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Groundwater Development And management in Egypt

Main Issues and Possible Strategies

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GROUNDWATER DEVELOPMENT AND MANAGEMENT IN EGYPT MAIN ISSUES AND POSSIBLE STRATEGIES

Fatma A. R. Attia

INTRODUCTION

Physical Setting

Egypt lies for the most part within the temperate zone, and the climate varies from arid to extremely arid. The air temperature frequently rises to over 40^0 C in daytime during summer, and seldom falls to zero in winter. The average rainfall over Egypt as a whole is only 10 mm/year. Along the Mediterranean, where most of the winter rain occurs, the annual average rainfall is less than 200 mm/year, decreasing rapidly inland. The evaporation rates are high, being in excess of 3,000 mm/year.

The hydrography of Egypt comprises two systems: (i) a system related to the Nile; and (ii) a system related to the rainfall in the past geological times, particularly in the Late Tertiary and Quaternary. The Nile system comprises the Valley and Delta regions, which are morphologic depressions filled with Pliocene and Quaternary sediments. In the Nile flood plain there are extensive man-made drainage systems, especially in the traditionally cultivated old land. Some extend to the fringes where land reclamation takes place. Such drainage systems discharge to the Nile itself or to the sea. The other hydrographic system in Egypt is the complex network of dry streams (wadis), the formation of which dates back to past wet periods in the Tertiary and Quaternary. This system covers more than 90% of the surface area of Egypt, including the Western Desert, the Eastern Desert, and Sinai. The main catchment areas drain towards the Nile Valley and Delta, to the coastal zones, and to inland depressions.

Population Distribution

Egypt's population is estimated at 63 million (1998). About 63% of the population is concentrated in the Nile Delta area (including the city of Cairo and the coastal Governorates), 36% in the Nile Valley (between Aswan and Giza), and the rest distributed among the remaining area of the country (see Figure 1). This indicates that about 99% of the population is concentrated over 11% of the physical area of Egypt. This situation resulted in: (i) a continuous pressure on the agricultural land and Nile water resources; (ii) a continuous degradation of land and water resources; and (iii) an unhealthy life style.

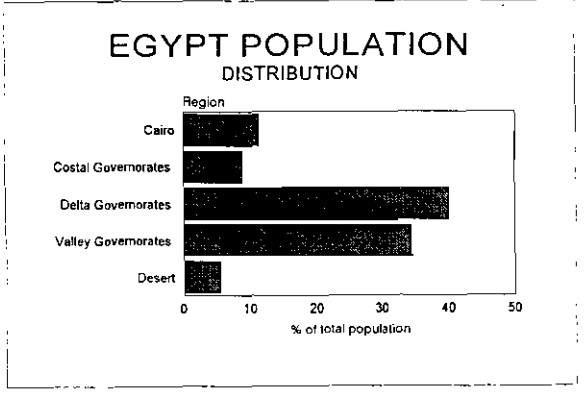
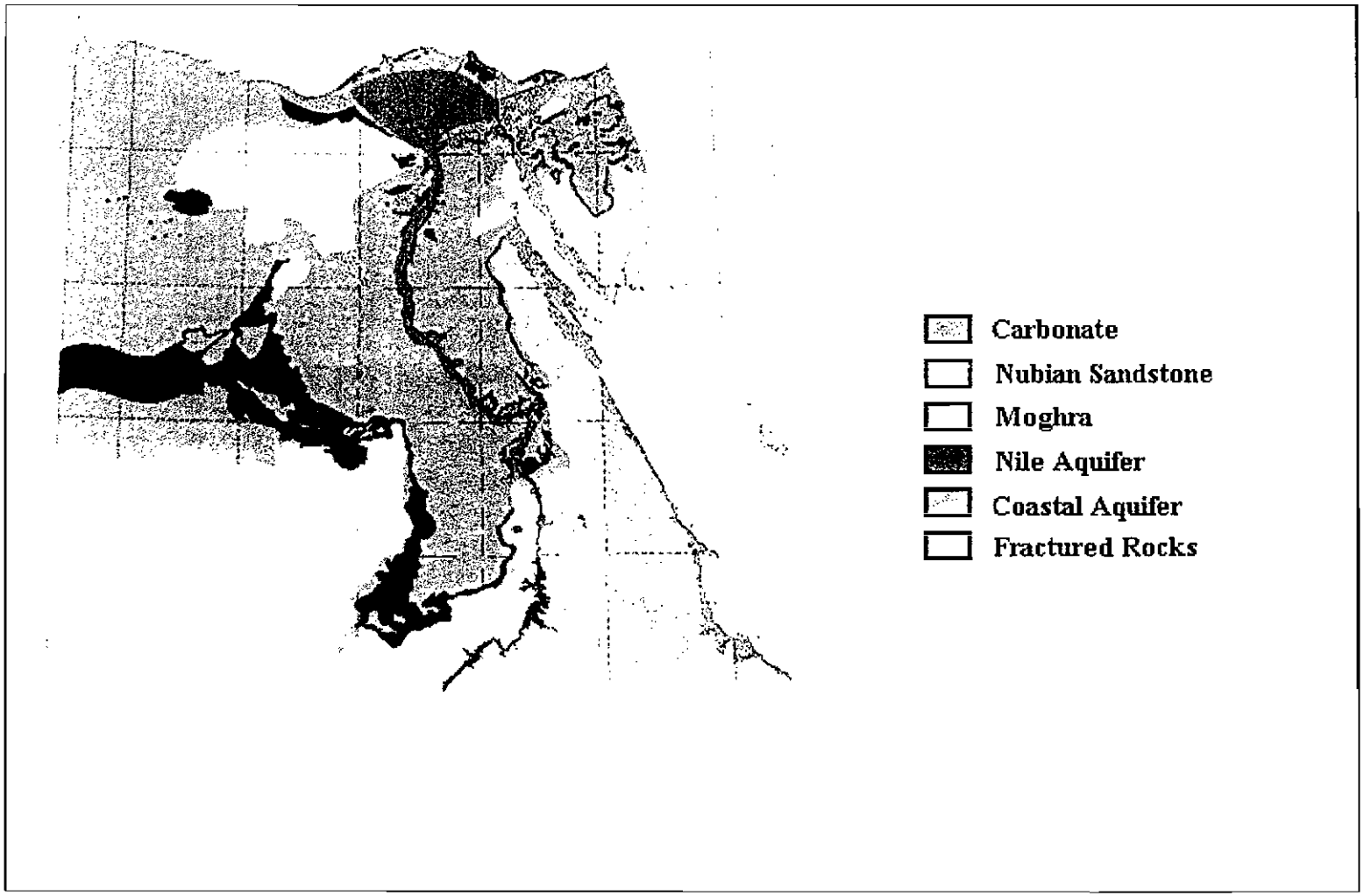


