MEDITERRANEAN DOCUMENT ON GROUNDWATER

Groundwater Resources Management in Egypt In the Concept of IWRM

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GROUNDWATER OCCURRENCE IN EGYPT

Geographical Distribution of Aquifer Systems

Aquifer systems are distributed over the country (Figure 1). Prior to the discussion of their characteristics, it may be helpful to locate aquifers within the geographic regions of the country, as summarized in Table 1.

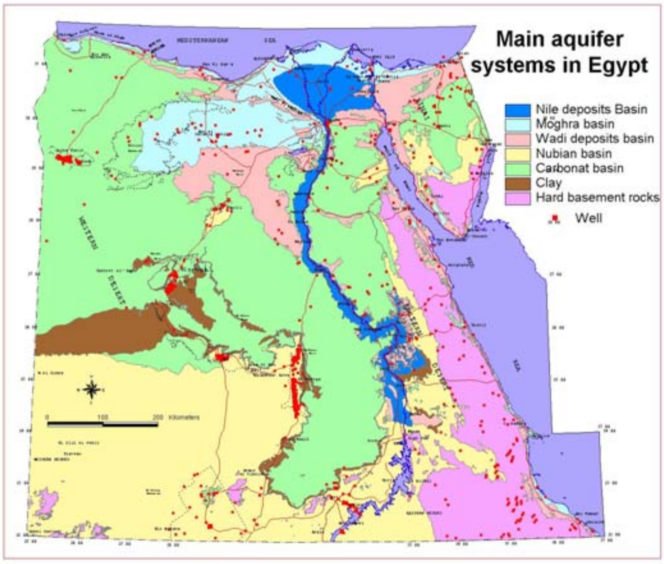


Figure 1. Surface distribution of aquifer systems

Table 1. Geographic Distribution of Aquifer Systems

Aquifer System	Geographical Region						
	Nile Valley and Delta		Western Desert			Eastern Desert	
	Valley	Delta	New Valley	North-West coast	South West desert	Eastern Desert	Sinai
Nubian sandstone							
Nile alluvium							
Hard rocks							
Coastal							
wadi deposits							
Moghra							
Carbonate							

Legend	fresh	brackish
Major Aquifer		
Minor Aquifer		

Characteristics of Main Aquifer Systems

The Hydrogeological framework of Egypt comprises six main aquifer systems. They differ in general characteristics, including extension, transmissivity, renewability, etc. In the following paragraphs, characteristics of such aquifer systems are discussed as an introduction to the assessment of their potential.

The Nile Alluvium

The Nile alluvium is assigned to the Quaternary and Late Tertiary. It occupies the Nile flood plain and a portion of the desert fringes. The aquifer consists of a thick layer of graded sand and gravel covered by clay to silty clay formations in its major part (thickness ranging from 5 to 50 m). The aquifer thickness varies from 300 m (at Suhag) to only a few meters (at Cairo and Aswan). North of Cairo, the aquifer thickness increases gradually until it reaches more than 1,000 m along the Mediterranean coast line.

The transmissivity of the aquifer is considerably high, with an average of about 10,000 m^2/day. This makes the aquifer a good transmitter of water from recharge to discharge locations. The total storage capacity of the system is about 500 million m^3. Groundwater is essentially replenished from activities originating from the Nile, including seepage from irrigation and drainage canals and deep percolation (drainage surplus). Accordingly, it can not represent a resource in itself; but the aquifer can be considered a storage and regulation reservoir.

The high productivity of the aquifer and the shallow depth to groundwater allow the artificial abstraction of large rates (100-300 m^3/hour) with relatively shallow wells (50-150 m) against relatively low pumping cost.

