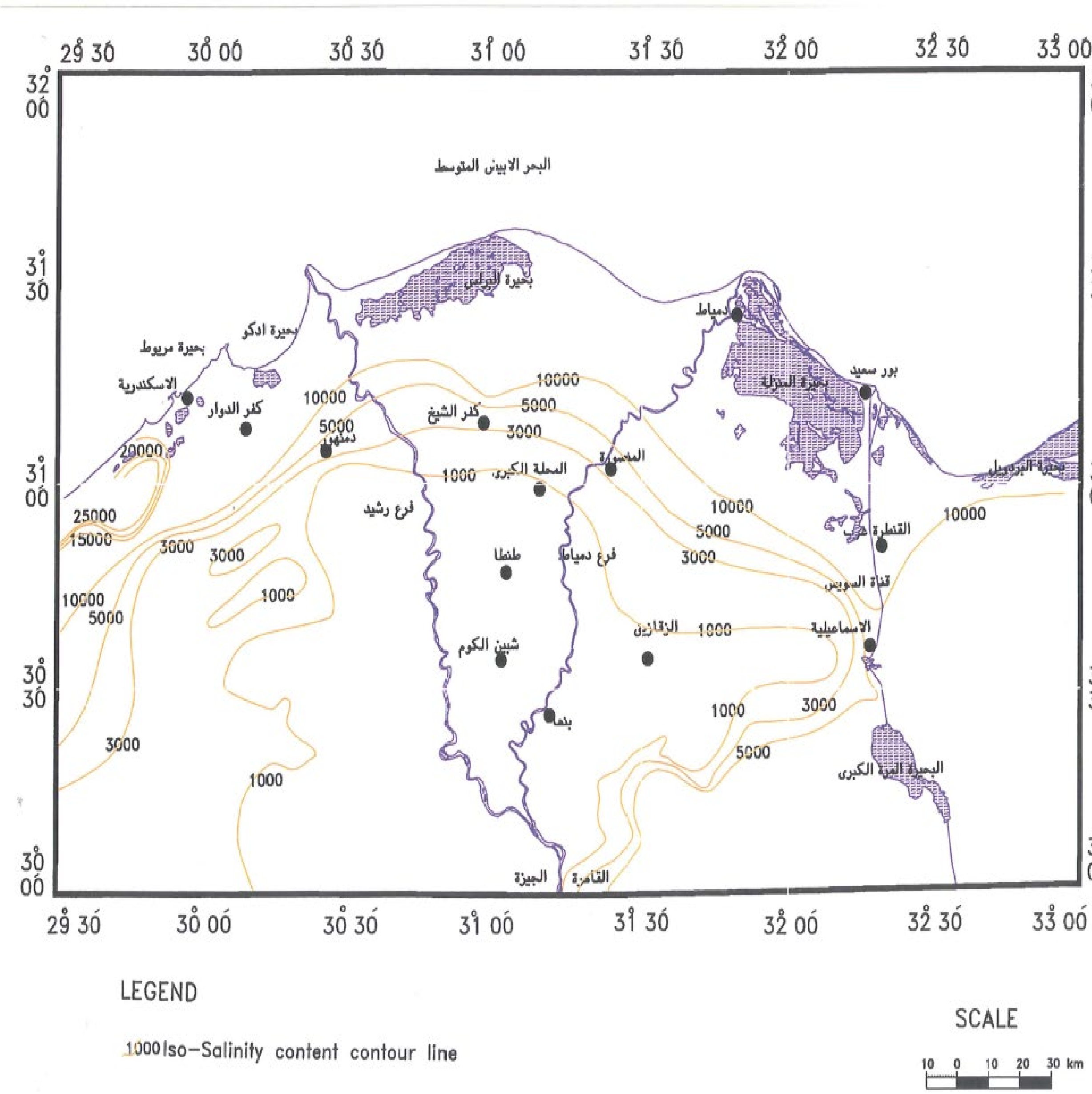


Figure 14: TDS in ppm in the Delta Area [11]

4.7 LITHOLOGICAL CHARACTERISTICS

The alluvial plain areas are identified with a typical soil formation of agriculture silty clay layer at top with a thickness 0.5-2 m, then a silty clay hard layer with average depth of 9 m followed by sandy soil up to 25 m and more, depending on the location. The groundwater level is ranging from 0.1 to 6 m below ground level (bgl) and reaches 8 m bgl in Aswan.

4.8 WATER SUPPLY THREATS

In Egypt, water supply based on the River Nile as surface water source is suffering in some cases from water pollution events and low water levels. The Nile water level sometimes is lower than the considered one during the design of the intake structures of surface water treatment plants. In such cases, the water supply stops which is a real threat to any community. In case of high turbidity of Nile water some surface water treatment units are overloaded and have to be taken out of operation for a few days. At some locations oil spills are observed affecting appropriate surface water treatment using conventional methods. Accordingly, having a backup water supply which cannot be affected with such threats like RBF will help to avoid such situation which happens from time to time, or seasonally.

Water pollution comes from many sources including pesticides and fertilizers that wash away from farms, untreated human wastewater, sudden oil spills and industrial waste. Even groundwater is not safe from pollution, as many pollutants can leach into underground aquifers. Some effects are immediate, as when harmful bacteria from human waste contaminate water and make it unfit to drink or swim in. In other instances—such as toxic substances from industrial processes—it may take years to build up in the environment and food chain before their effects are fully recognized.

Climate change effects are also affecting water management in Egypt. Droughts will become more common in some places, floods in others. Construction of new dams in the catchment of the River Nile may compensate some changes if the management of storage and release of water will be organized to take into account interests of all users.

From previous reports produced by HCWW concerning experienced threats for water supply schemes based on surface water sources, major threats are briefly described below.

Sudden unexpected Pollution

Since the River Nile is used for transportation of products such as phosphates, oil, and pesticides, occasionally happening accidents pose a risk for water supply. Pollutants might be released to the Nile water affecting surface water quality and shut down of all downstream water treatment plant intakes. In such cases the water supply to the related served communities is completely stopped until removing the reason of the threat.

Severe unusual Climate Conditions

Heavy rainfall hardly affected the Upper Egypt region in 2014-2016 and the floods were hydrodynamically directed toward the valley and River Nile. The Nile water turbidity level was highly affected and reached up to 100 NTU during the heavy rain times and continued for a few days. Such high level of turbidity disturbed dramatically the operation of the surface water treatment plants (SWTP) for at least 72 to 100 hours.

Silting

Sedimentation of deposits along the shore of the Nile River causes operation problems for the SWTP intakes and deteriorate raw water quality. Moreover, such silting might prevent water to reach the intake pipes either due to accumulation of deposits or due to low water level, especially in winter.

High Water Demand

High water demand is mainly due to two main factors:

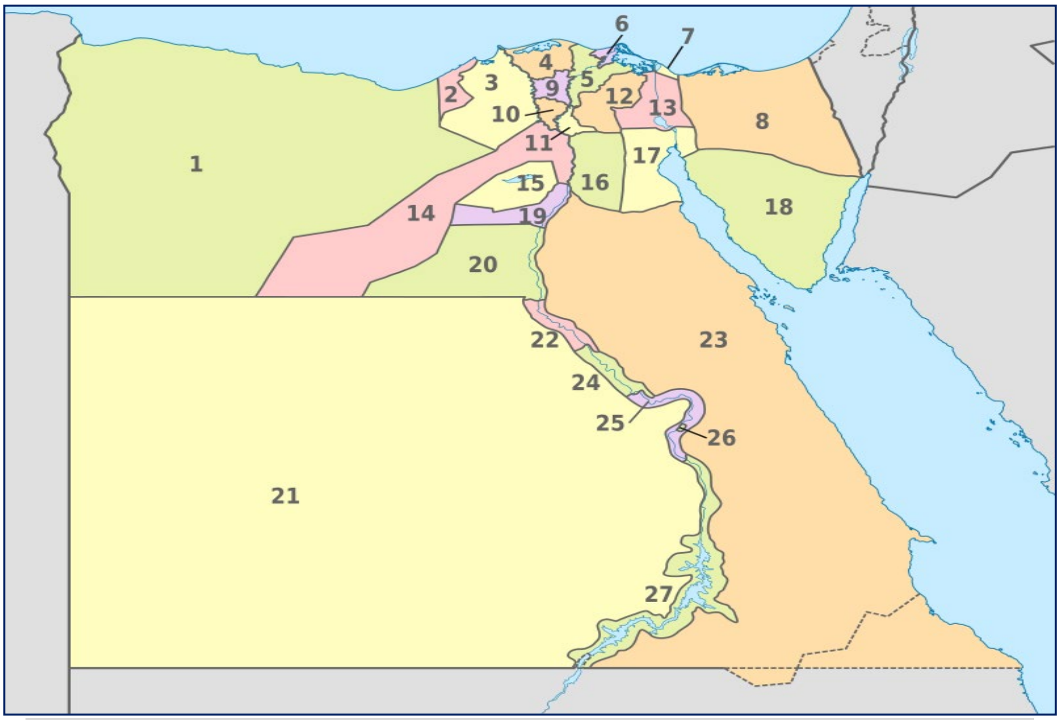
1- The population growth has been increasing rapidly over the last few years which means an extension of existing urban and rural areas. The water demand increases accordingly which leads to rapid reduction in specific water availability reaching below 500 m^3 per capita by the year 2025.

2- Groundwater deterioration: due to the fact that most of GW aquifers, away from the Nile main stream, in Upper Egypt suffer from high concentration of iron and manganese, the only solution to this problem is either to install iron and manganese removal plants or to stop using such groundwater. Another factor affecting groundwater quality is the lack of sanitation services in rural areas leading to potential risk of polluting groundwater in those areas.

5. APPLICATION OF THE PROPOSED SELECTION METHODOLOGY - STEP 1: POTENTIAL RIVER BASIN LEVEL, ATTEMPTS TO IDENTIFY THE RBF POTENTIAL AREAS IN THE RIVER NILE BASIN - REGIONAL SCALE

The proposed selection methodology has been applied as described in section 3. Three steps on different scales are applied. The following sections provide the results of application of the selection methodology on river basin scale, then on regional area scale, and finally on site location scale.

The map of Egypt in Figure 15 shows the location and border limits of each governorate. This map will help in the selection process of potential governorates based on the proposed criteria of Step-1 indicated in section 3. This has been developed by overlaying with other maps presented earlier indicating the selection criteria as specified above. It should be noted that, at this stage, failure to meet a single criterion is enough to exclude the concerned governorate.



1- Matrouh	8- N Sinai	15- Fayoum	22- Assiut
2- Alexandria	9- Gharbeya	16- Cairo	23- Red Sea
3- Beheira	10- Menoufeya	17- Suez	24- Sohag
4- Kafr Al Sheikh	11- Qalubeya	18- S Sinai	25- Qena
5- Daqahleya	12- Sharqeya	19- Beni Suif	26- Luxor
6- Damietta	13- Isamailia	20- Minya	27- Aswan
7- Port Said	14- Giza	21- New Valley	

Figure 15: Governorates of Egypt

Based on the above-mentioned survey and the related investigated data from previous studies regarding the geological, hydrogeological, and hydrology aspects as well as other indicated criteria, the following can be concluded: Main Selection criteria are: Quaternary Geology, Young Alluvial Plains, TDS

<500 ppm, and being on the main stream of the Nile River. Accordingly, Table 5 is concluded from Step-1 to select the potential areas based on the river basin scale categorised by governorates.

Table 5: Selection matrix of governorates having high potential for RBF

#	Governorate	Criterion 1 Quaternary Geology [11]	Criterion 2 Hydrogeology (Alluvial Plain and GW TDS <500 ppm) [11]	Criterion 3 Hydrology (Main River Basin) [11]	Selection
1	Matrouh	x	x-x	x	x
2	Alexandria	√	√-x	x	x
3	Beheira	√	√-x	√	x
4	K Al Sheikh	√	√-x	√	x
5	Daqahleya	√	√-x	√	x
6	Damietta	√	√-x	√	x
7	Port Said	x	x-x	x	x
8	N Sinai	x	x-x	x	x
9	Gharbeya*	√	√-x	√	2nd priority
10	Menoufeya*	√	√-x	√	2nd priority
11	Qalubeya*	√	√-x	√	2nd priority
12	Sharqeya	√	√-x	x	x
13	Ismailia	x	x-x	x	x
14	Giza	√	√-√	√	√
15	Fayoum	√	√-x	x	x
16	Cairo	√	√-√	√	√
17	Suez	x	x-x	x	X
18	S Sinai	x	x-x	x	X
19	B. Suif	√	√-√	√	√
20	Minya	√	√-√	√	√
21	New Valley	x	x-x	x	X
22	Assiut	√	√-√	√	√
23	Red Sea	x	x-x	x	X
24	Sohag	√	√-√	√	√
25	Qena	√	√-√	√	√
26	Luxor	√	√-√	√	√
27	Aswan	√	√-√	√	√

* TDS levels more than 500 ppm but less than 1000 ppm

Based on the above selection matrix, there is a clear potential for RBF on the river basin scale in the Nile valley governorates from Aswan to Giza and partially for Cairo. It is important to indicate that certain areas in those governorates will be reconsidered and assessed in more detail on the level of the area and then on the site level to finally conclude the final feasibility of RBF. As for Qalubeya, Gharbeya, and Menoufeya governorates, although they have access to the main stream in some districts, the potential is considered as second priority due to high TDS levels in groundwater.

6. POTENTIAL RBF AREAS BASED ON AREA LOCAL SCALE LEVEL AND POTENTIAL SITE LEVEL (STEPS 2 AND 3)

In this part, step 2 of the proposed selection methodology has been performed in order to select the most eligible areas on the level of the governorate level. Based on the river basin selection criteria the Nile valley zone was identified as more eligible and suitable than the Delta zone. Moreover, Cairo governorate was excluded due to the urban structure of Cairo community rather than rural which encourage reliance on main SWTP dealing with complex water distribution system. Following the proposed procedures of selection, the following governorates were identified to have more potential for RBF. Eight governorates along the Nile valley from Aswan to Giza are selected based on data presented in Table 5.

1- Aswan
2- Luxor
3- Qena
4- Sohag
5- Assiut
6- Minya
7- Beni Suif
8- Giza

The following sections will study and address the RBF potential districts (Markaz) in each of the eligible governorates identified above. Moreover, potential locations will be also identified based on the information provided by the concerned water company. It is important to indicate that no site investigations have been done during this study. The available collected data and investigated literature and studies plus accumulated experiences as well as the need assessment provided by each water company form the main basis of developing this study.

<u>Due to the fact that both Steps 2 and 3 are related geographically to the same area or governorate, it is proposed to present the two selection steps to be governorate specific in order to avoid text interruption and for the ease of following the selection results for each governorate. i.e. for each affiliated water company.</u>

It should be noted that the indicated lists for each governorate resulting from step 3 are considered preliminary lists. Before starting any sort of construction, site specific detailed technical studies would be needed. **It is important to indicate that those detailed studies are beyond the scope of current study**. The detailed technical studies should include the following:

- **Preliminary assessment of site**: Potential sources of seasonal pollution of the River Nile, groundwater characteristics, and site specific lithological description

- **Site specific hydrogeological studies**: Hydraulic seepage line between the river and the GW at the selected site, water current velocity, water quality parameters (physico-chemical and biological), and bottom sediments characterisation.
- **Design and implementation of test well**: detailed soil formation, grain size analysis, coefficient of soil permeability, distance between the river and the test well.
- **Design and construction of production well(s):** based on the results of the test well, production well will be designed in detail including all components (screens, pumps, pipes), as well as connection to the existing water distribution system.

6.1 POTENTIAL RBF AREAS / SITES IN ASWAN GOVERNORATE

6.1.1 BACKGROUND INFORMATION

Location: 879 km south to Cairo (Figure 16)

Agricultural Area extent: 2-16 km

Length along the River Nile: 140 km

Population: 1,431,488 (42% urban)

No of districts (Markaz) 5 (The Nile passes through 2 of them and 3 of them by western side of the Nile), Named: Al-Sabaiya, Edfu, Kom-Ombo, Naser, and Aswan.

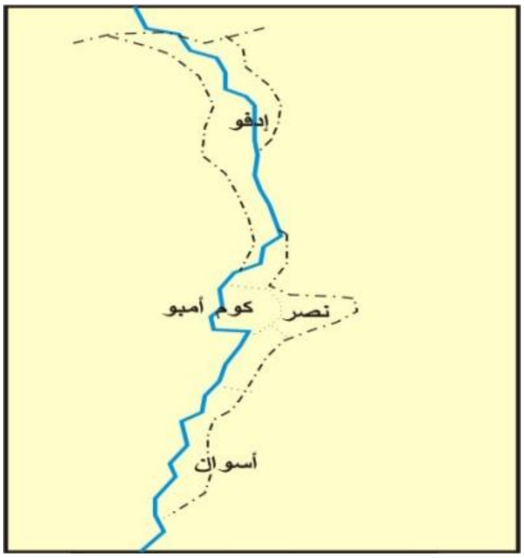


Figure 16: Location map of Aswan Governorate

6.1.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Total water production capacity of water supplies in Aswan Governorate is @ 500000 m^3/day where about 50000 m^3/day are considered as water shortage. Such water shortage is mainly in Aswan, Edfu, and Kom-Ombo, as reported by Aswan water company.

6.1.3 GEOLOGY AND HYDROLOGY - ASWAN

Based on the proposed methodology for area / site selection, and Figures 17 and 18, the following conclusions could be made based on the geology and hydrology of Aswan:

- Only in Al-Sabaaiya and Edfu districts, western side areas with respect to the River Nile main stream is a very good potential area for the RBF in terms of geological, hydrogeological, and geotechnical aspects.

- As for the eastern side, only Kom-Ombo, Al-Sabaaiya (east), and Edfu (east) have good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters, except Aswan and Naser districts.

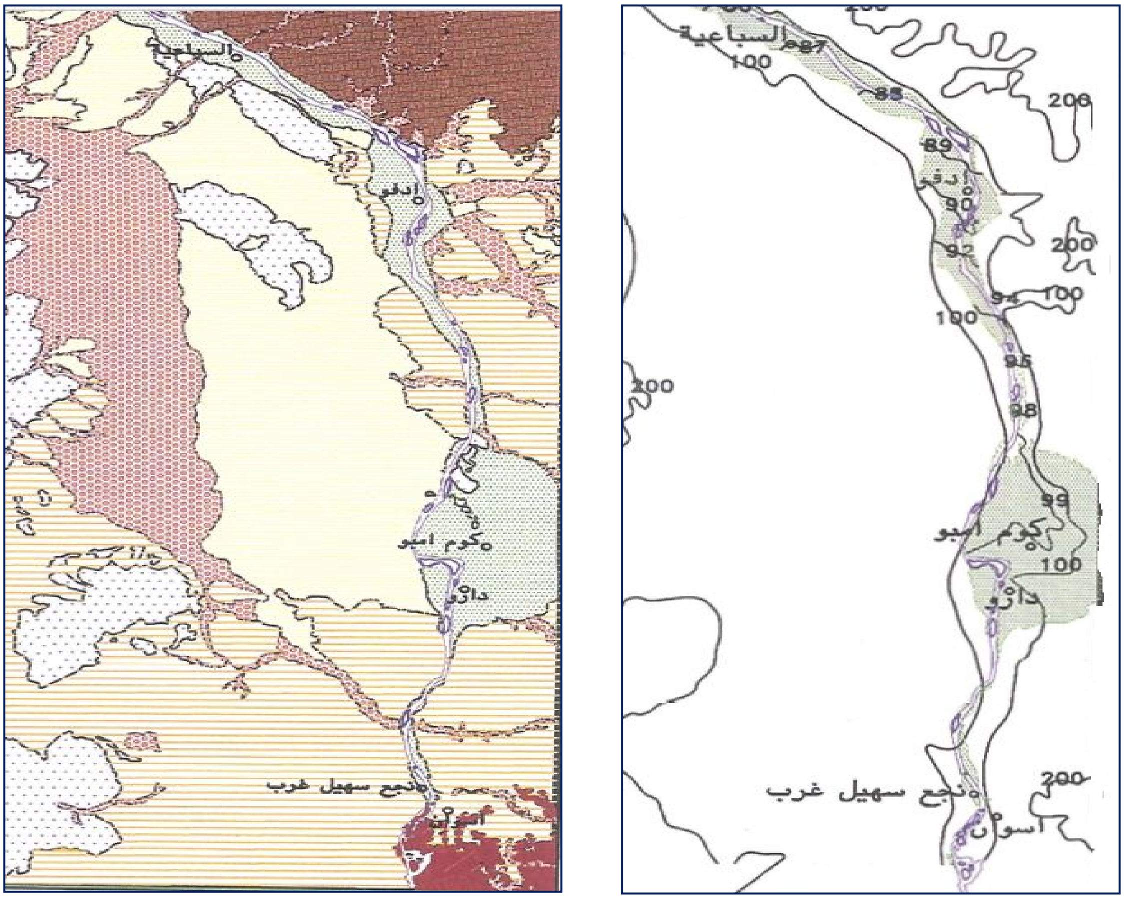


Figure 17: left: Alluvial Plain of Aswan, right: Topography of Aswan

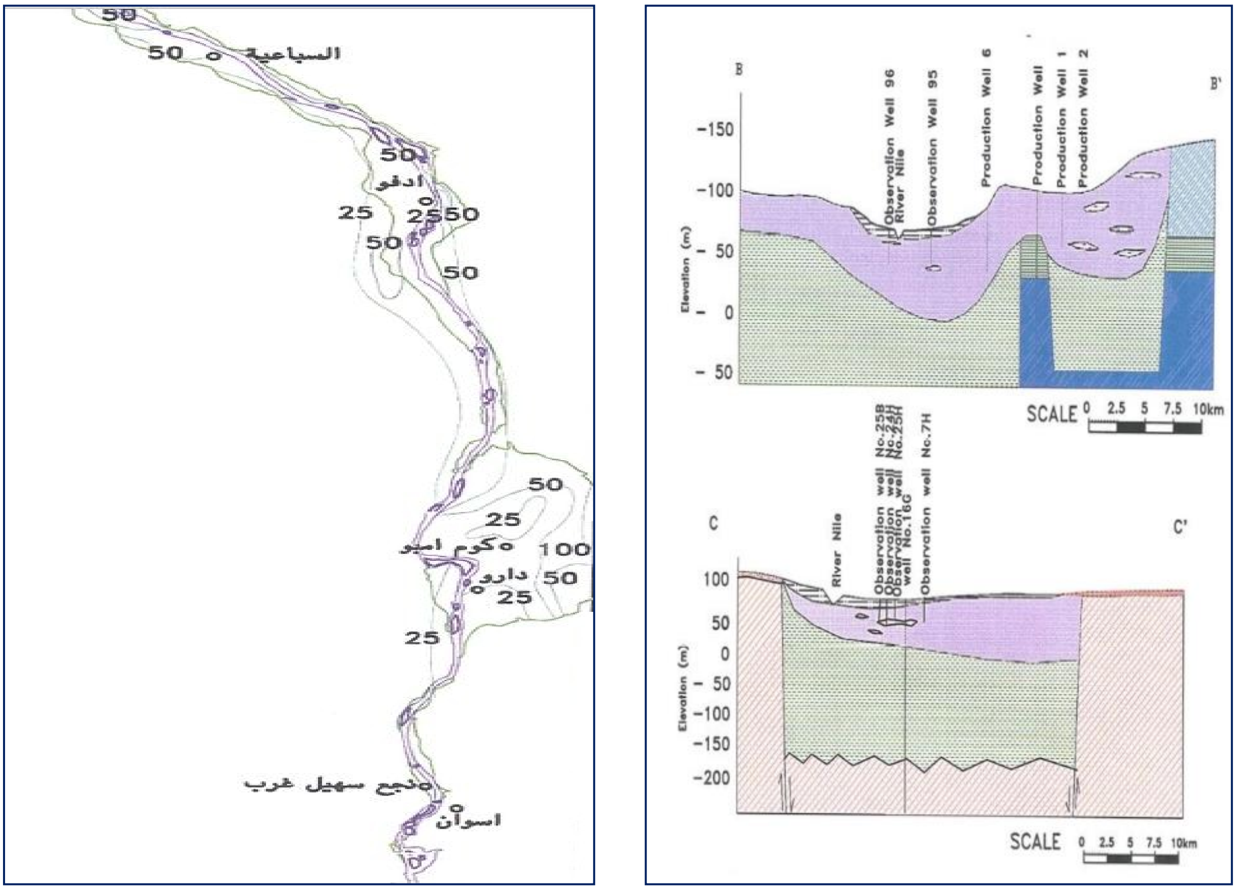


Figure 18: Aquifer depth and Extent in Aswan Governorate [11]

6.1.4 LITHOLOGICAL DESCRIPTION - ASWAN

Figure 19 indicates the areas where the lithological description is convenient for the RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 19, it is possible to conclude the following:

- The western and eastern parts of Al-Sabaaiya and Edfu Markaz are eligible in terms of lithological formation.
- Kom-Ombo district is only eligible for the eastern part.
- Aswan has no potential for RBF.

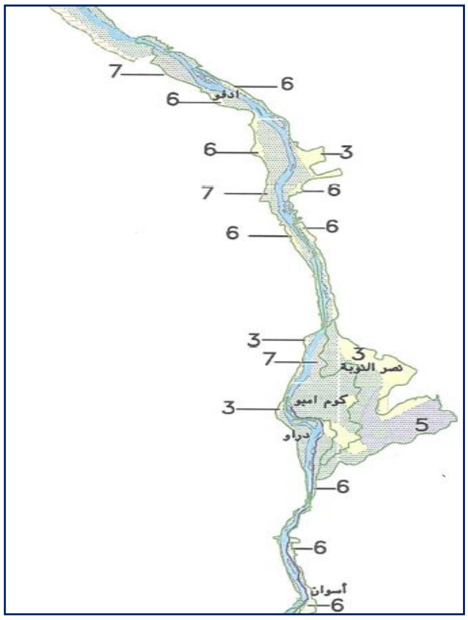


Figure 19: Lithological zoning of Aswan Governorate districts [11]

6.1.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - ASWAN

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Aswan Governorate on the district level is indicated in Table 6.

Table 6: Selection matrix of potential districts for RBF – Aswan

#	District	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality - Urgent Water Need	Selection
1	Edfo	√	√	√-√	√
2	Al-Sabaaiya	√	√	√-x	2nd priority
3	Kom Ombo	√	√	√-√	√
4	Aswan	√	x	√-√	x
5	Nasr AlNoba	x	√	√-x	x

Based on the applied criteria in Table 6, it is concluded that only sites related to Edfu and Kom Obmo have good potential for RBF. Other districts are excluded due to the following reasons:

1- Al-Sabaaiya: No water shortage
2- Aswan: Lithological reasons
3- Nasr AlNoba: Not located on the Nile main stream

6.1.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF - ASWAN

Based on the selection matrix indicated in Table 6, the following results could be concluded:

- Apart from Nasr AlNoba district case, where its location is not eligible, the only prevailing parameter is then the water need assessment at each district to provide RBF facilities in those areas, and Aswan due to lithological reasons. Based on water need assessment provided by Aswan Water Company, it is concluded that mainly two districts will be suffering from water shortage in near future. These districts are Kom Ombo and Edfo.
- Accordingly, and based on the preliminary list received from Aswan governorate the potential RBF sites, indicated in Table 7, were identified for further detailed investigation in terms of soil conditions and GW quality assessment. It is important to indicate that Aswan Water Company list included some other areas which have not been selected (in Table 6. However, these locations could be included later as second priority when water shortage will be observed. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low.

Table 7: Potential sites for RBF - Aswan Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeolo gy (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selection
1	Kom Ombo	Al Tewesa	√	√	√-√	√	√
2	Aswan	Al-Shalal	√	X	√-√	√	x
3		Abo El-Resh	√	x	√-√	√	x
4	Edfo	Al-Hasaya	√	√	√-√	√	√
5		Wady El-Saayda	√	√	√-√	√	√

6.1.7 FINAL LIST OF IDENTIFIED RBF UNITS - ASWAN

Based on the selection process applied on the site level as indicated in Table 7, the final list of sites has been developed in order to be investigated in terms of field measures. Based on the availability of land and the current shortage in water supply, the number of RBF wells are identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 8 shows the proposed number of RBF wells and capacitiesfor each eligible location.

Table 8: Potential sites for RBF units – Aswan Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Kom Ombo	Al Tewesa	3	90
2	Aswan	Al-Shalal	--	--
3		Abo El-Resh	--	--
4	Edfo	Al-Hasaya	3	90
5		Wady El-Saayda	3	90
	Total		**9**	**270**

Figure 20 provides a map of potential RBF sites in Aswan Governorate, as presented by Aswan Water and Wastewater Company.

 Location of potential RBF sites - Aswan Governorates

Figure 20: Potential sites for RBF - Aswan [12]

6.2 POTENTIAL RBF AREAS / SITES IN LUXOR GOVERNORATE

6.2.1 BACKGROUND INFORMATION

Location: 635 km south to Cairo (Figure 21)

Agricultural Area extent: 2-10 km

Length along the River Nile: 110 km

Population: 1,147,058 (37.8% urban)

No of districts (Markaz) 7 (4 located on the eastern side of the Nile and 3 on the western side). These districts are: East Side: Al-Zainia, Luxor city, Al-Baiadeya, and Al-Tod; West side: Al-Qarana, Armant, and Esna.

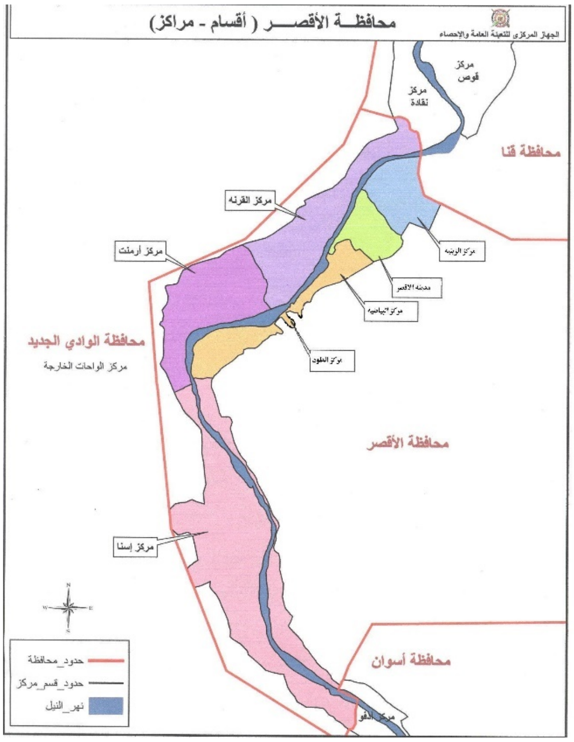


Figure 21: Location map of Luxor Governorate [13]

6.2.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Based on the information provided from Luxor Water Company, it was indicated that Luxor governorate is suffering from water supply shortages in different locations. Such shortage mainly exists in 4 districts: Luxor, Al-Tod, Armant, and Esna.

6.2.3 GEOLOGY AND HYDROLOGY - LUXOR

Based on the proposed methodology for area / site selection, and Figures 22 & 23, the following conclusions could be made based on the geology and hydrology of Luxor:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- Also, the eastern side districts have good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters.

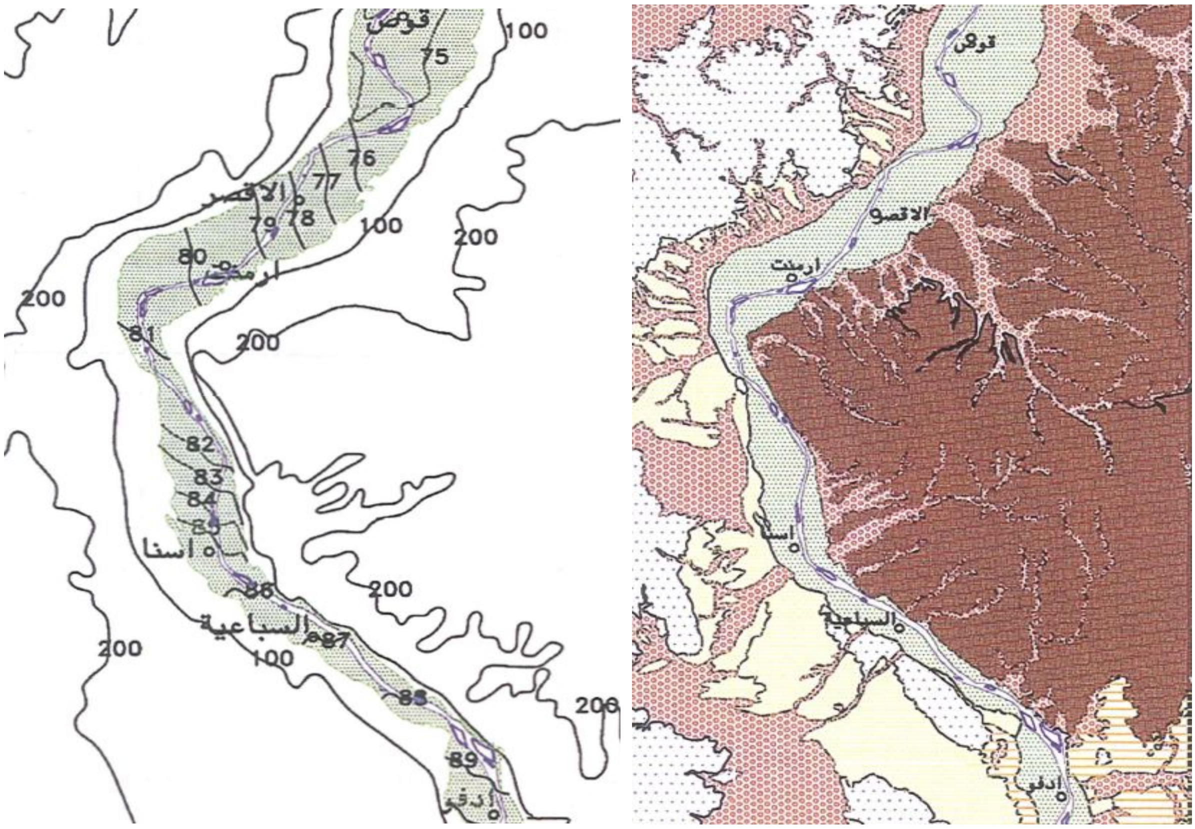


Figure 22: left: Alluvial Plain of Luxor, right: Topography of Luxor [11]

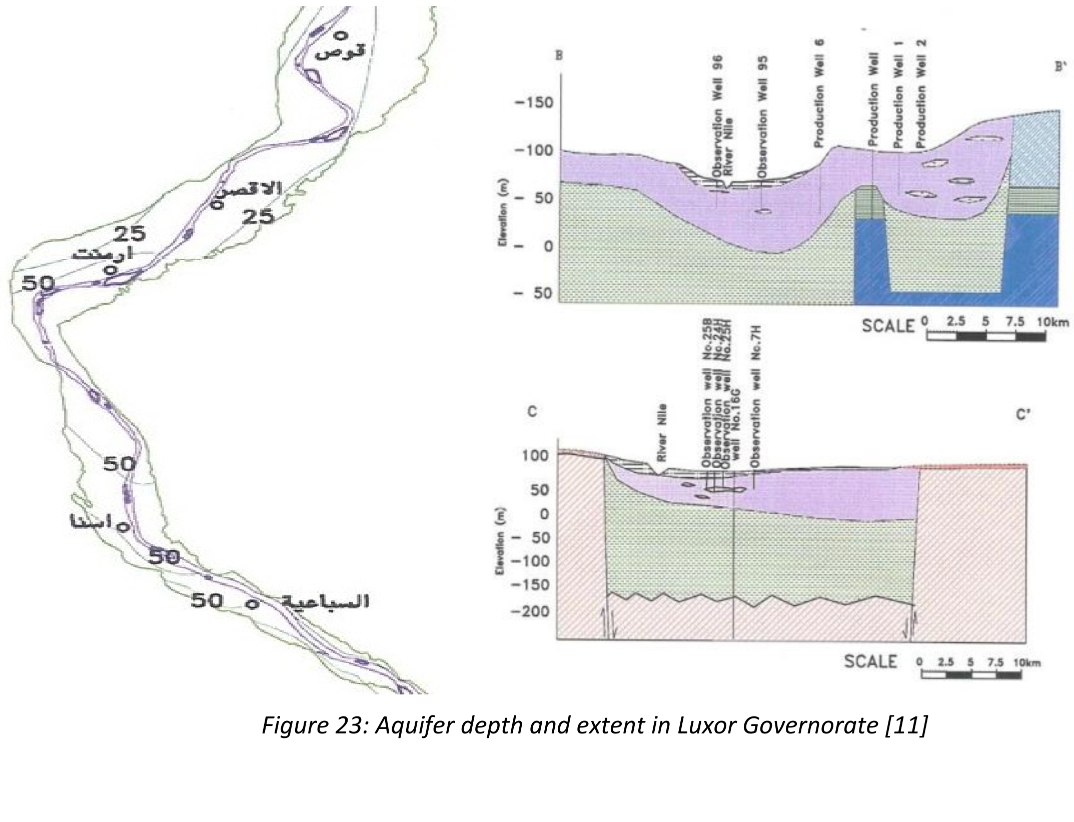


Figure 23: Aquifer depth and extent in Luxor Governorate [11]

6.2.4 LITHOLOGICAL DESCRIPTION - LUXOR

Figure 24 indicates the areas where the lithological description is convenient for the RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 24, it is possible to conclude the following:

- The western part of all Markaz is eligible in terms of lithological formation.
- Some areas on the eastern part are eligible

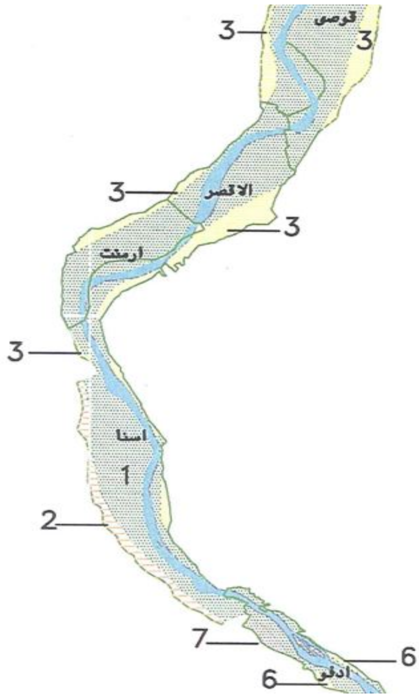


Figure 24: Lithological zoning of Luxor Governorate districts [11]

6.2.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - LUXOR

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Luxor Governorate on the district level is indicated in Table 9.