The Nile alluvium extends into the (higher situated) desert fringes, east and west of the flood plain. In the early sixties, with the beginning of land reclamation, large areas along the fringes have been reclaimed, mainly on surface water lifted from main canals. Additional water is also used from locally pumped groundwater wherever the aquifer permits, especially in areas far from the surface irrigation system. Conjunctive use of surface water and groundwater is experienced either spatially or temporally (during the high demand seasons). On the fringes, the aquifer system is replenished from the Nile aquifer system due to their hydraulic interaction. At larger distances (>10 km) groundwater is considered non-renewable due to the low travel time.

One of the main considerations in the allocation of groundwater to user sectors is its generally good quality and the flexibility of operation. Groundwater salinity levels in the Nile valley and southern portion of the delta are below 1,000 ppm which makes groundwater a proper supply for domestic uses. Salinity levels increases sharply to the north.

Nubian Sandstone

The Nubian Sandstone aquifer system is assigned to the Paleozoic-Mesozoic. It occupies a large area in the Western Desert, and parts of the Eastern Desert and Sinai. Groundwater can be found at very shallow depths, where the water bearing formation (horizon) is exposed; or at very large depths (up to 1,500 m), where the aquifer is (semi)confined. The deepest water bearing horizons are generally encountered in the north (Siwa); while the shallowest are encountered in the southern portion (East Uweinat and Kharga). The aquifer transmissivity is generally medium to low, varying from 1,000 to 4,000 m^2/day.

The Nubian sandstone aquifer system is a regional system. It extends into Libya, Sudan and Chad. The aquifer contains a huge amount of non-renewable groundwater dating back to the rainy period (25,000 to 40,000 years). Groundwater quality is generally good (<500 ppm) in the major part, except near the coastal regions and Sinai. Groundwater recharge is limited (estimated at 500 million m^3/year) across the boundaries with Chad and Sudan.

Coastal Aquifer Systems

The Coastal aquifer systems are assigned to the Quaternary and Late Tertiary. They are found in the littoral zones along the Mediterranean and Red sea coasts in the form of scattered pockets.

In the western Mediterranean littoral zone, the water-bearing formation constitutes of oolitic limestone and calcareous sandstone with a thickness of about 40 m. Groundwater is generally under phreatic conditions in the form of thin lenses floating over saline water. It is replenished from rainfall.

The hydrogeologic conditions in north Sinai littoral zone are comparable to those of the north-western coast. Four aquifer systems are distinguished in north Sinai: (i) shallow sand dunes; (ii) alluvial deposits in the delta of wadi el Arish; (iii) calcareous sandstone; and (iv) fluviatile sand and gravel (containing mainly saline groundwater). The fresh water lenses in the shallow sand dunes are exploited through a number of dug wells and galleries. The slightly brackish groundwater in the calcareous sandstone and in the alluvial aquifer of delta wadi el Arish is exploited by shallow bored wells.

Along the Gulf of Suez, the main formation consists of alluvial Quaternary deposits. Miocene sandstone and Nubian sandstone formations also act as local aquifers. Groundwater is generally brackish.

In the littoral area west of the Gulf of Suez, the strata of Hydrogeological interest is the Miocene and the Nubian sandstone. Groundwater recharge occurs from local rainfall; while discharge takes place mainly through groundwater abstraction by wells.

In the littoral area of the Red sea proper, the main strata of Hydrogeological interest comprise the Quaternary and Late Tertiary sandstone. Locally, the fissured Upper Cretaceous and the Late Tertiary act as potential aquifers. Recharge is achieved mainly from local rainfall (Gebal Elba). Discharge, on the other hand, takes place in the form of groundwater flow (natural) and abstraction through dug shallow wells.

The Moghra Aquifer System

The Moghra aquifer system is assigned to the Lower Miocene. It occupies mainly the western edge of the Delta up to the Quattara depression. The Moghra outcrops on the surface in Wadi el Natrun and Wadi el Farigh. The aquifer thickness varies from about 200 m in the east (Wadi el Farigh) to about 800 m in the west (east of Quattara depression). The aquifer transmissivity varies from 500 to 5,000 m^2/day.

Groundwater quality varies from good (500 ppm in Wadi el Farigh) to marginal (10,000 ppm near Quattara). Recharge is achieved mainly through deep percolation from the Nile alluvium (in the east) and groundwater flow across the common boundary of the Moghra and the Nile alluvium.

The Fissured Carbonate Aquifer System

The fissured Carbonate aquifer system is assigned to the Eocene and to the Upper Cretaceous. It predominates essentially in the north and middle parts of the Western Desert, covering about 50% of the surface area of the country. It overlies the Nubian sandstone, and underlies the Nile aquifer system.

The rocks consist of limestone, dolomite, chalk and marl. Locally, they may include phosphate and shale intercalations. The formation of groundwater basins in the carbonate rocks is either a result of land and sea bed subsidence or a result of structural series of faults forming graben shapes favoring the deposition of other rocks and sediments.

The thickness of the carbonate aquifer system varies from 200 m (at Farafra oasis) to about 900 m (at Siwa oasis). The system is characterized by secondary porosity that is considerably higher than the rock porosity (and hydraulic conductivity). Recharge of the aquifer is achieved mainly through: (i) upward leakage from the underlying sandstone; (ii) groundwater flow from adjacent formations (e.g Moghra); and (iii) infiltration from the surface (e.g. irrigation or rainfall). Groundwater quality shows large variations with salinity ranging from 1,000 to 8,000 ppm.

Hard Rocks

Hard rocks are outcropping in southern Sinai and the Eastern Desert. They consist of Precambrian igneous rocks and Mesozoic and Tertiary volcanic rocks. Very little is known about this aquifer system. However, it is expected that the occurrence of groundwater is restricted to fractures and fissures since the rock has no primary porosity. The permeability of the smaller fissures diminishes usually with depth. Hence, groundwater (below e.g. 100 m depth) is only expected in large regional fractures. The aquifer is essentially recharged from its extension in Sudan, and, locally from rainfall (Sinai).

Shallow groundwater is expected to be recharged either through seepage from wadis or by direct infiltration from rainfall. The volume of groundwater in storage is expected to be very limited; and quality is expected to show large variations.

Groundwater Management-Issues and Constraints

Estimation of groundwater potential is an important step that should be carried out carefully prior to planning groundwater development. However, potential may be affected (positively or negatively) by the applied management technology and constraints/issues facing groundwater use and allocation. An effort is made in this section to classify development technologies and major issues facing groundwater development and management. Moreover, potential functions of aquifer systems are discussed as a mean to support allocation decisions. Tables 2 through 4 present the initial/global distinctions, from which the following can be concluded:

- Groundwater in the Nile alluvium can be developed through relatively shallow wells and the aquifer can be used to store water in the fresh zones. Groundwater is suitable for almost all types of uses without any treatment; while desalination (or direct use) can be applied in the northern portion of the delta. However, groundwater is subject to pollution if no controls and actions are taken to protect the resource.
- Development of groundwater in the Nubian aquifer system requires high costs due to the investment on deep wells and the continuous lowering of the groundwater head (operational cost). Groundwater is generally less subjected to pollution; however actions should be taken to protect it. Groundwater is suitable for almost every type of uses, and especially for bottling industry.
- The coastal aquifer systems, although limited in extent, form a very important source of water to coastal communities especially when proper technologies are applied (e.g. rainwater harvesting, skimming). The major issues are represented in the risk of salinization. Desalination is also an important technology especially for drinking and

industrial water supply.