Table 9: Selection matrix of potential districts for RBF - Luxor

#	District (Markaz)	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality- Urgent Water Need	Selection
1	Al Zaineya	√	√	√-x	Less priority
2	Luxor	√	√	√-√	√
3	Esna	√	√	√-√	√
4	Al Bayadeya	√	√	√-x	Less priority
5	Al Tod	√	√	√-√	√
6	Armant	√	√	√-√	√
7	Luxor (Al-Karanak)	√	√	√-√	√

Based on the applied criteria in Table 9, it is concluded that all districts have a more or less positive potential for RBF application. Excluding the water need criterion, all 7 districts have good potential for RBF implementation.

6.2.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF - LUXOR

Based on the selection matrix indicated in Table 9, the following results could be concluded:

- The only prevailing parameter is the water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Luxor Water Company, it is concluded that mainly five districts will be suffering from water shortage in near future. These districts are: Luxor, Esna, Al-Tod, Armant, Luxor (Al-Karanak).
- Accordingly, and based on the preliminary list received from Luxor Water Company, the potential RBF sites indicated in Table 10, were identified for further detailed investigation in terms of soil conditions and GW quality assessment. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low. Figure (23) provides an illustrative map for the potential RBF sites in Luxor Governorates, as presented by Luxor Water and WW Company.

Table 10: Potential sites for RBF – Luxor Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeolo gy (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selecti on
1	Luxor	Luxor Gharbeya- S	√	√	√-√	√	√
2	Al Tod	Al-Tod CU	√	√	√-√	√	√
3		Al-Odaysat-CU	√	x	√-√	√	x
4		Nagaa Khames-CU	√	x	√-√	√	x
5	Esna	Al-Wehda CU	√	√	√-√	√	√
6		Al-Admaya CU	√	√	√-√	√	√
7		Al-Hanady CU	√	√	√-√	√	√
8		Al-Gharera Cu	√	√	√-√	√	√
9		Al-Der CU	√	√	√-√	√	√
10		Al-Dbayba CU	√	√	√-√	√	√
11	Armant	Gezeret Armant CU	√	√	√-√	√	√
12		Armant CU	√	√	√-√	√	√
13	El-Karanak	Al Boayrat- CU	√	√	√-√	√	√
14		Al Akalta- CU	√	√	√-√	√	√

6.2.7 FINAL LIST OF IDENTIFIED RBF UNITS - LUXOR

Based on the selection process applied on the site level as indicated in Table 10, the final list of sites has been developed in order to be investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells is identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 11 indicates the final list of identified RBF units for each eligible location.

Table 11: Potential sites for RBF units – Luxor Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Luxor	Luxor Gharbeya- S	2	60
2	Al Tod	Al-Tod CU	1	30
3	Esna	Al-Wehda CU	1	30
4		Al-Admaya CU	1	30
5		Al-Hanady CU	1	30
6		Al-Gharera Cu	1	30
7		Al-Der CU	1	30
8		Al-Dbayba CU	1	30
9	Armant	Gezeret Armant CU	1	30
10		Armant CU	2	60
11	Luxor (El-	Al Boayrat - CU	1	30
12	Karanak)	Al Akalta - CU	1	30
	Total		**14**	**420**

Figure 25 provides a map of potential RBF sites in Aswan Governorates, as presented by Aswan Water and Wastewater Company.

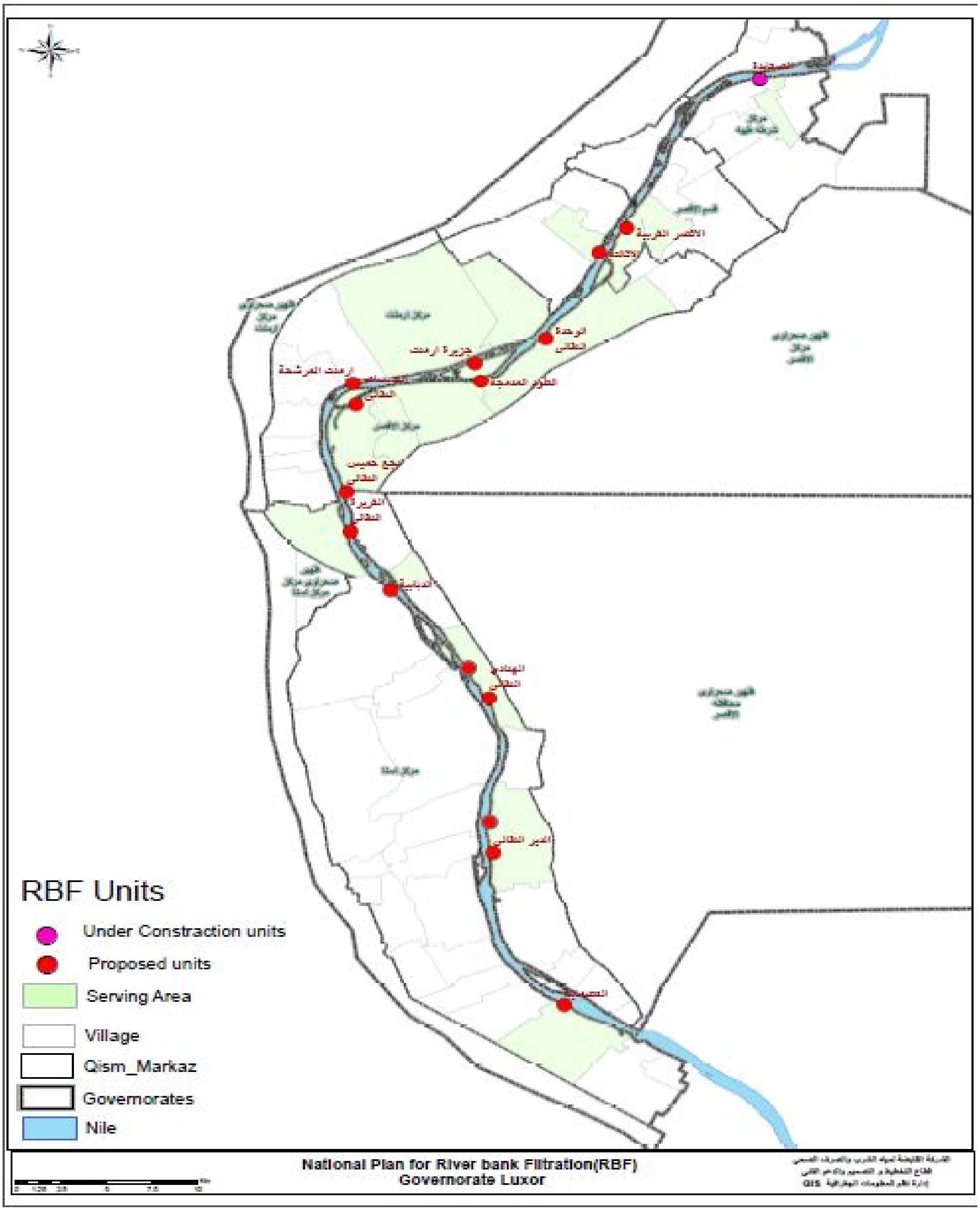


Figure 25: Potential sites for RBF units - Luxor [13]

6.3 POTENTIAL RBF AREAS / SITES IN QENA GOVERNORATE

6.3.1 BACKGROUND INFORMATION

Location: 600 km south to Cairo (Figure 26)

Agricultural Area extent: 2.5-18 km

Length along the River Nile: 180 km

Population: 2,657,669 (17% urban)

No of districts (Markaz) 9 (The Nile passes through 8 of them and 6 of them by western side of the Nile and 3 at the east side), Farshoout Markaz has no access to the Nile at its boundaries.

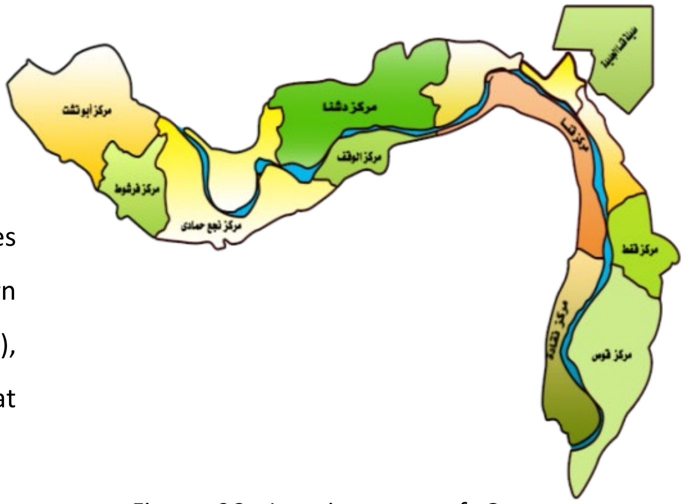


Figure 26: Location map of Qena Governorate

6.3.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Based on the information provided from Qena Water Company, it was indicated that Qena governorate is suffering from water supply shortages in different locations. Such shortage mainly exists in 6 districts: Nagaa Hamadi, Deshna, Qena, Qeft, Al-Waqf, and Qos.

6.3.3 GEOLOGY AND HYDROLOGY - QENA

Based on the proposed methodology for area / site selection, and Figures 27 & 28, the following conclusions could be made based on the geology and hydrology of Qena:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- Also, the eastern side has very good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters, except Farshout.

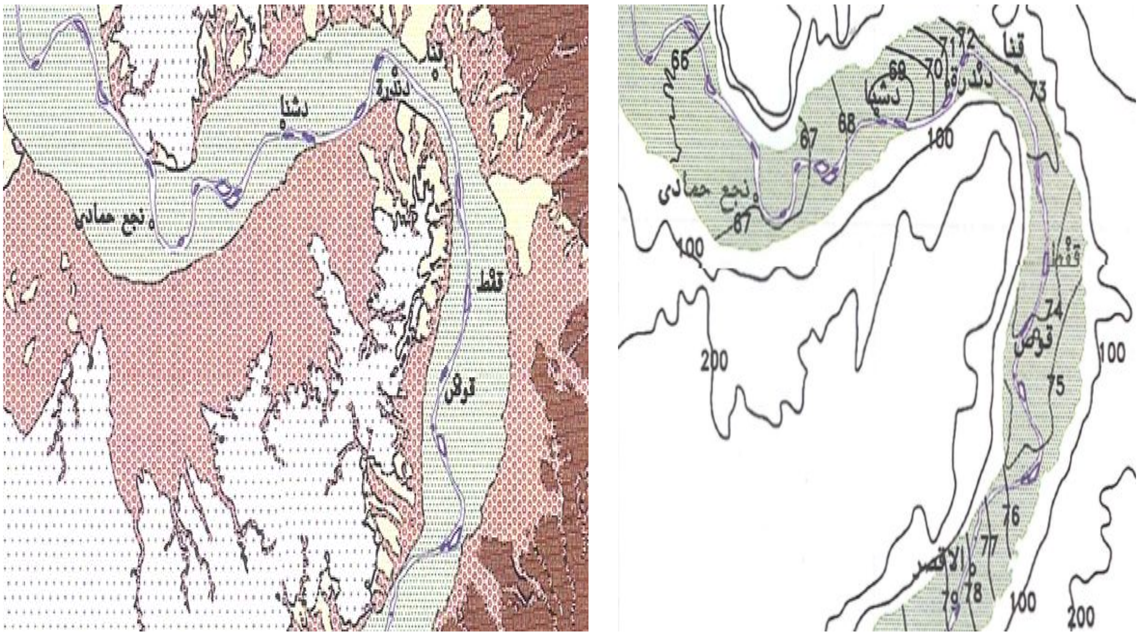


Figure 27: left: Alluvial Plain of Qena, right: Topography of Qena [11]

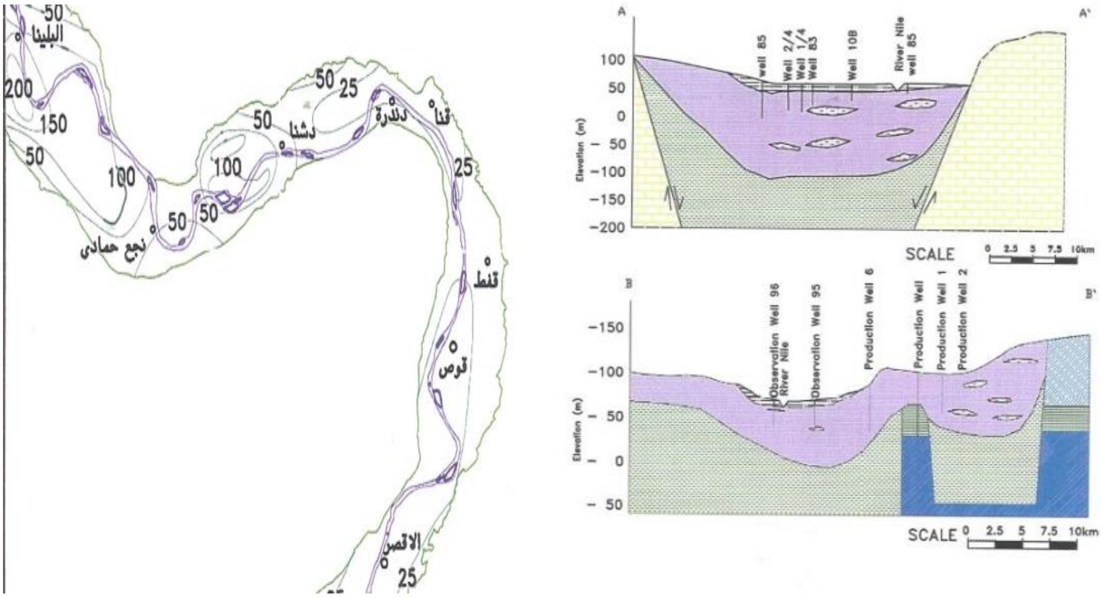


Figure 28:Aquifer depth and extent in Qena Governorate [11]

6.3.4 LITHOLOGICAL DESCRIPTION - QENA

Figure 29 indicates the areas where the lithological description is convenient for the RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 29, it is possible to conclude the following:

- The western parts of all Markaz are eligible in terms of lithological formation.
- Most of the eastern part is eligible.

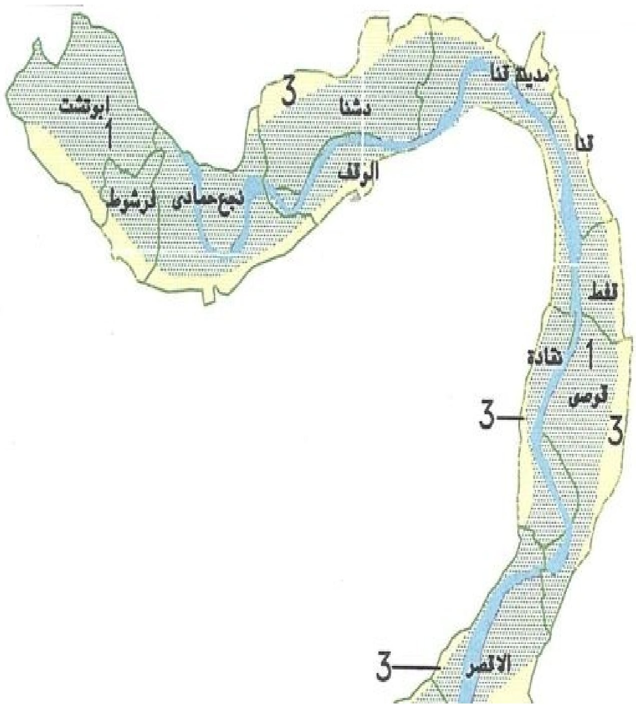


Figure 29: Lithological zoning of Qena Governorate districts [11]

6.3.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - QENA

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Qena Governorate on the district level is indicated in Table 12.

Table 12: Selection matrix of potential districts for RBF- Qena

#	District (Markaz)	Criterion 1 River Flow- Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality - Urgent Water Need	Selection
1	Abo Tesht	√	√	√-x	Less priority
2	Farshout	x	√	√-x	Less priority
3	Nagaa Hamady	√	√	√-√	√
4	Deshna	√	√	√-√	√
5	Qena	√	√	√-√	√
6	Qeft	√	√	√-√	√
7	Al-Waqf	√	√	√-√	√
8	Qos	√	√	√-√	√
9	Nakada	√	√	√-x	Less priority

Based on the applied criteria in Table 12, it is concluded that half the districts have a positive potential for RBF application. Excluding the water need criterion, 6 out of 9 districts, have good potential for RBF implementation.

6.3.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF- QENA

Based on the selection matrix indicated in Table 12, the following results could be concluded:

- The only prevailing parameter is water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Qena Water Company, it is concluded that mainly six districts will be suffering from water shortage in near future. These districts are: Nagaa Hamady, Deshna, Qena, Qeft, Al-Waqf, and Qos.
- Accordingly, and based on the preliminary list received from Qena governorate the following potential RBF sites, indicated in Table 13, were identified for further detailed investigation in terms of soil conditions and GW quality assessment. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low. Figure (27) provide an illustrative map for the potential RBF sites in Qena Governorates, as presented by Qena Water and Wastewater Company.

Table 13: Potential sites for RBF- Qena Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeology (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selection
1	Qena	Al-Tawabeya-CU	√	√	√-√	√	√
2		Nagaa AlDom-S	√	√	√-√	√	√
3		Al-Kanaweya-CU	√	√	√-√	√	√
4	Al Waqf	Al Hamody-S	√	√	√-√	√	√
5	Qeft	Kaft-S	√	√	√-√	√	√
6	Qos	Kos-S	√	√	√-√	√	√
7	Nagaa Hamady	Nagaa Salem-S	√	√	√-√	√	√
8		Nagaa Hamady-S	√	√	√-√	√	√
9		Alkasr & Alsayad CU	√	√	√-√	√	√
10	Deshna	Al-Helfaya K-CU	√	√	√-√	√	√
11		Al-Samata-CU	√	√	√-√	√	√
12		Fawe B-Compact	√	√	√-√	√	√

6.3.7 FINAL LIST OF IDENTIFIED RBF UNITS - QENA

Based on the selection process applied on the site level as indicated in Table 13, the final list of projects has been developed in order to be deeply investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells are identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 14 indicates the final list of identified RBF units for each eligible location.