Table 2. Classification of Groundwater Management Technologies

Aquifer System	**Technology**					
	Desalination	Artificial recharge	Deep wells	Shallow wells	Skimming	Rainwater harvesting
Nubian sandstone	Potential	Potential	Current			
Nile alluvium	Potential	Current		Current		
Hard rocks				Current		
Coastal	Current	Potential		Current	Current	Current
wadi deposits		Potential		Current	Current	Current
Moghra	Potential	Potential	Current	Current		
Carbonate	Potential		Current	Current		

Legend	
Current	(light grey)
Potential	(dark grey)

Table 3. Classification of Management Issues

Aquifer System	**Management issue**				
	Groundwater lowering	Groundwater rise	Salinization	Pollution	Land subsidence
Nubian sandstone	Current			Potential	
Nile alluvium	Potential	Current	Current	Current	Potential
Hard rocks	Potential				
Coastal	Potential		Current	Potential	Potential
wadi deposits			Current	Potential	
Moghra	Potential		Potential	Current	
Carbonate				Potential	

Legend	
Current	(light grey)
Potential	(dark grey)

- The Moghra aquifer system is highly affected by the continuous lowering of groundwater and its salinization due to the limited recharge received by the aquifer. Groundwater quality at present is marginal, but may face deterioration if no actions are taken to control abstractions.
- The carbonate aquifer system is a very complex system with respect to of groundwater management and protection from degradation. However, the groundwater quality at several locations is very suitable for medicinal tourism.
- The hard rocks, although unexplored yet, may constitute a promising source of fresh water supply in many regions where other sources of water are absent or limited.
- Finally, shallow wadi aquifer systems can constitute potential sources of fresh water if groundwater management is combined with runoff management. They are subjected to salinization risks if not properly managed.

Table 4. Possible Functions of Aquifers

Aquifer System	Function/Use					
	Large scale irrigation	Small scale irrigation	Industrial	Domestic	Conjunctive use	Storage
Nubian sandstone	Current	Current	Potential	Current	Potential	Potential
Nile alluvium	Current	Current	Current, Potential	Current	Current	Current, Potential
Hard rocks				Current, Potential		
Coastal		Current	Current, Potential	Current, Potential	Potential	Potential
wadi deposits		Current		Current, Potential	Potential	Potential
Moghra	Current	Current	Current, Potential	Current, Potential	Current, Potential	Potential
Carbonate		Potential	Potential	Potential	Potential	

Legend	
Current	(light grey)
Potential	(dark grey)

Groundwater Potential

General

Groundwater potential, as used in this document, refers to the total rates that can be abstracted on a sustainable base; for future uses the term reserves is utilized. Sustainability, on the other hand, can be given several definitions. However, in all cases, the quality of the resource base should be maintained suitable to the originally allocated sector (i.e. no deterioration) and the environment enhanced. Three distinct examples are given below.

1. In the case of renewable groundwater from external sources (e.g. the coastal aquifers and shallow wadi aquifers), the permissible development should be equal to the rate of recharge received. This may not imply that the time span be restricted to a season or a year.
2. In the case of renewable groundwater from internal sources (e.g. the Nile alluvium), the permissible development should be equal to the recharge without affecting flow in surface water channels and the river. Again, this does not imply specific time spans.
3. In the case of non-renewable groundwater (e.g. the Nubian sandstone, Moghra), the permissible development is made to satisfy the economy of developmental activities and to ensure that groundwater will serve several generations (up to e.g. 500 years).

Based on the previous criteria, the country groundwater potential, uses and reserves have been assessed, as summarized in Table 5.

Nile Valley and Delta

A distinction is made in this specific region between old and new lands. In the old land, where the main source of irrigation water originates from the Nile river, the potential is assumed to equal the annual recharge from the various activities (mainly irrigation). On the fringes, where irrigation water is mainly based on groundwater, the potential is estimated based on the saturated thickness of the aquifer, storativity, transmissivity and infiltration rate.

Table 6 summarizes the potential by sub-region; from which it can be observed that the main reserves are confined to the old land. Further development of groundwater on the fringes should thus be considered with extreme care.

Table 5. Potential of Fresh Groundwater in Egypt (year 2000)

Region	Potential (million m^3/year)	Usage (million m^3/year)	Reserves (million m^3/year)
Delta	5,220	4,195	1,025
Valley	3,170	1,932	1,238
Western Desert	3,748	817	2,931
Eastern Desert	90	8	82
Sinai	210	89	121
North-West coast	80	2	78
Total country	12,518	7,043	5,475

Table 6. Groundwater Potential in the Nile Valley and Delta

REGION	SUB-REGION	POTENTIAL (million cum/year)	USAGE (million cum/year)	RESERVES (million cum/year)	DEVELOPMENT
DELTA	West delta	1,425	1,365	60	96%
	East Delta	1,385	1,260	125	91%
	Middle delta	2,410	1,570	840	65%
VALLEY	flood plain	2,420	1,932	1,238	61%
	fringes	750			
TOTAL		8,390	6,127	2,263	73%

Western Desert

In the Western desert, groundwater is mainly abstracted from the Nubian sandstone and carbonate aquifers. The origin of groundwater in the carbonate is, however, mainly from the sandstone. Groundwater is considered, in general, non-renewable both due to the limited recharge across the country boundaries and the large travel time. Restrictions are made in the assessment to ensure economic returns (based on pumping heads and return from agriculture). Potential is estimated only for the oases and their peripheries. Table 7 summarizes the potential by sub-region.

The North-West Coast

For the North-West coast, no reliable figures are available neither on groundwater potential nor on current usage. The figures provided on Table 5 are based on estimations from possible recharge to groundwater using available rainfall data. Although this region of the country has sustained scattered developmental activities on rain and groundwater, settlements have never been stable for a long period. The resources can be enhanced if proper investigations are carried out, taking into consideration the entire catchments of wadis and suitable development technologies.

Table 7. Groundwater Potential in the Western Desert

SUB-REGION	POTENTIAL (million cum/year)	USAGE (million cum/year)	RESERVES (million cum/year)	DEVELOPMENT
SIWA	193	141	52	73%
BAHARYIA	258	61	197	24%
FARAFRA	832	92	740	11%
DAKHLA	913	270	643	30%
KHARGA	163	133	30	82%
EAST UWEINAT	1,205	108	1,097	9%
DARBEL ARBAIN	83	8	75	10%
TOSHKA	101	4	97	4%
TOTAL	3,748	817	2,931	22%

Eastern Desert

The present developmental schemes are confined to shallow wells dugged in wadi aquifer systems and desalination of groundwater. The total groundwater usage is estimated at about 5 million m^3/year (1984) and is likely to reach about 8 million m^3/year at present. There is a potential for further development, especially based on the Nubian sandstone aquifer through deep wells (200-500 m) and in the large wadis which drain in the Nile valley and Lake Nasser.

In addition to the fresh groundwater, large amounts of brackish groundwater are expected to be available in the region. This requires proper assessment and prediction of possible change in salinity as a result of development. One of the areas of special interest is the Red sea coastal area where a variety of aquifers are present. Signs of water availability are the flowing springs

Sinai

In estimating the groundwater potential in Sinai, distinction is made between shallow groundwater in the Quaternary aquifer and deep groundwater in the fissured carbonate and Lower Cretaceous (Nubian sandstone) aquifer, as summarized in Table 8.

The total present usage is about 90 million m^3/year. A large portion of the water is pumped from the Quaternary aquifer in the northern part of Sinai (El Arish, Rafah, Bir el Abd). Most of the groundwater is slightly brackish and poses limitations on its use for potable supplies without further treatment. Fresh groundwater is mainly confined to the sand dunes which are recharged from direct rainfall.

Groundwater salinity shows wide variations with values often exceeding 1,000 ppm (TDS). At El Arish and Rafah the usage has already exceeded the potential resulting in a continuous increase in salinity. In Bir el Abd and Sahl el Qaa, on the other hand, small reserves are still available provided the wells are properly cited.

Both the carbonate and sandstone aquifers can be developed, based on the amount of water in storage and recharge from rainfall. The major portion of available groundwater is found in middle Sinai.