Table 14: Potential sites for RBF units - Qena Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Qena	Al-Tawabeya-CU	1	30
2		Nagaa Al-Dom-S	2	60
3		Al-Kanaweya-CU	1	30
4	Al Waqf	Al Hamody-S	1	30
5	Qeft	Kaft-S	1	30
6	Qos	Kos-S	1	30
7	Nagaa Hamady	Nagaa Salem-S	2	60
8		Nagaa Hamady-S	1	30
9		Alkasr & Alsayad CU	1	30
10	Deshna	Al-Helfaya K-CU	1	30
11		Al-Samata-CU	1	30
12		Fawe B-Compact	1	30
	Total		**14**	**420**

Figure 30 provides a map of potential RBF sites in Qena Governorate, as presented by Qena Water and WW Company.

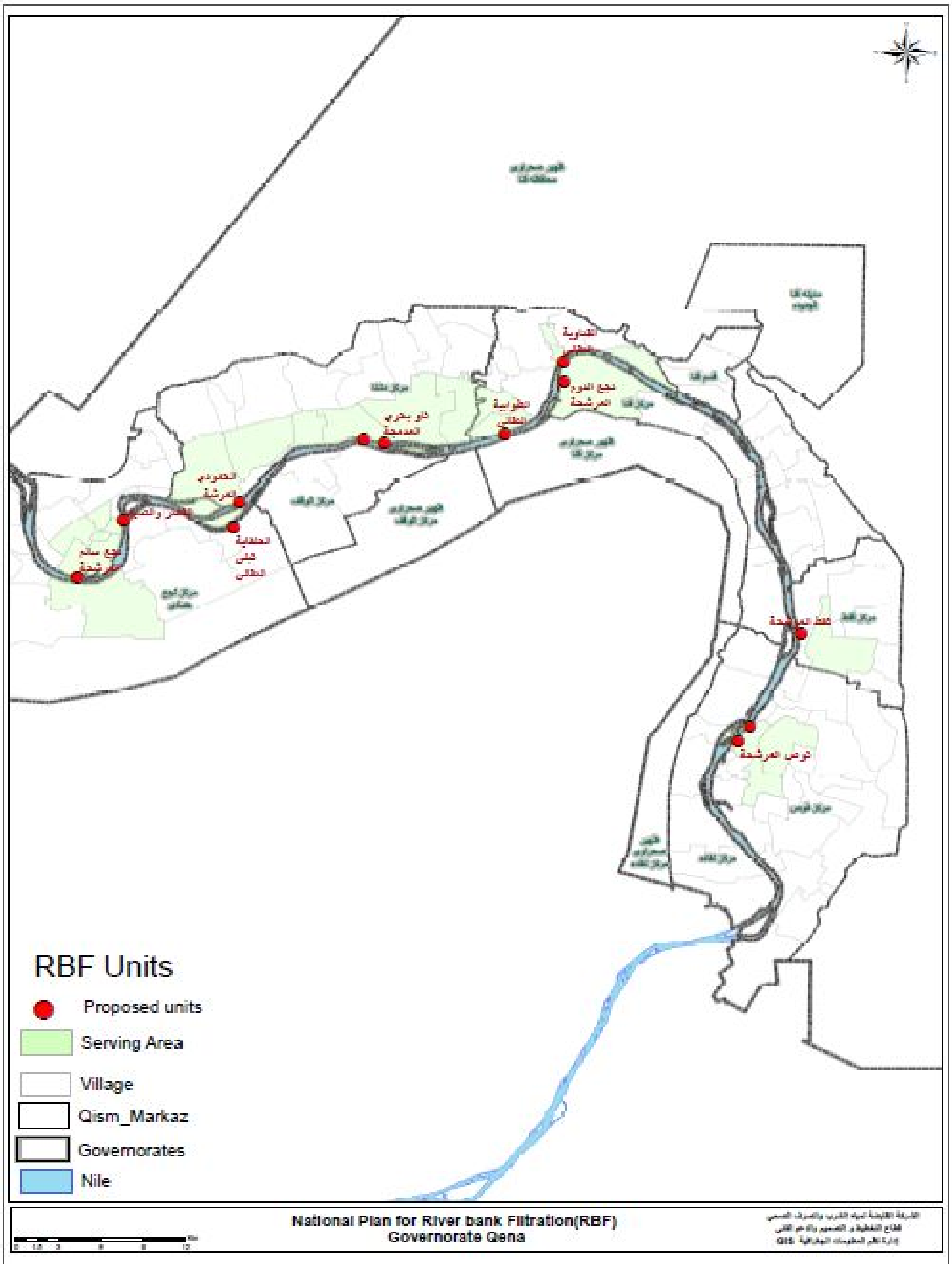


Figure 30: Potential sites for RBF units – Qena [13]

6.4 POTENTIAL RBF AREAS / SITES IN SOHAG GOVERNORATE

6.4.1 BACKGROUND INFORMATION

Location: 470 km south to Cairo (Figure 31)

Agricultural area extent: 15-21 km

Length along the River Nile: 120 km

Population: 4,600,000 (21% urban)

No of districts (Markaz) 11 (3 located on the eastern side of the Nile and 8 on the western side)

Figure 31: Location map of Sohag Governorate

6.4.2 WATER SUPPLY FACILITIES AND WATER BALANCE

The number of conventional SWTP is 11 producing about 0.314 Mm^3/day. Moreover, there are 52 compact unit SWTP with a total production of 0.118 Mm^3/day. In addition, there are 198 GWTP with a production capacity of 0.327 Mm^3/day. Total overall water production capacity is 759,000 m^3/day.

Although the calculated per capita average water consumption is about 165 LPCD, Sohag, like most of Upper Egypt governorates, is suffering from unbalanced distribution of production facilities which lead to shortage in some areas and surplus in other areas.

Based on the water balance survey and the data received from HCWW, most of water shortage problem is mainly concentrated in 4 districts namely: Al-Monshaa, El-Maragha, Saqolta, Akhmim, and Gehena. However, it should be noted that Gehena Markaz boundary is not along the River Nile main stream as indicated on the related maps.

6.4.3 GEOLOGY AND HYDROLOGY - SOHAG

Based on the proposed methodology for area / site selection, and Figures 32 &33, the following conclusions could be made based on the geology and hydrology of Sohag:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- At the eastern side only Saqulta, Akhmim, and Dar Al Salam districts have good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters.

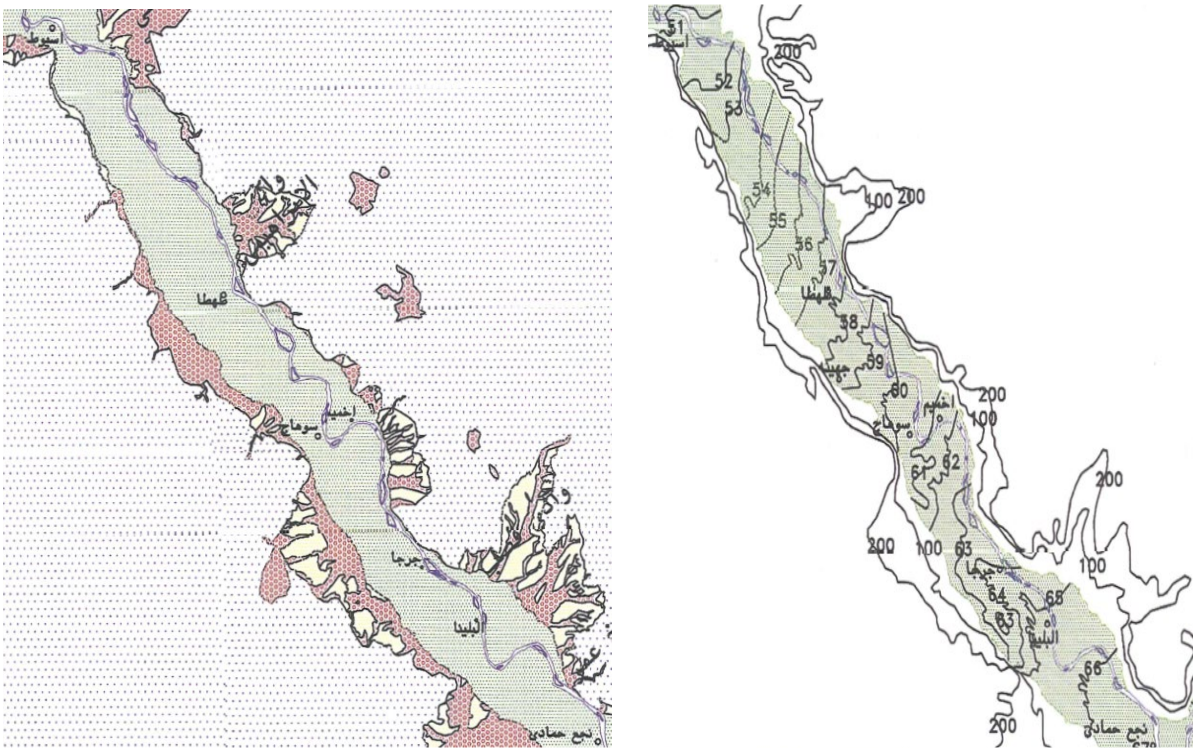


Figure 32 left: Alluvial Plain of Sohag, right: Topography of Sohag [11]

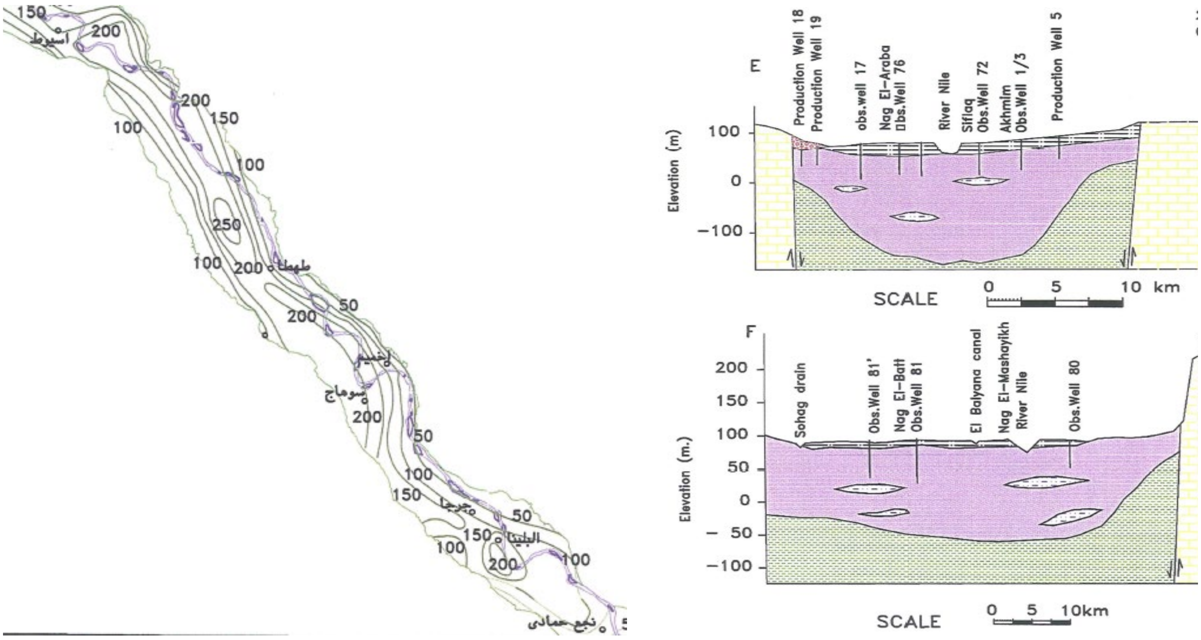


Figure 33: Aquifer depth and extent in Sohag Governorate [11]

6.4.4 LITHOLOGICAL DESCRIPTION - SOHAG

Figure 34 indicates the areas where the lithological description is convenient for the RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 34, it is possible to conclude the following:

- The western part of all Markaz is eligible in terms of lithological formation.
- Some areas on the eastern part are eligible in Saqolta, Akhmim, and Dar Al Salam Markaz.

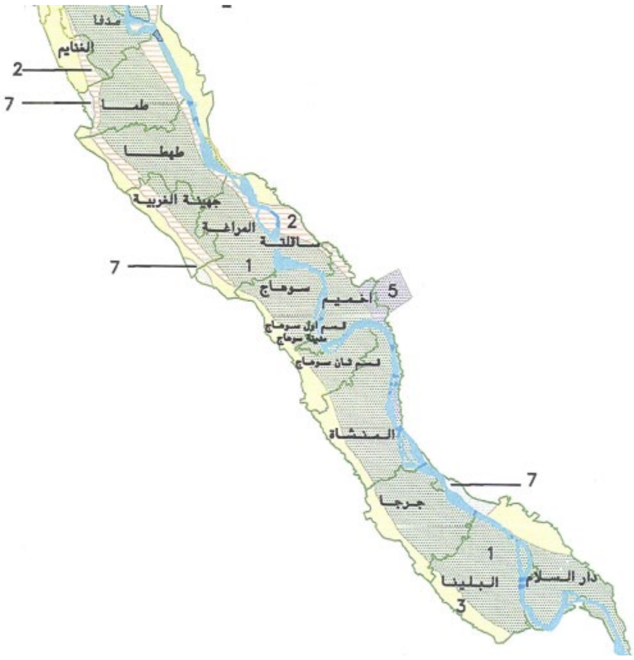


Figure 34:Lithological zoning of Sohag Governorate districts [11]

6.4.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - SOHAG

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Sohag Governorate on the district level are indicated in Table 15.

Table 15: Selection matrix of potential districts for RBF - Sohag

#	District (Markaz)	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality- Urgent Water Need	Selection
1	Tema	√	√	√-x	Less priority
2	Tahta	√	√	√-x	Less priority
3	Gehena	x	x	x-√	x
4	Al Maragha	√	√	√-√	√
5	Saqolta	√	√	√-√	√
6	Sohag	√	√	√-x	Less priority
7	Akhmim	√	√	√-√	√
8	El-Monsha	√	√	√-√	√
9	Gerga	√	√	√-x	Less priority
10	El-Baliana	√	√	√-x	Less priority
11	Dar El Salam	√	√	√-x	Less priority

Based on the applied criteria in Table 15, it is concluded that all districts have positive potential for RBF application. Excluding the water need criterion, almost 10 out of 11 districts, have good potential for RBF implementation. Only Gehena district is not eligible due to its location.

6.4.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF - SOHAG

Based on the selection matrix, the following results could be concluded:

- Apart from the Gehena district case, where RBF is not eligible, the only prevailing parameter is then the water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Sohag Water Company, it is concluded that mainly four districts will be suffering from water shortage in near future. These districts are: El Monsha, Saqulta, Akhmim and Al Maragha.
- Accordingly, and based on the preliminary list received from Sohag governorate the following potential RBF sites, indicated in Table 16, were identified for further detailed investigation in terms of soil conditions and GW quality assessment. It is important to indicate that Sohag Water Company list included some other areas which are not selected in Table 15. However, these locations could be included later as second priority when water shortage is observed. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low.

Table 16: Potential sites for RBF- Sohag Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeo-logy (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selection
1	Tema	Al Seksaka - S	√	√	√-x	√	Less priority
2	Tahta	Shatoura - S	√	√	√-x	√	Less priority
3		Shatoura - CU	√	√	√-x	√	Less priority
4		Khazendara - CU	√	√	√-x	√	Less priority
5	Maragha	Shouranya - CU	√	√	√-√	√	√
6		Maragha - S	√	√	√-√	√	√
7	Saqolta	Mostamara - CU	√	√	√-√	√	√
8		Z Sahrawy	√	√	√-√	√	√
9	Al Monshah	Gezeiret M CU	√	√	√-√	√	√
10		Tokh CU	√	√	√-√	√	√

6.4.7 FINAL LIST OF IDENTIFIED RBF UNITS - SOHAG

Based on the selection process applied on the site level as indicated in Table 16, the final list of projects has been developed in order to be investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells is identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 17 indicates the final list of identified RBF units for each eligible location.

Table 17: Potential sites for RBF units - Sohag Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	El-Monshaa	Al Monsha WTP-CU/ 180000	3	90
2		Tokh WTP-CU/ 80000	3	90
3		Al Zaheer WTP/ 75000	3	90
4	Saqoulta	Al-Mostamara WTP/ 75000	3	90
5	El-Maragha	Al Shouranya- CU	2	60
6		S Maragha/ 70000	2	60
	Total		**16**	**480**

Figure 35 provides a map of potential RBF sites in Sohag Governorate, as presented by Sohag Water and Wastewater Company.

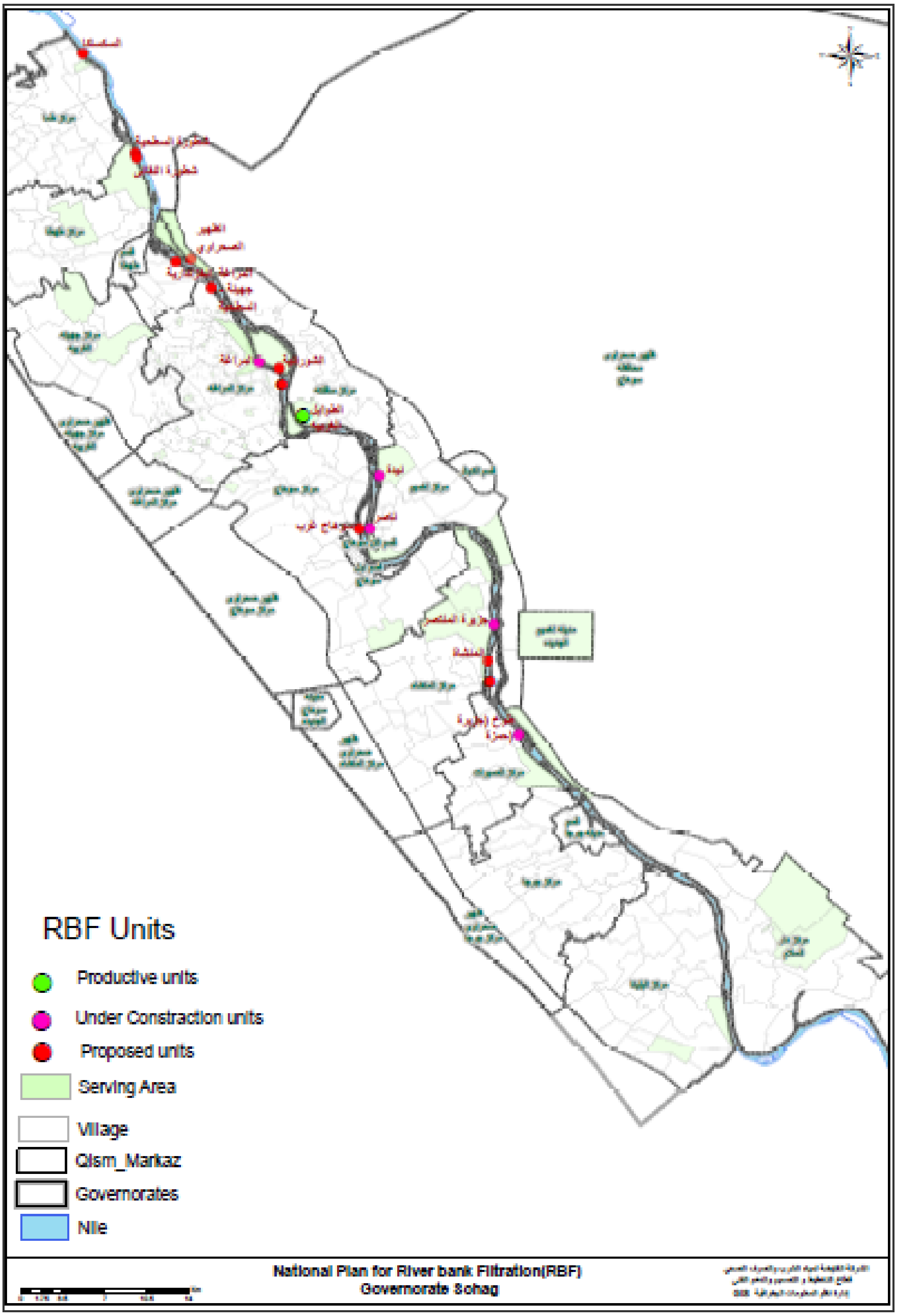


Figure 35:Potential sites for RBF units - Sohag [13]

6.5 POTENTIAL RBF AREAS / SITES IN ASSIUT GOVERNORATE

6.5.1 BACKGROUND INFORMATION

Location: 375 km south to Cairo (Figure 36)

Agricultural area extent: 9-20 km

Length along the River Nile: 100 km

Population: 400,000 (50% urban)

No of districts (Markaz) 11 (4 located on the eastern side of the Nile and 7 on the western side)

Figure 36: Location map of Assiut Governorate

6.5.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Based on the information provided from Assiut Water Company, it was indicated that Assiut governorate is suffering from water supply shortages in different locations. Such shortage mainly exists in 7 districts: Al-Qouseya, Manfalout, Al-Fath, Assiut, Abu-Tig, Al-Badary, and Sedf.

6.5.3 GEOLOGY AND HYDROLOGY – ASSIUT

Based on the proposed methodology for area / site selection, and Figures 37 and 38, the following conclusions could be made based on the geology and hydrology of Assiut:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- At the eastern side only Al fath, Sahil salim, and Al Badary districts have good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters.
- Only Al-Ghanayem has no access to the Nile stream.

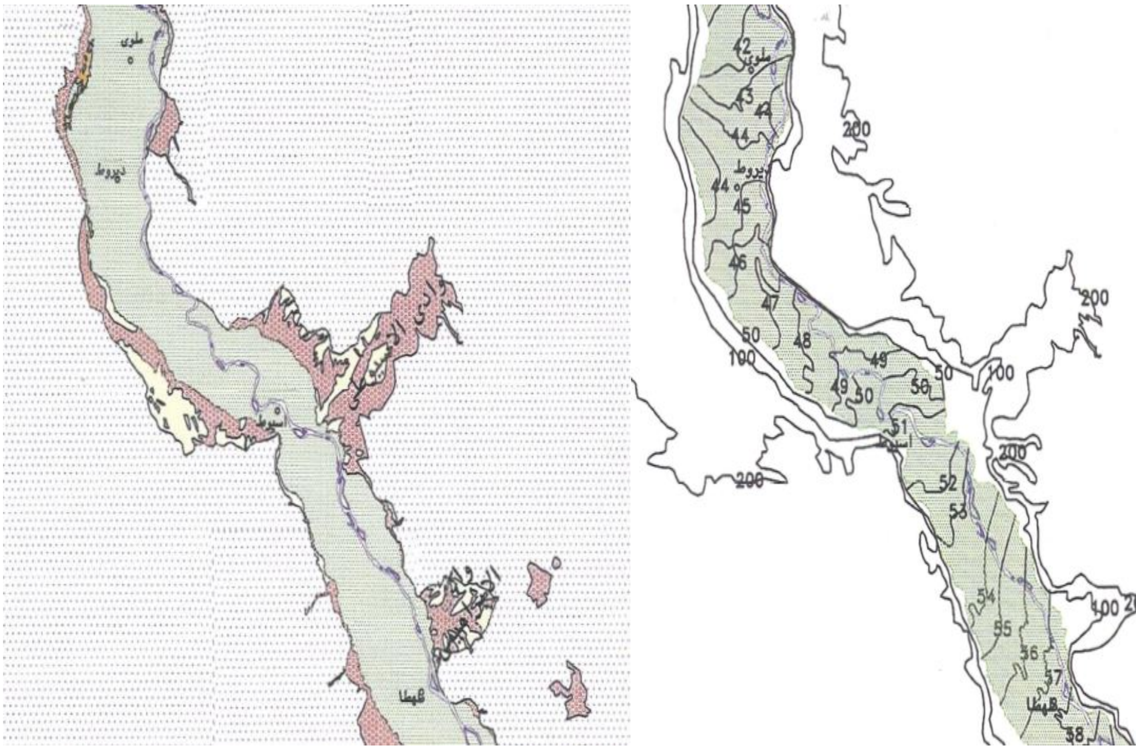


Figure 37: left: Alluvial Plain of Assiut, right: Topography of Assiut [11]

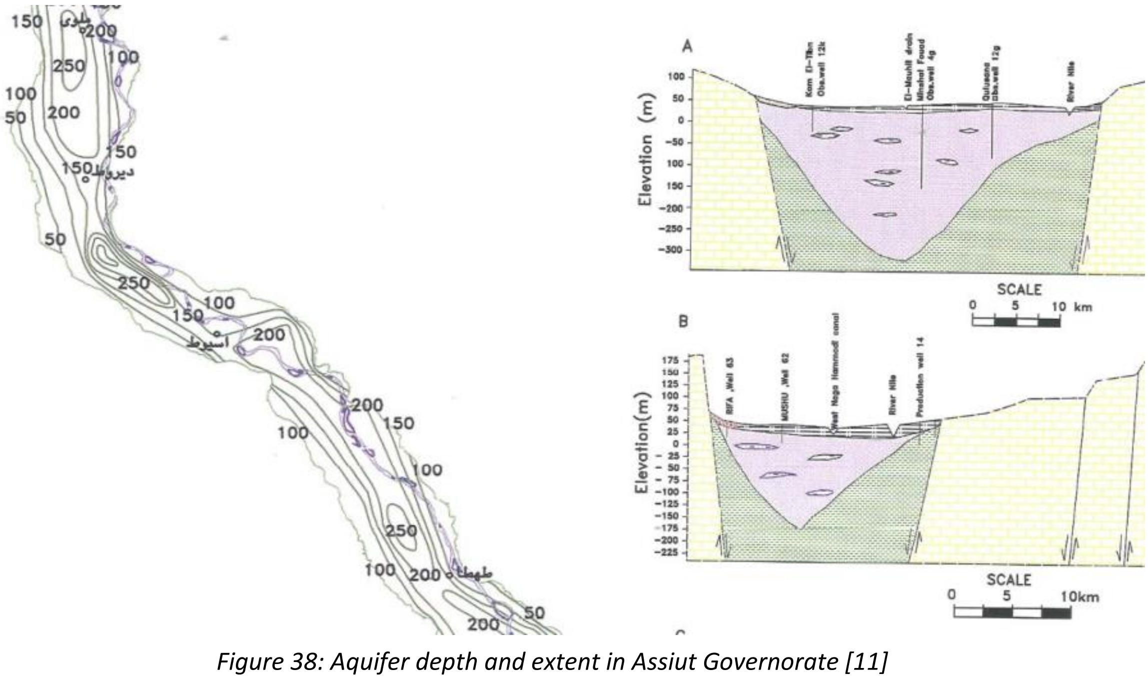


Figure 38: Aquifer depth and extent in Assiut Governorate [11]

6.5.4 LITHOLOGICAL DESCRIPTION - ASSIUT

Figure 39 indicates the areas where the lithological description is convenient for the RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 39, it is possible to conclude the following:

- The western parts of all Markaz is eligible in terms of lithological formation.
- Some areas on the eastern part are eligible in Al fath, Sahil salim, and Al Badary Markaz.

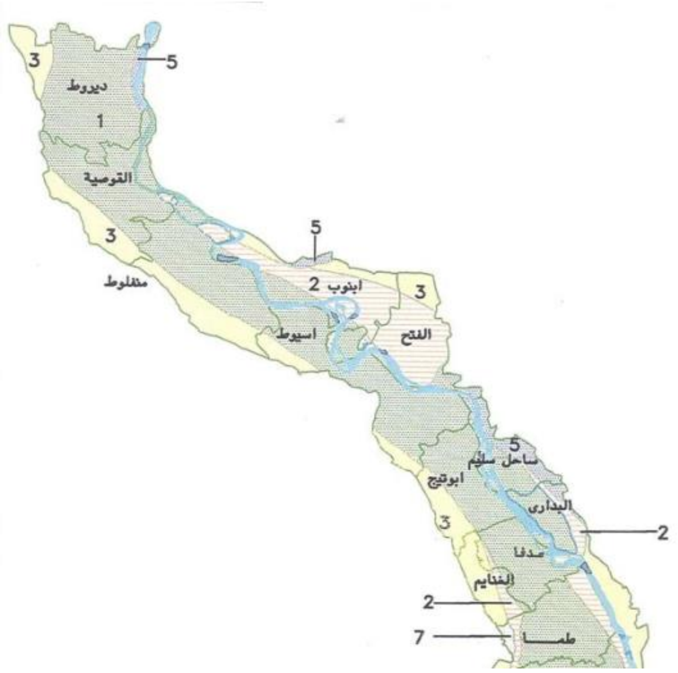


Figure 39: Lithological zoning of Assiut Governorate Districts [11]

6.5.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - ASSIUT

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Assiut Governorate on the district level is indicated in Table 18.

Table 18: Selection matrix of potential districts for RBF - Assiut

#	District (Markaz)	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality - Urgent Water Need	Selection
1	Dayrout	√	√	√-x	Less priority
2	Al qusiya	√	√	√-√	√
3	Manfalut	√	√	√-√	√
4	Abnoub	√	x	√-x	x
5	Al fath	√	√	√-√	√
6	Assiut	√	√	√-√	√
7	Sahil Salim	√	√	√-x	Less priority
8	Abu Tig	√	√	√-√	√
9	Al Badary	√	√	√-√	√
10	Sidfa	√	√	√-√	√
11	Al Ghanayem	x	x	x-x	x

Based on the applied criteria in Table 18, it is concluded that all districts have positive potential for RBF application. Excluding the water need criterion, almost 9 out of 11 districts, have good potential for RBF implementation.

6.5.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF - ASSIUT

Based on the selection matrix indicated in Table 18, the following results could be concluded:

- Apart from Al Ghanayem and Abanoub districts, where RBF is not eligible, the only prevailing parameter is then the water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Assiut Water Company, it is concluded that mainly seven districts will be suffering from water shortage in near future. These districts are: Al Qusiya, Manfalut, Al Fath, Assiut, Abu Tig, Al Badary, and Sidfa.
- Accordingly, and based on the preliminary list received from Assiut governorate the following potential RBF sites, indicated in Table 19, were identified for further investigation in terms of soil conditions and GW quality assessment. It is important to indicate that Assiut Water Company list included some other areas which are not selected in Table 19. However, these locations could be included later as second priority when water shortage is observed. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low.

Table 19: Potential sites for RBF - Assiut Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeo-logy (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selection
1	Abu Tig	Abu Tig - S	√	√	√-√	√	√
2		Abu Tig - CU	√	√	√-√	√	√
3	Al Fath	El Wasaty - GW	√	√	√-√	√	√
4		Bany Mor	√	√	√-√	√	√
5		El Tawabeya	√	√	√-√	√	√
6	Manfalut	Manfalut - S	√	√	√-√	√	√
7	Assiut	Assiut - S	√	√	√-√	√	√
8		Assiut El Tesheky	√	√	√-√	√	√
9		Nazlet Abdellah	√	√	√-√	√	√
10		Menkebad-CU	x	√	√-√	√	x
11		Elgamaa-CU	x	√	√-√	√	x
12	Sidfa	Sidfa-S	√	√	√-√	√	√
13	Al Badary	Al Badary-S	√	√	√-√	√	√
14	Al Qusiya	Al Qusiya-S	√	√	√-√	√	√

6.5.7 FINAL LIST OF IDENTIFIED RBF UNITS- ASSIUT

Based on the selection process applied on the site level as indicated in Table 19, the final list of projects has been developed in order to be deeply investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells are identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 20 indicates the final list of identified RBF units for each eligible location.

Table 20: Potential sites for RBF units - Assiut Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Abu Tig	Abu Tig - S	2	60
2		Abu Tig - CU	1	30
3	Al Fath	El Wasaty - GW	1	30
4		Bany Mor	1	30
5		El Tawabeya	1	30
6	Manfalut	Manfalut - S	2	60
7	Assiut	Assiut - S	2	60
8		Assiut El Tesheky	1	30
9		Nazlet Abdellah	1	30
10	Sidfa	Sidfa-S	1	30
11	Al Badary	Al Badary - S	1	30
12	Al Qusiya	Al Qusiya - S	2	60
	Total		**16**	**480**

Figure 40 provides a map of potential RBF sites in Assiut Governorate, as presented by Assiut Water and Wastewater Company.

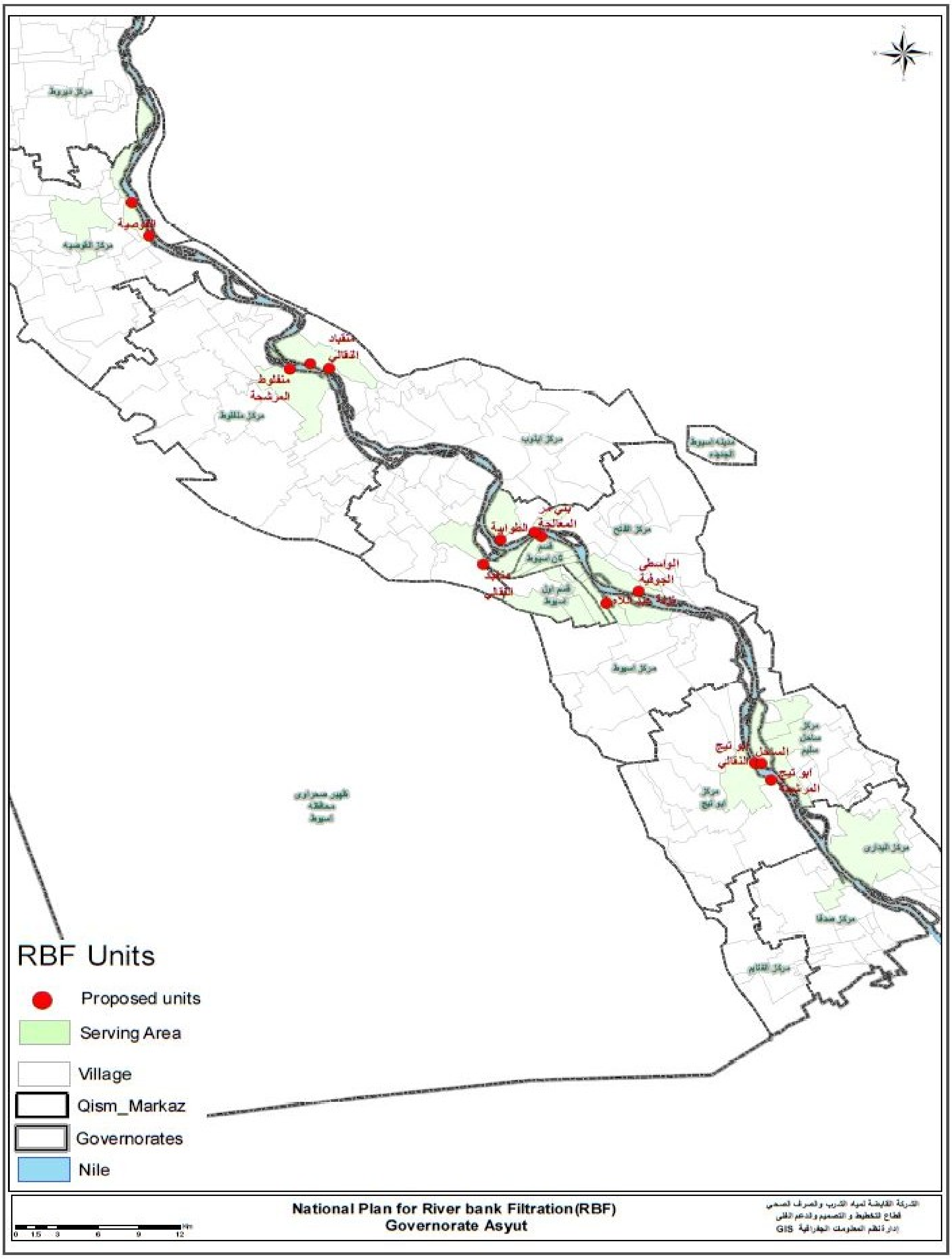


Figure 40: Potential sites for RBF units - Assiut [13]

6.6 POTENTIAL RBF AREAS / SITES IN MINYA GOVERNORATE

6.6.1 BACKGROUND INFORMATION

Location: 135 km south to Cairo

Agricultural area extent: 8-12 km

Length along the River Nile: 10 km

Population: 5,564,000 (28.6% urban)

No of districts (Markaz): 9 (The Nile passes through 9 of them).

Figure 41: Location map of Minya Governorate

6.6.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Based on the information provided from Minya Water Company, it was indicated that Minya governorate is suffering from water supply shortages in different locations. Such shortage mainly exists in 5 districts: Beni mazar, Magag, Samloat, Minya, Malwya.

6.6.3 GEOLOGY AND HYDROLOGY - MINYA

Based on the proposed methodology for area / site selection, and Figures 42 & 43, the following conclusions could be made based on the geology and hydrology of Minya:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- The eastern side has also very good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters.