Table 8. Groundwater Potential in Sinai

Aquifer	POTENTIAL (million cum/year)	USAGE (million cum/year)	RESERVES (million cum/year)	DEVELOPMENT
QUATERNARY	81	83	0	102%
CARBONATE	90	2	88	2%
NUBIAN SANDSTONE	40	5	35	12%
TOTAL	211	90	123	42%

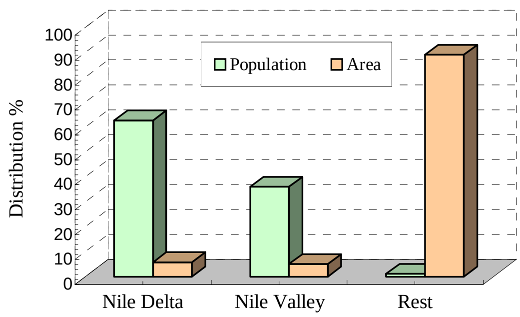
IMPORTANCE OF GROUNDWATER TO THE COUNTRY

Water Resources

Water resources in the country can be summarized as follows:

- A system related to the *Nile…One point delivery at Aswan Dam.*
- Groundwater systems…*Distributed with different characteristics and potential.*
- Flash Flood in Wadis…*Localized but with a wide distribution.*
- Rainfall…*Scarce, Uncertain, Irregular*

Main Issues



First Set: Population Growth

- Population growth against constant quota from the Nile.
- Population growth against a constant inhabited physical area.
- Uneven distribution of water resources over the country physical area.
- Population growth against a decrease in arable land.

Second Set…Inappropriate management of Groundwater and Related Water Resources

- Poor control on wells drilling.
- Poor control on flowing wells.
- Sustainability of non-renewable groundwater
- Allocation of groundwater to uses does not make use of the comparative advantage.
- Inappropriate rain water harvesting techniques.
- Inappropriate protection works from flood risks.

Third Set…Climate Change

- Less rainfall on the Nile basin resulting in less water reaching Aswan.
- Sea water rise and resulting sea water encroachment to the coastal aquifers.
- Cycles of drought and high rainfall on the coastal areas.

- Cycles of flash floods and drought in wadis.

Fourth Set…Pollution

- Poor awareness with respect to groundwater pollution (confusion between pollution of water wells and the whole storage in various aquifers.
- Water supply is not accompanied by sanitary drainage and treatment.
- Uncontrolled reuse of agricultural drainage.
- Uncontrolled damping of solid wastes.
- Poor protection of well heads and well proper (drinking water wells).

Fifth Set…Poor Knowledge on Other possible sources of water

Some sources of water are not receiving attention (Non-fresh groundwater), irrespective its wide distribution and economic use.

Sixth Set…Poor Decentralization, Participation

- Participation in water management is very poor.
- Decentralization is not applied.

The Need for IWRM and Challenges for the Future

The water resources and irrigation sector in Egypt has evolved over thousands of years. At present, the MWRI is responsible for drawing up and implementing water resources policies in coordination with other ministries, for managing and controlling the different water uses. At the same time, various other public institutions, especially at lower administrative levels (e.g. agricultural cooperatives, administrations in reclaimed lands and local representatives of other ministries) have an interest and a role to play in the use and management of water resources. Over the years, various activities and tasks were added to the original activities of the MWRI to improve water management.

A multi-sectoral National Water Resources Plan was prepared under the guidance of MWRI in the years 2000-2004 and was recently approved formally by the Cabinet. The plan has as planning horizon the year 2017 and the water management strategy is aptly called the “Facing the Challenge”. The strategy consists of three basic approaches, supported by a number of institutional (reform) measures.