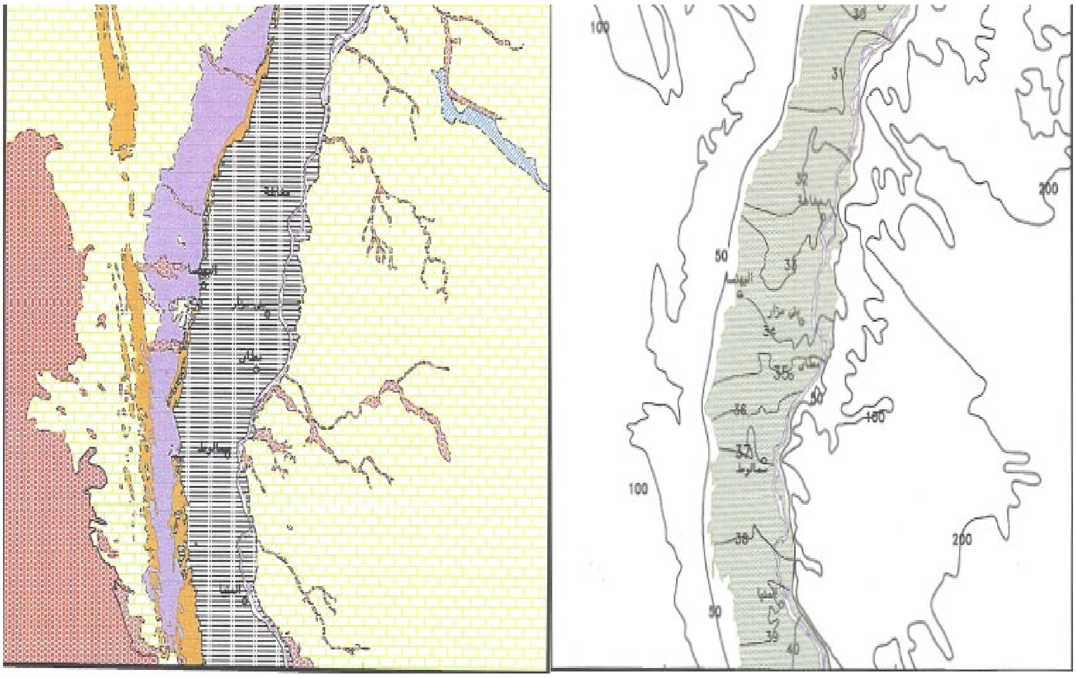


Figure 42: left: Alluvial plain of Minya, right: Topography of Minya [11]

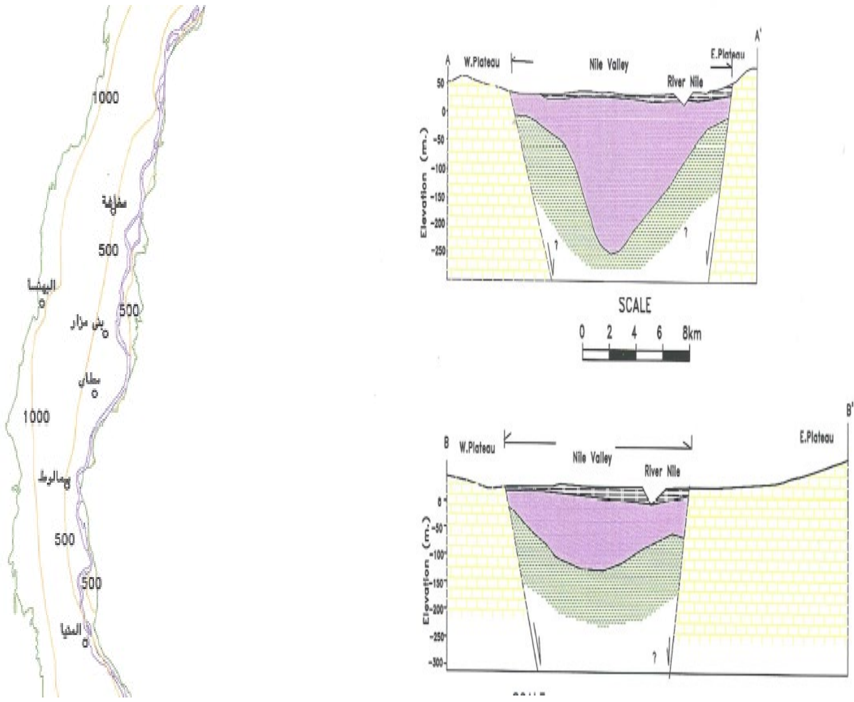


Figure 43: Aquifer depth and extent in Minya Governorate [11]

6.6.4 LITHOLOGICAL DESCRIPTION - MINYA

Figure 44 indicates the areas where the lithological description is convenient for RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 44, it is possible to conclude the following:

- The western parts of all Markaz are eligible in terms of lithological formation.

- Most of the eastern part is eligible.

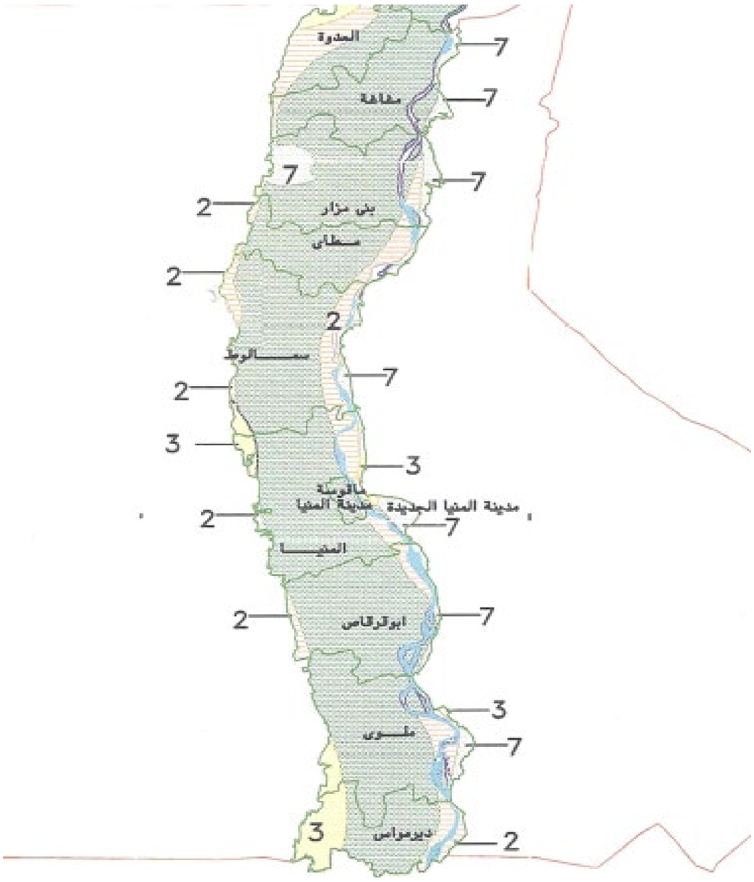


Figure 44: Lithological zoning of Minya Governorate [11]

6.6.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - MINYA

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Minya Governorate on the district level is indicated in Table 21.

Table 21: Selection matrix of potential districts for RBF - Minya

#	District (Markaz)	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality - Urgent Water Need	Selection
1	Magaga	√	√	√-√	√
2	Beni Mazar	√	√	√-x	x
3	Samloat	√	√	√-√	√
4	Minya	√	√	√-√	√
5	Maloay	√	√	√-x	Less Priority
6	El-Adwaa	√	√	√-x	Less Priority
7	Matay	√	√	√-x	Less Priority
8	Abo-karkas	√	√	√-x	Less Priority

Based on the applied criteria, it is concluded that half the districts have positive potential for RBF application. Excluding the water need criterion, 6 out of 9 districts, have good potential for RBF implementation.

6.6.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF - MINYA

Based on the selection matrix indicated in Table 21, the following results could be concluded:

- The only prevailing parameter is water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Minya Water Company, it is concluded that mainly four districts will be suffering from water shortage in near future: Maga, Beni mazar , Samloat, Minya.
- Accordingly, and based on the preliminary list received from Minya governorate the following potential RBF sites, indicated in Table 22, were identified for further investigation in terms of soil conditions and GW quality assessment. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low. Figure 45 provides an illustrative map for the potential RBF sites in Minya Governorate, as presented by Minya Water and Wastewater Company.

Table 22: Potential sites for RBF - Minya Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeo-logy (Aquifer)	Criterion 3 Av. of land W shortage	Criterion 4 GWQ (TDS) as indicator	Selecti on
1	Magaga	Shwarna-S	√	√	√-√	√	√
2	Beni Mazar	Beni mazar-S	√	√	√-√	√	√
3	Samloat	Arab El-zina -S	√	√	√-√	√	√
4	Minya	Beni-Ahmed -S	√	√	√-√	√	√

6.6.7 FINAL LIST OF IDENTIFIED RBF UNITS - MINYA

Based on the selection process applied on the site level as indicated in Table 22, the final list of projects has been developed in order to be investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells are identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 23 indicates the final list of identified RBF units for each eligible location.

Table 23: Potential sites for RBF units - Minya Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Magaga	Shwarna - S	2	60
2	Samloat	Arab El-zina - S	2	60
3	Minya	Beni-Ahmed - S	3	90
	Total		**7**	**210**

Minya Water Company did not submit any proposal for new sites of RBF units. All proposed units have already been implemented or under construction. Figure 45 indicates the location map for those units as provided by El-Minya Water Company.

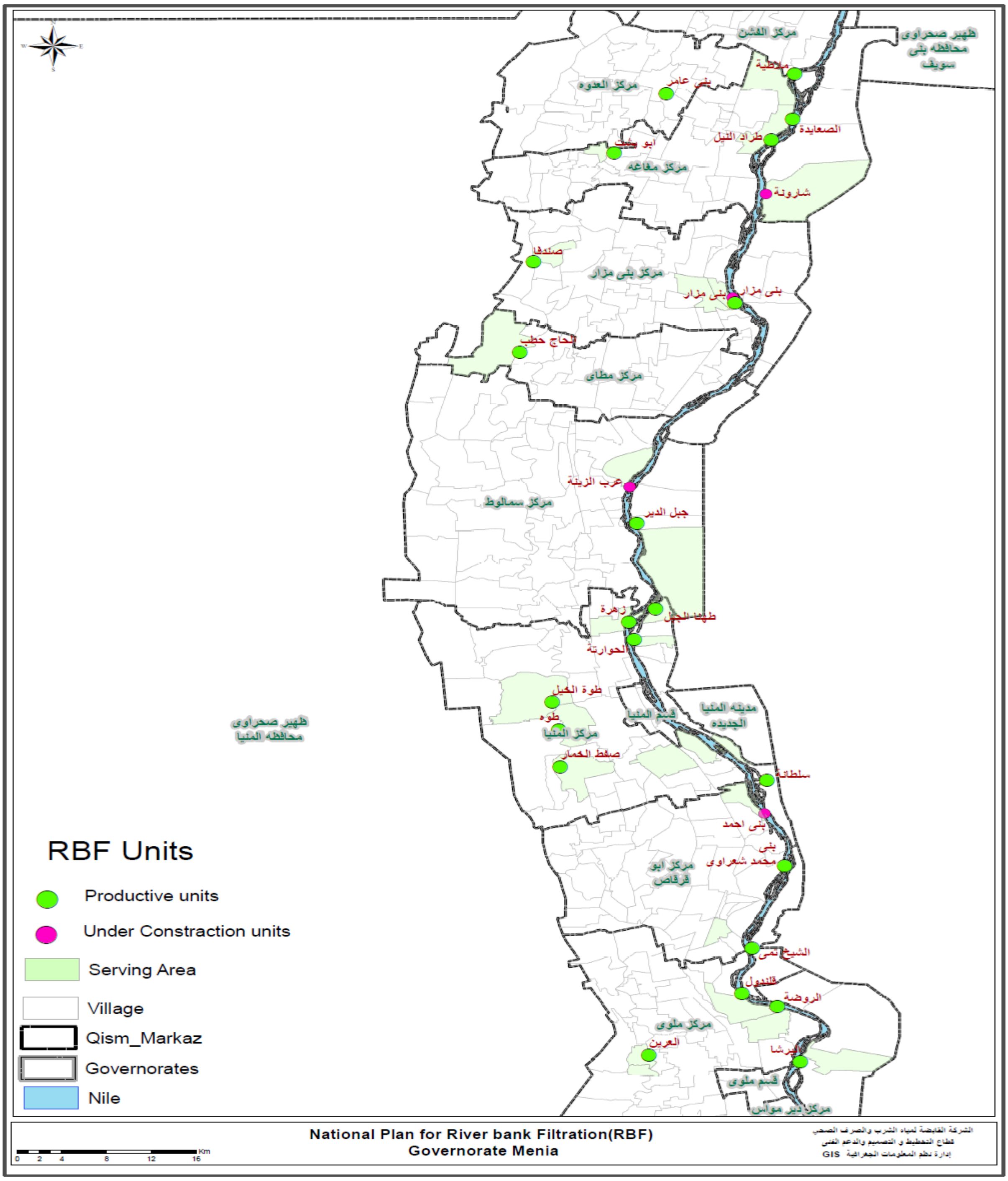


Figure 45: Location map of RBF units at El Minya Governorate [13]

6.7 POTENTIAL RBF AREAS / SITES IN BENI-SUIF GOVERNORATE

6.7.1 BACKGROUND INFORMATION

Location: 124 km south to Cairo (Figure 46)

Agricultural area extent: 2.5-11 km

Length along the River Nile: 10 km

Population: 2,771,000 (28.6% urban)

No of districts (Markaz): 7 (The Nile passes through 5 of them), Ahnsea, Samata Markaz has no access to the Nile at its boundaries.

Figure 46: Location map of Beni-Suif Governorate

6.7.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Based on the information provided from Beni-suif Water Company, it was indicated that Beni-suif governorate is suffering from water supplies shortages in different locations. Such shortage mainly exists in 5 districts: Wasta, Naser, El-Fashen , Samata and Ahnsea.

6.7.3 GEOLOGY AND HYDROLOGY - BENI-SUIF

Based on the proposed methodology for area / site selection, and Figures 47 & 48, the following conclusions could be made based on the geology and hydrology of Beni-suif:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- The eastern side has also very good potential for RBF.
- Most districts have good potential for RBF implementation in terms of defined parameters, except Farshout.

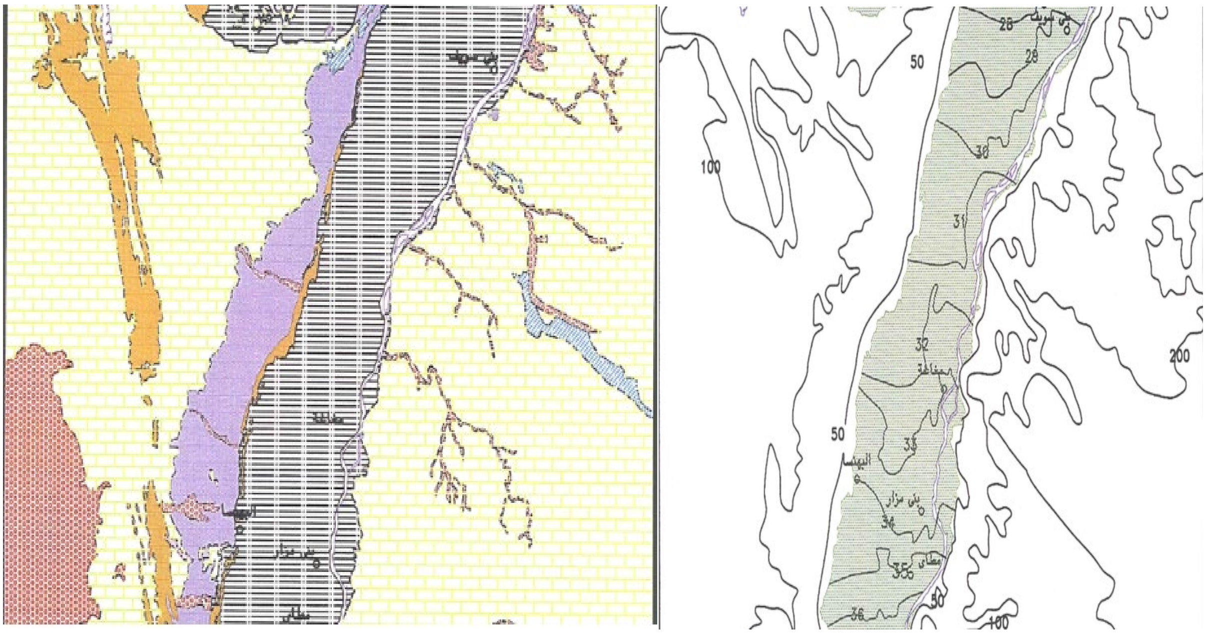


Figure 47: left: Alluvial Plain of Beni-suif, right: Topography of Beni-suif [11]

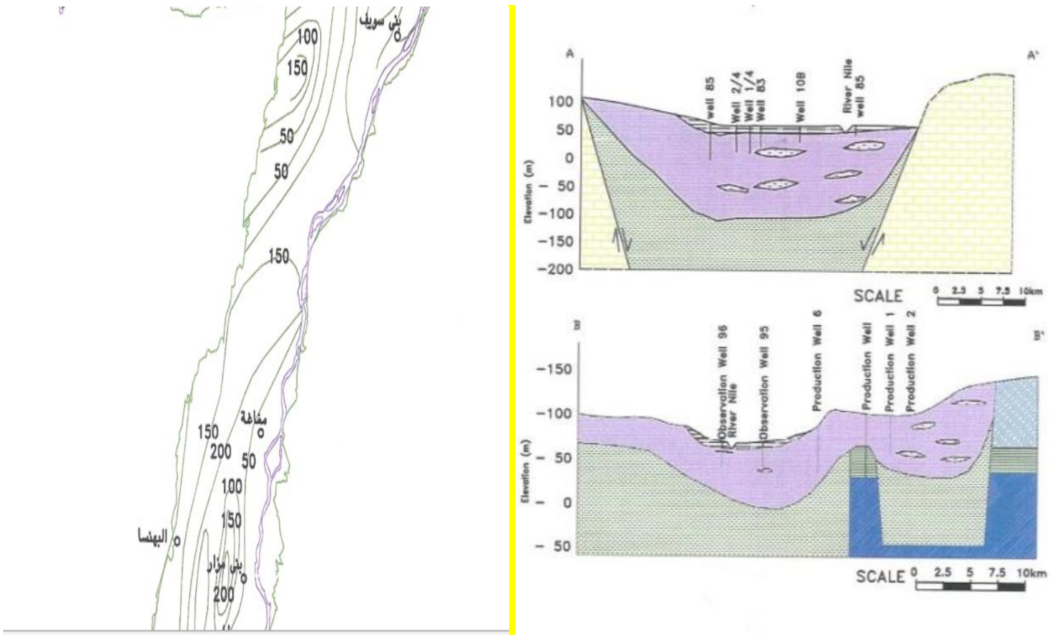


Figure 48: Aquifer depth and extent in Beni-suif Governorate [11]

6.7.4 LITHOLOGICAL DESCRIPTION - BENI-SUIF

Figure 49 indicates the areas where the lithological description is convenient for RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 49, it is possible to conclude the following:

- The western parts of all Markaz are eligible in terms of lithological formation.
- Most of the eastern part is eligible.

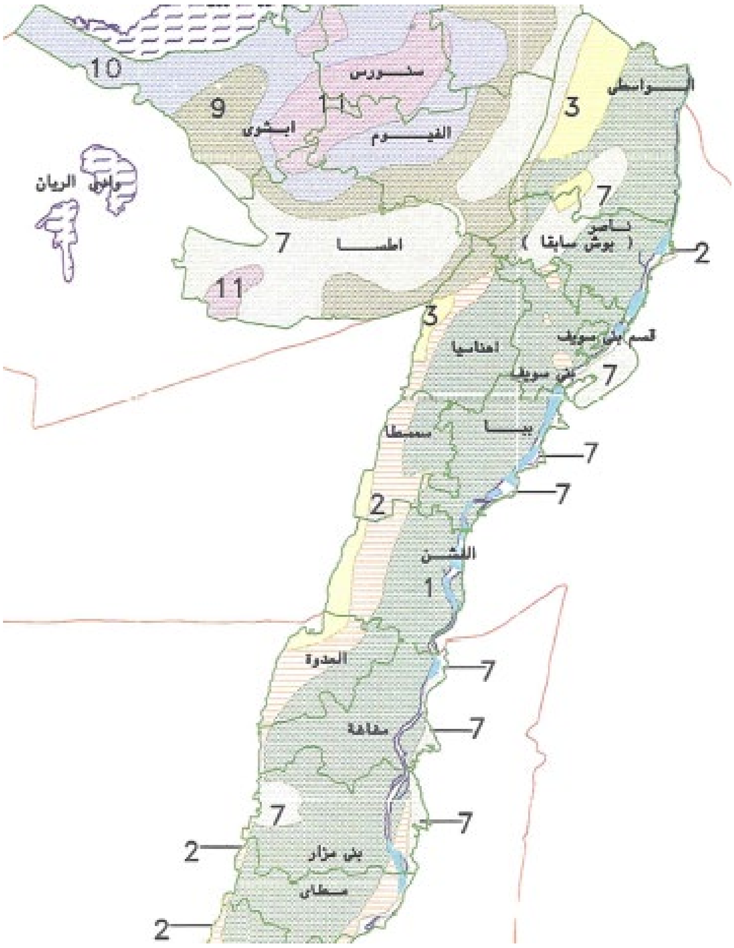


Figure 49: Lithological zoning of Beni-suif [11]

6.7.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - BENI-SUIF

To select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Beni-suif Governorate on the district level is indicated in Table 24.

Table 24: Selection matrix of potential districts for RBF - Beni-Suif

#	District	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality- Urgent Water Need	Selection
1	Al-wasta	√	√	√-√	√
2	Naser	√	√	√-√	√
3	Beni-suif	√	√	√-√	√
4	Ahnsea	x	√	x-x	x
5	Babba	√	√	√-√	√
6	Samata	x	√	x-x	x
7	Al-Fashen	√	√	√-√	√

Based on the applied criteria in Table 24, it is concluded that half the districts have positive potential for RBF application. Excluding the water need criterion, 5 out of 7 districts have good potential for RBF implementation.

6.7.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF- BENI-SUIF

Based on the selection matrix indicated in Table 24, the following results could be concluded:

- The only prevailing parameter is water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Beni-suif Water Company, it is concluded that mainly six districts will be suffering from water shortage in near future. These districts are: Al-wasta, Nasar, Beni-suif, Babba, Samata, and El-fashen.
- Accordingly, and based on the preliminary list received from Beni-suif governorate the following Potential RBF sites, indicated in Table 25, were identified for further deep investigation in terms of detailed soil conditions and GW quality assessment at the installation sites. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low.

Table 25: Potential sites for RBF – Beni-Suif Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeo-logy (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selecti on
1	Al-wasta	Atwab - S	√	√	√-√	√	√
2		Gazerat El-Masada - S	√	√	√-√	√	√
3	Nasar	Al Hamody - S	√	√	√-√	√	√
4	Beni-suif	El-shanwaya - S	√	√	√-√	√	√
5	Babba	Malahya Ali gomma - S	√	√	√-√	√	√
6	Al-Fashen	El-kadabi - S	√	√	√-√	√	√

6.7.7 FINAL LIST OF IDENTIFIED RBF UNITS- BENI-SUIF

Based on the selection process applied on the site level as indicated in Table 25, the final list of projects has been developed in order to be investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells are identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 26 indicates the final list of identified RBF units for each eligible location. However, most of these plants are under construction, no fund is required for the time being.

Table 26: Potential sites for RBF units – Beni-Suif Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Al-wasta	Atwab-S	1	30
2		Gazerat El-Masada-S	1	30
3	Nasar	El-shanwaya -S	1	30
4	Beni-suif	El Dawea -S	1	30
5	Babba	Malahya Ali gomma-S	1	30
6	Al-Fashen	El-kadabi –S	1	30
	Total		**6**	**180**

Beni Suif Water Company did not submit any proposal for new RBF units. All proposed units have been already implemented or under construction. Figure 50 indicates the location map for those units as provided by Beni Suif Water Company.

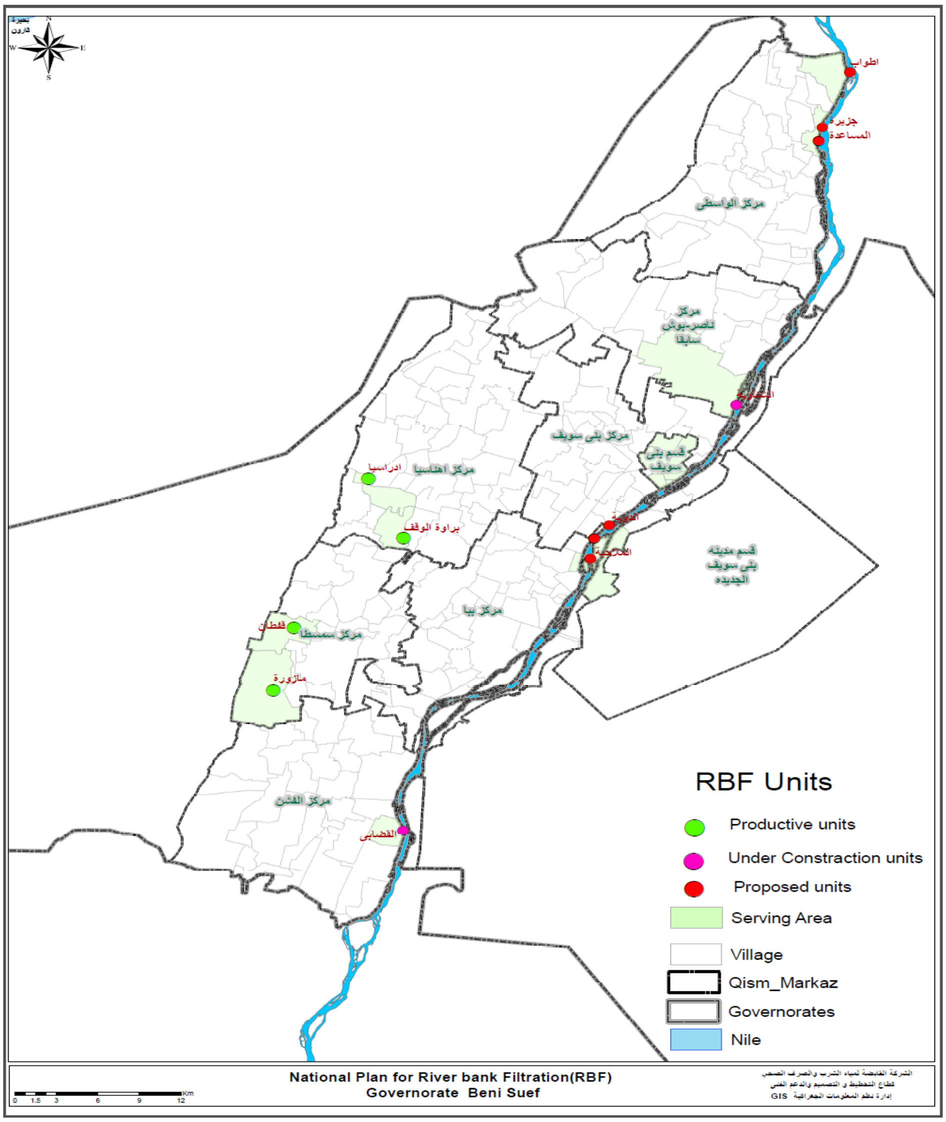


Figure 50: Location map of RBF units at Beni Suif Governorate [13]

6.8 POTENTIAL RBF AREAS / SITES IN GIZA GOVERNORATE

6.8.1 BACKGROUND INFORMATION

Location: Next to Cairo

Agricultural area extent: 5-12 km

Length along the River Nile: 70 km

Population: 7,486,361 (50% urban)

No of districts (Markaz) 10 (5 of them located by eastern side of the Nile and 1 of them by western side), the others are located away from the River Nile.

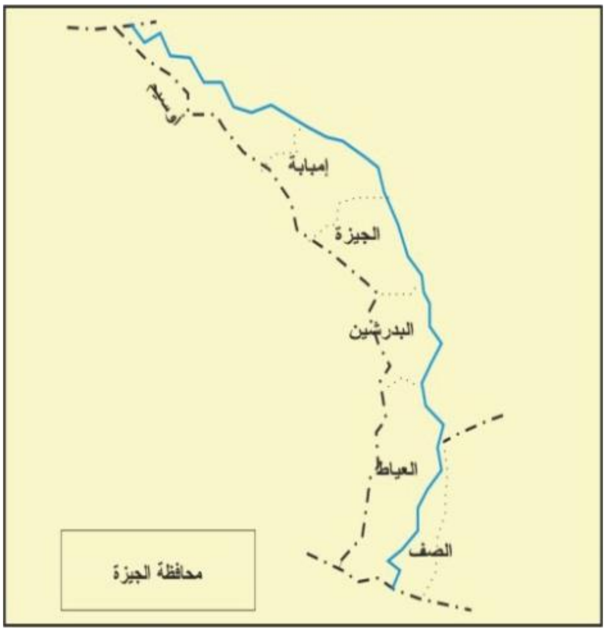


Figure 51: Location map of Giza Governorate

6.8.2 WATER SUPPLY FACILITIES AND WATER BALANCE

Based on the information provided from Giza Water Company, it was indicated that Giza governorate is suffering from water supply shortages in different locations. Such shortage mainly exists in 2 districts: Al-Hawamdeya and Al-Badrasheen.

6.8.3 GEOLOGY AND HYDROLOGY - GIZA

Based on the proposed methodology for area / site selection, and Figures 52 & 53, the following conclusions could be made based on the geology and hydrology of Giza:

- Western side areas with respect to the River Nile main stream have a very good potential for RBF in terms of geological, hydrogeological, and geotechnical aspects.
- The eastern side Al Saf district has good potential for RBF.
- Nearly half of districts have good potential for RBF implementation in terms of defined parameters.

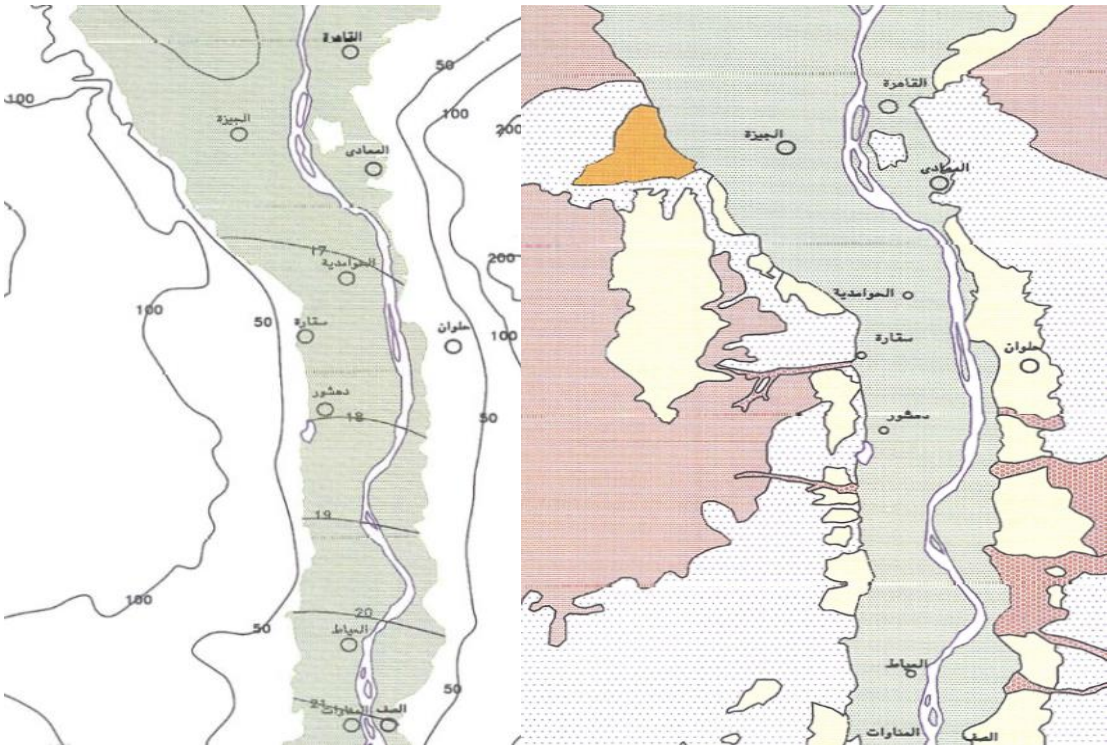


Figure 52: left: Alluvial Plain of Giza, right: Topography of Giza [11]

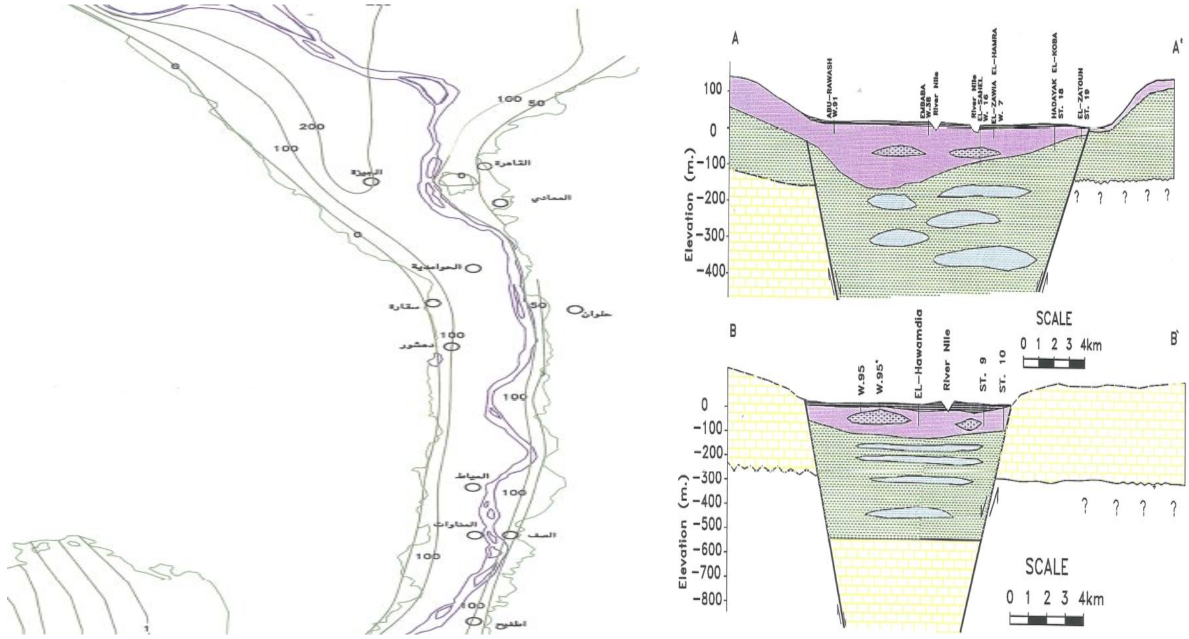


Figure 53: Aquifer depth and extent in Giza Governorate [11]

6.8.4 LITHOLOGICAL DESCRIPTION - GIZA

Figure 54 indicates the areas where the lithological description is convenient for RBF in terms of soil formation and characterisation. All areas under category 1, 2, or 4 are considered suitable for water extraction due to existence of permeable sandy layers at depths ranging from 8 to 15 m below ground surface with a depth ranging from 10-20 m. From Figure 54, it is possible to conclude the following:

- The western parts of all Markaz are eligible in terms of lithological formation.
- Markaz Al Saf on the eastern part is eligible.

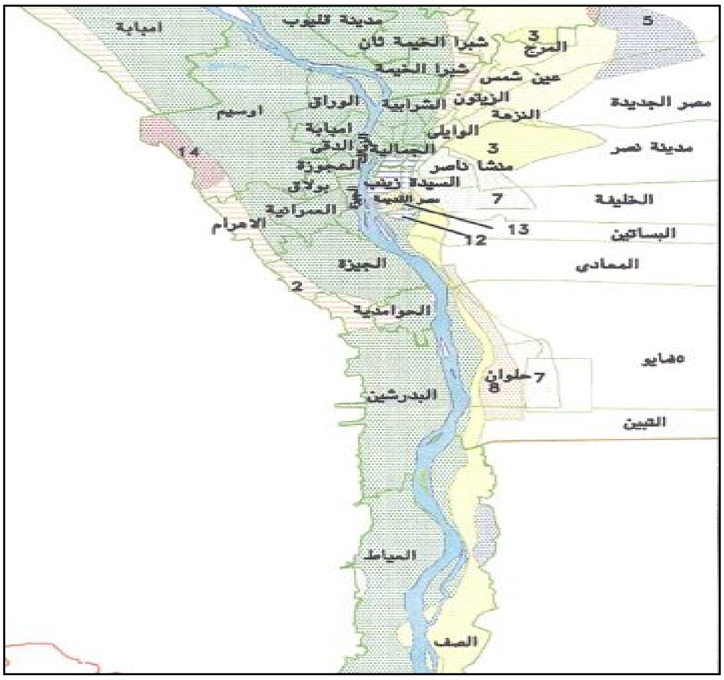


Figure 54: Lithological zoning of Giza Governorate [11]

6.8.5 STEP-2: SELECTION OF POTENTIAL DISTRICTS FOR RBF - GIZA

In order to select the potential areas for RBF on the district (Markaz) level, the criteria stated in step-2 have been applied on the Markaz level. The selection matrix of Giza Governorate on the district level is indicated in Table 27.

Table 27: Selection matrix of potential districts for RBF - Giza

#	District (Markaz)	Criterion 1 River Flow Availability (Located on River Basin)	Criterion 2 Hydrogeology and Lithology	Criterion 3 Good Water Quality - Urgent Water Need	Selection
1	**Embaba**	√	√	√-x	Less priority
2	**Osem**	√	√	√-x	Less priority
3	Kerdasa	x	√	√-x	x
4	**Abo El Nomros**	√	√	√-x	Less priority
5	Al-Hawamdeya	√	√	√-√	√
6	Giza	√	√	√-x	Less priority
7	Al-Badrashen	√	√	√-√	√
8	**Al-Ayat**	√	√	√-x	Less priority
9	Al Saf	√	X	√-x	x
10	Atfih	√	x	√-x	x
11	Al-Wahat Al-Bahareya	x	x	x-x	x

Based on the applied criteria in Table 27, it is concluded that around half the districts have positive potential for RBF application. Excluding the water need criterion, 7 out of 11 districts have good potential for RBF implementation.