The future approach to Water Resources management, as outlined in the NWRP, involves the following:

- *Water management is conducted at the lowest appropriate level.*
- The MWRI is transferred from a vertically oriented structure to a more streamlined regulatory body with utmost decentralization potential. This would be achieved as a consequence of conducting a grass root institutional reform program.
- Awareness on IWRM is raised at all levels.
- Awareness efforts are coordinated and complimenting each other.
- *Effective and efficient stakeholders’ participation is achieved.*
- Water is being treated as a holistic resource.
- Smooth and transparent flow of information through appropriate channels.
- Communication and coordination between all levels horizontally and vertically is being achieved.
- The water sector is integrated into one economic national entity supported by a secured national water fund.
- The political will is mobilized to support IWRM initiatives.
- Water quality is fully controlled and monitoring.
- Water quality issues, plans, and actions are executed at the hydrological basin level.
- Agricultural policies and plans are coordinated with irrigation plans.

- Laws of relevance to the water sector are being enforced and environmental compliance is achieved.
- Research is directed to solving national problems

Distinction of Regional Applications

> Water management practices are deeply embedded in history, culture, religion, politics and even language

Different forms, based on regional Characteristics:

- Geographic regions (Oases, Wadis, Nile system (old land, new land), deserts).
- Historic water management (indigenous versus new).
- Water resources (rates and quality, time/seasonal availability)
- Users/Sectors and Types of development.
- Institutions.
- Suitable technologies
- Awareness.

Distinction of Stakeholders of the Groundwater and Flash Floods

REGION	SUBREGION	SOURCE(S) OF WATER	USES/SUITABILITY	STAKEHOLDER
COASTAL	North-West	Rainfall and Runoff	small scale farming drinking	Natives (human) and cattle
		Fresh Groundwater	small scale irrigation drinking	Natives and cattle
		Brackish Groundwater	small scale irrigation fish farming integrated (desal)	Natives Investors Resorts, Investors
	North Sinai	Rainfall and Runoff	small scale farming	Natives and cattle
		Fresh Groundwater	drinking	Natives and cattle
		Brackish Groundwater	small scale farming fish farming integrated (desal)	Natives Investors Resorts, Investors
	South Sinai	Rainfall and Runoff	drinking	Natives and cattle
		Fresh Groundwater	drinking small scale irrigation	Urban, Natives Natives and settlers
		Brackish Groundwater	integrated (desal)	Resorts, Investors
	Eastern Desert	Rainfall and Runoff	drinking small scale farming	Locals and cattle Local
		Fresh Groundwater	drinking	Urban

		Brackish Groundwater	integrated (desal)	Resorts, Investors
INTERNAL	Middle Sinai	Rainfall and Runoff	small scale farming drinking	Natives and cattle
		Fresh Groundwater	drinking small scale irrigation	Urban and natives natives
		Brackish Groundwater	integrated (desal)	Industries, Investors
	Oases	Fresh Groundwater	small scale farming large scale irrigation drinking	Locals and settlers Investors urban and rural
		Brackish Groundwater	Fish farming integrated (desal)	Investors and natives Investors
	Eastern Desert	Rainfall and Runoff	small scale farming drinking	Locals Locals and cattle
		Fresh Groundwater	small scale irrigation drinking	locals
		Brackish Groundwater	fish farming integrated (desal)	Investors Investors
SOUTH EGYPT	Uweinat	Fresh Groundwater	large scale irrigation drinking	Investors
		Brackish Groundwater	fish farming integrated (desal)	Investors
	Darbel Arbain	Fresh Groundwater	small scale farming drinking	Settlers
		Brackish Groundwater	fish farming	Settlers
	Tushka	Fresh Groundwater	medium scale farming drinking	Settlers
		Brackish Groundwater	integrated (desal)	Investors
Nile valley and delta		Fresh Groundwater	drinking, industries supplemental irrigation	urban and rural, investors farmers
		Brackish Groundwater	Fish farming integrated (desal)	fishermen Investors
Fringes of the Nile valley and delta		Fresh Groundwater	small to medium scale irrigation drinking/industries	urban and rural, investors investors
		Brackish Groundwater	integrated (desal)	Investors