6.8.6 STEP-3: SELECTION OF POTENTIAL SITES FOR RBF - GIZA

Based on the selection matrix indicated in Table 27, the following results could be concluded:

- The only prevailing parameter is water need assessment at each district to provide RBF facilities in those areas. Based on water need assessment provided by Giza Water Company, it is concluded that mainly two districts will be suffering from water shortage in near future. These districts are: Al-Hawamdeya and Al-Badrashen.
- Accordingly, and based on the preliminary list received from Giza governorate the following potential RBF sites, indicated in Table 28, were identified for further investigation in terms of soil conditions and GW quality assessment. It is important to indicate that Giza Water Company list included some other areas which are not selected in Table 28. However, these locations could be included later as second priority when water shortage is observed. The priorities can be categorised during the phase of detailed investigations to define level of priority as: urgent, high, moderate, or low.

Table 28: Potential sites for RBF- Giza Governorate - Step 3

#	District	Location	Criterion 1 Hydrology (River vel. & duration)	Criterion 2 Hydrogeology (Aquifer)	Criterion 3 Av. of land/ W shortage	Criterion 4 GWQ (TDS) as indicator	Selection
1	AlHawamdeya	AlHawamdeya	√	√	√-√	√	√
2		Masghona	√	√	√-√	√	√
3	Al-Badrashen	Al-Shobak Al-Gharby	√	√	√-√	√	√

6.8.7 FINAL LIST OF IDENTIFIED RBF UNITS - GIZA

Based on the selection process applied on the site level as indicated in Table 28, the final list of projects has been developed in order to be investigated in terms of field measures. Based on the availability of land and the current shortage in water supplies, the number of RBF wells is identified as a step ahead to the cost estimates either for investment or operation and maintenance costs. Table 29 indicates the final list of identified RBF units for each eligible location.

Table 29: Potential sites for RBF units - Giza Governorate

#	District	Plant Location	No. of wells	Capacity in l/s
1	Al-Hawamdeya	Al-Hawamdeya	2	60
2		Masghona	1	30
3	Al-Badrashen.	Al-Shobak Al-Gharby	2	60
	Total		**5**	**150**

Figure 55 provides a map of potential RBF sites in Giza Governorate, as presented by Giza Water and Wastewater Company.

Figure 55: Potential sites for RBF units - Giza [13]

7. COST ESTIMATES AND ESTIMATES AND IMPLEMENTATION PLAN

7.1 INTRODUCTION

In order to have a unified and reliable base for cost calculations, cost tables following the concept of unit rates of each component have been developed for the RBF system components considering the prevailing prices of the project area. This would facilitate the cost calculations for both investment as well as operation and maintenance (O&M) cost. This would be a step ahead to the calculation of the total life cost of the different options for proper selection of the technically eligible option. It should be noted that the cost unit rates should be considered for land acquisition, detailed investigation studies, test well, and the RBF well including drilling, casing pipes, pumps etc. Other appurtenant will be considered for delivery lines, valves, as well as electrical connections and panels.

Nevertheless, keeping in mind that almost all proposed RBF units are planned to be installed within existing water facilities, the following items will be excluded from the RBF system costs:

1- Cost of land acquisition
2- Cost of main power supply, transformers, and generators
3- Cost of connection to the main water distribution system

Section 7.2 represents the basis for RBF system components.

7.2 BASIS OF COST CALCULATIONS AND ESTIMATES

7.2.1 TYPICAL RBF SYSTEM COMPONENTS

Typical RBF system components are mainly composed of a vertical well withdrawing a mixture of river bank filtrate and land-side groundwater from a shallow depth. The main physical components of such RBF well are as the following:

1- Well casing
2- Well screen
3- Well pump and associated pipes/ valves
4- Electrical connections
5- Operation room, installed above the well

In order to have proper sizing for such components, a typical well design following a typical soil formation was considered as an estimate at this stage. Figure 56 illustrates typical well components.

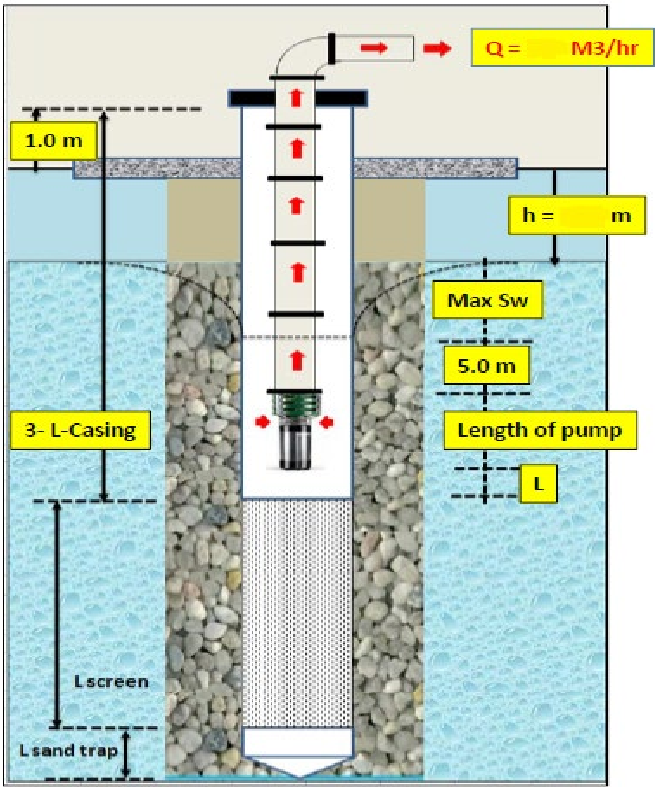


Figure 56: Typical RBF well components

Figures 57 & 58 illustrate the main design data as well as the typical soil formation considered in the design of typical RBF system.

Calculation Sheet For a Typical well

INPUTS

1-Required Well Discharge(Q design)

Qd	30 L/s	
	108 m3/hr	

2-Pump working hours

Working Hours	16 hour	(8-16) hours

3- Levels (Ground Level , Static water level , total aquifer depth -if available-)

Ground level (GL)	m
Static water level (SWL)	m
Depth of Aquifer	m

DESIGN

1- Selection of Diameters (pump, casing and drilling)

Selection depends on required well discharge. Diameters are selected from the following table:-

Q(Well Discharge	50-60	60-100	100-180	m3/hr
D1(Pump Diameter)	6	8	10	inch
D2(casing Diameter)	8	10	12	inch
D3(Drilling Diameter)	15	17.5	20	inch

D1(pump)	10 inch
D2(Casing)	12 inch
D3(Drilling)	20 inch

2- Casing length

Casing are pipe joinin from well cap (1m above ground level) to screens

The casing length is the sum of all the follwing

*Height Above Ground Level	1 m	Standard
*Depth to Static Water Level	3.74 m	From Soil report and equals GL - SWL
*Max permissible drowdown	8 m	it's the max difference between static water level and dynamic water level
*Min water height above pump(NPSH allowable)	5 m	Net postive suction head it's assume 5 m and adjusted at final pump selection
Length of Pump	3 m	Pump length and assumed 3 m till the final pipe selection
*Length between pump bottom level and screen	2 m	Distance between bottom of pump and top of screen taken 2 m as a safety factor
Lcasing	23 m	

Figure 56: Typical hydraulic calculation sheet for RBF wells (a)

Calculation Sheet For a Typical well

3- Screen length

Dscreen(Ds)	12 inch	Assume Dscreen = Dcasing
Opening Ratio(O.R)	8 %	(8-10)catalogue
Ventrance(Ve)	0.02 m/sec	(0.03-0.01)
Factor in safety(F.S)	1.25 unitless	
Length screen (Ls)	25 m	$Ls = \frac{Qw}{(\pi) * (Ds) * (O.R) * (Ve)} * F.S$

4- Sand Trap Length

length	6 m	Standard
Dsand trap	12 inch	Dsand trap = Dcasing
Total well length	54 m	Lcasing + Lscreen + Lsandtrap

OUTPUT

Well summary		
Diameters		
Dpump	10	inch
Dcasing	12	inch
Ddrilling	20	inch
Length		
Lcasing	23	m
Lscreen	25	m
Lsandtrap	6	m
Ltotal	54	m

*After well construction a step pumping test is performed to get well yield, optimum opertaing point (Q,H)

Figure 57: Typical hydraulic calculation sheet for RBF wells (b)

Comments:

Before drilling for the implementation of RBF wells, a test well having a smaller diameter should be drilled and used for water level assessment to determine the groundwater flow gradient toward the river. The drilling should also be used to get depth-specific sediment samples for sieving analysis according to international standard procedures. Parameters gained from the determined grain-size distribution curves are used to order the appropriate filter sand or gravel.

At sites with limited aquifer thickness (<50 m), the length of casing could be reduced to 15 - 20 m depending on water level and drawdown. Not all pumps require 5 m water level above water entrance of the pump. Also, the screen length could be shorter if the hydraulic conductivity is sufficient or a lower pumping could be accepted. The sand trap length could be 1 – 2 m only.

To design RBF systems with only 16 working hours may result in a lower portion of bank filtrate in the pumped water and higher Fe and Mn concentrations due to the higher portion of land-side groundwater. Thus, it is advised to run the pumps continuously if possible and to operate the RBF units in combination with water storage tanks.

All RBF wells should be equipped with an inner and outer piezometer to allow monitoring of water levels and potential well clogging. Furthermore, proper sealing around the well casing is required to prevent input of pathogens via preferential flow paths.

In contradiction to Figures 56 and 59, the filter sand/gravel should only filled up to 2 – 4 m above the filter screen, not up to the static water level.

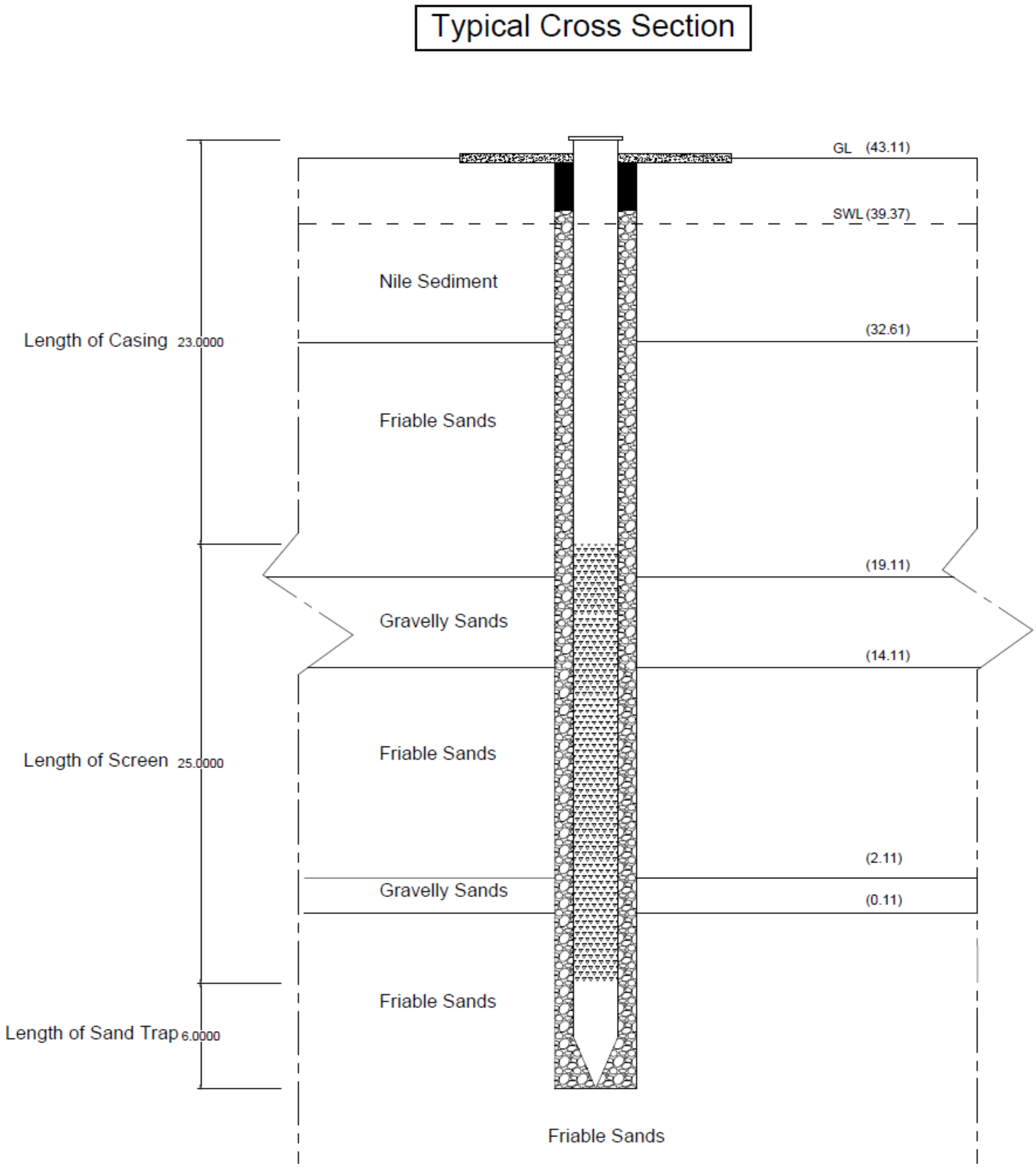


Figure 58: Typical well profile – Cross section, Levels provided as a rough guide

7.2.2 CAPITAL COSTS

- **Well Casing**
  - ***Drilling:*** In order to install the well casing drilling should be done first in order to ensure the soil formation as well as testing potential well productivity. Drilling diameter is 20 inches.
  - ***Casing Pipes:*** HDPE pipes is assumed to be used as well casing due to its high durability for corrosion due to salinity and other soil conditions. Moreover, it does not need any cathodic protection in case of highly conductive soil conditions. Casing pipe diameter is 12 inches.

- **Well Screen**
  - Based on the specific soil formation of each site, the length and depth of the well screen are selected. Stainless steel 316 is proposed to be installed as a well screen to ensure high durability and lifetime. Well screen is 12 inches in diameter.

- **Well Pump**
  - A submersible well pump IP68 with a capacity of 30 l/s is employed to be installed at 5 m depth below the min water level. The total head of pump is assumed to be between 30 - 40 m, depending on the requirements from the local water distribution network.
  - UPVC delivery pipe 8 inches size and NP 10 bars is considered for cost estimates including necessary fittings and valves as appropriate.

- **Electric Components**
  - This item is mainly for operation / control panel and cabling as well as protection of well pump.

- **Operation Room**
  - A small room 3 m x 3 m is considered as operation room for each group of wells at a site.

7.2.3 OPERATION AND MAINTENANCE COSTS

The operation part assumed to be based on two main parameters, personnel and consumables costs including power costs. Based on the organization of each facility, personnel structure can be defined for each system component. Keeping in mind that all of RBF facilities will be installed within existing water facilities, this part of personnel cost is ignored.

As for maintenance cost, the cost is based on the normal preventive maintenance programs, which is not yet fully followed by the WSCs, as well available SOPs. An institutional support program is now being implemented via HCWW programs to strength the capabilities WSCs operation team. To avoid complicated procedures for calculation of O&M cost at this stage an overall average figure was considered based on the system components and type of works; civil or electro-mechanical. The annual O&M costs for civil works were estimated by 5-7% of the capital investments. Electro-mechanical is based on 10-15% of the associated capital investments.

7.2.4 TYPICAL CAPITAL AND RUNNING COSTS FOR RBF UNIT

Based on the above described system components as well as the associated cost analysis the following cost figures have been developed.

- **Civil Works:**
  - Well drilling and casing EGP 150,000
  - Well Operation Room EGP 25,000
- **Electro-mechanical Works:**
  - Pumps and accessories EGP 175,000
  - Electrical Works EGP 50,000

In order to consider the geographical location effects on the related costs a multiplier factor will be considered based on the distances from Cairo. An assumption of 5% for each 100 km from Cairo is considered. Accordingly, the following multiplier cost factors are considered:

Giza, 1; Beni-suif, 1.05; Minya, 1.15; Assiut, 1.2; Sohag, 1.3; Qena/Luxor, 1.4; Aswan, 1.5.

7.3 ESTIMATED COSTS FOR POTENTIAL RBF UNITS IN SELECTED GOVERNORATES

Based on the results of the selection procedure described in section 6 for each eligible governorate and location, as well as the basis of cost estimates described above, the following cost estimates have been developed and indicated in Table 30. It should be noted that a fixed figure of EGP 60,000 should be added to each site in order to cover the cost of detailed site investigation.

Table 30: Estimated capital and O&M cost for potential RBF units

#	Governorate	No. of Units	No. of Sites	Capital Cost EGP			Annual Running Costs-EGP	Cost of D Investigation-EGP
				Civil Wks	ME Works	Total	O & M	
1	Aswan	9	3	2,475,000	3,037,500	5,512,500	427,500	270,000
2	Luxor	14	12	3,850,000	4,410,000	8,260,000	633,500	1,008,000
3	Qena	14	12	3,850,000	4,410,000	8,260,000	633,500	1,008,000
4	Sohag	16	6	3,835,000	4,680,000	8,515,000	659,750	468,000
5	Assiut	16	12	3,720,000	4,320,000	8,040,000	618,000	864,000
6	El Minya	0	0	0	0	0	0	0
7	Beni-Suif	0	0	0	0	0	0	0
8	Giza	5	3	950,000	1,125,000	2,075,000	160,000	180,000
	Total	**74**	**48**	**18,680,000**	**21,982,500**	**40,662,500**	**2,923,625**	**3,798,000**

7.4 PROPOSED IMPLEMENTATION PLAN

7.4.1 OVERALL PLAN

The following 3 years implementation plan is proposed for potential RBF projects:

- First year:
    - Detailed site investigation at all locations
    - Construction of urgent priority RBF units
- Second Year:
    - Assessment of implemented RBF units and feedback whenever required
    - Construction of high priority RBF units
- Third Year:
    - Assessment of implemented RBF units and feedback whenever required
    - Construction of moderate priority RBF units

7.4.2 FINANCING SCHEME

Based on the proposed overall implementation plan for the potential RBF units, the following financing plan is expected over the 3 years implementation plan. It is important to state that the priorities at each site will be defined later during the detailed investigation stage in order to categorize the level of priority: urgent, high, or moderate. Table 31 illustrates the financing plan for each governorate over the proposed 3 years implementation plan.

Table 31: Financing plan over the implementation period

#	Governorate	Year 1*	Year 2**	Year 3**	Total
1	Aswan	2,340,000.00	1,788,750.00	1,653,750.00	5,782,500.00
2	Luxor	3,808,000.00	2,982,000.00	2,478,000.00	9,268,000.00
3	Qena	3,808,000.00	2,982,000.00	2,478,000.00	9,268,000.00
4	Sohag	3,640,000.00	2,788,500.00	2,554,500.00	8,983,000.00
5	Assiut	3,648,000.00	2,844,000.00	2,412,000.00	8,904,000.00
6	Giza	920,000.00	712,500.00	622,500.00	2,255,000.00
	Total	**18,164,000.00**	**14,097,750.00**	**12,198,750.00**	**44,460,500.00**

- * year 1: 50% of detailed studies + 40% of Implementation Plan
- ** Year 2: 50% of detailed studies + 30% of Implementation Plan
- ***Year 3: 30% of Implementation Plan

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NATIONAL FEASIBILITY STUDY
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