Figure 1. Egypt Population Distribution

Director of the Research Institute for Groundwater, The National Water Research Center building, Egypt.


Carbonate
Nubian Sandstone
Moghra
Nile Aquifer
Coastal Aquifer
Fractured Rocks

Alleviation of the pressure, especially in the northern part of the country and Cairo, is a major concern of the Government. This dictates population redistribution, and initiation of new settlements and economic activities, in which groundwater will play an important role.

Hydrogeological Framework

The hydrogeological framework of Egypt comprises six aquifer systems (RIGW, 1993), as shown in Figure 2:

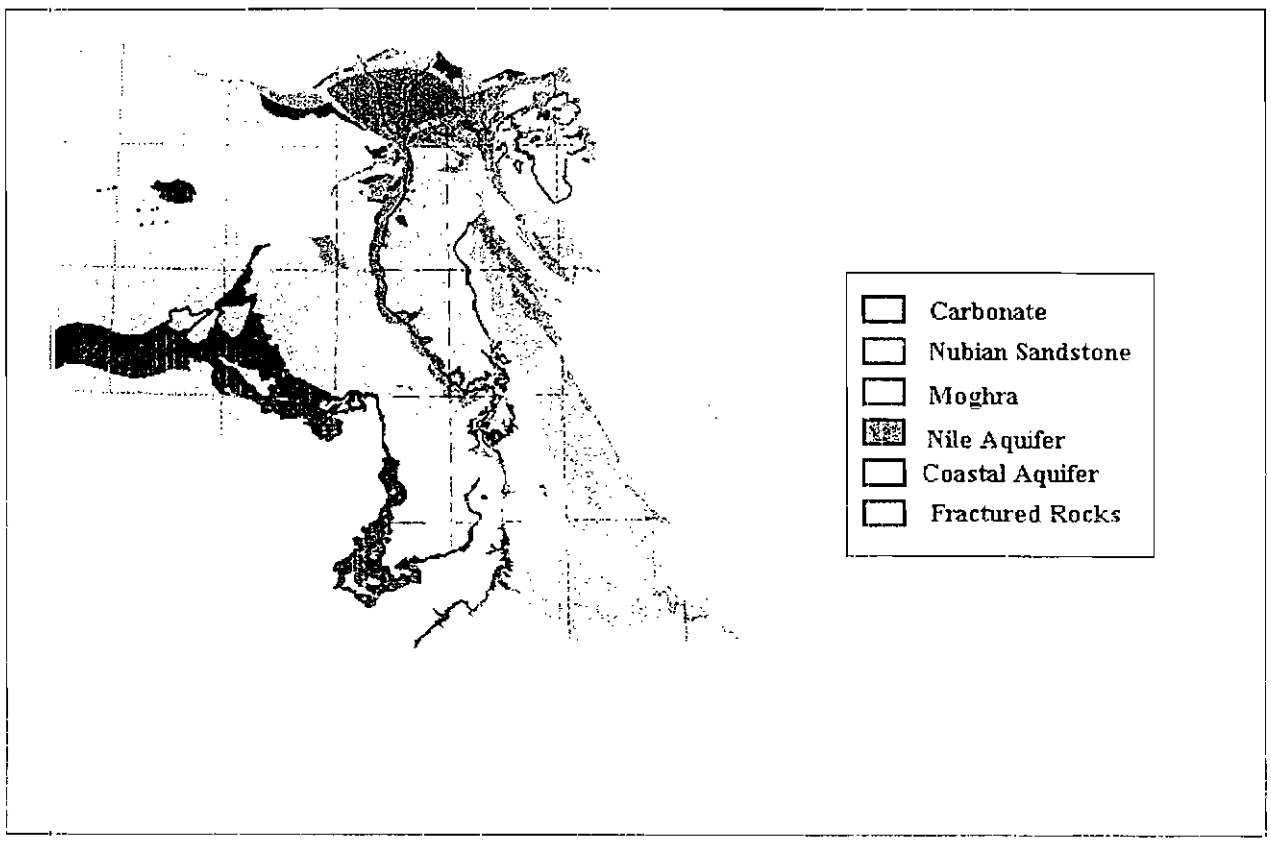


Figure 2. Surface Distribution of Main Aquifer Systems In Egypt

1) The Nile aquifer system, assigned to the Quaternary and Late Tertiary, occupies the Nile flood plain and desert fringes. The storage capacity of the system is about 500 million m^3. Groundwater is essentially replenished from activities originating from the Nile. Accordingly, it can not represent a resource in itself, but rather a storage and regulation reservoir.

2) The Nubian Sandstone aquifer system, assigned to the Paleozoic-Mesozoic, occupies a large area in the Western Desert, and parts of the Eastern Desert and Sinai. Its storage capacity is estimated at 200,000 Km^3, but groundwater is almost non-renewable. Groundwater can be found at very shallow depths, where the water bearing formation (horizon) is exposed; or very deep (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 of East Uweinat and Kharga.

3) The Moghra aquifer system, assigned to the Lower Miocene, occupies mainly the western edge of the Delta. Groundwater is almost non-renewable, except for the portion located on the border with the flood plain.

4) The Coastal aquifer systems, assigned to the Quaternary and Late Tertiary. They occupy the northern & western coasts. Groundwater is found in thin lenses floating over saline water. The main recharge source is rainwater.

5) The karstified Carbonate aquifer system, assigned to the Eocene and to the Upper Cretaceous, predominates essentially in the north-middle part of the Western Desert. It overlies the Nubian sandstone, and underlies the Nile aquifer system. It is essentially recharged through upward leakage from the Nubian sandstone.

6) The Fissured and Weathered hard rock aquifer system, assigned to the Pre-Cambrian, predominates in the Eastern Desert and Sinai. It is essentially recharged from its extension in Sudan, and, locally from rainfall in Sinai.

GROUNDWATER UTILIZATION IN EGYPT

History

The Egyptian civilization has always been based on the Nile. This made the Egyptians live around its course over the history. However, due to the irregularities of the Nile flow, groundwater has been used by the various sectors during the low flow (Tahariq) seasons.

After the completion of the High Aswan Dam (HAD) and complete regulations of the discharges, the Nile surface water became available almost all the year round, especially in the old cultivated land. Accordingly, a large number of wells have been abandoned within the flood plain at the beginning. But due to operational problems facing the surface water distribution, along with the increased land reclamation activities, groundwater became an important source of water for both drinking, supplemental irrigation, and land reclamation. Such developments dictated the initiation of well licensing and groundwater protection regulations. In the deserts, on the other hand, groundwater is the only source of fresh water.

Present Utilization

The present annual rate of groundwater withdrawal amounts to about 5.3 billion m^3 (Figure 3) from all aquifers/regions. It is used as a fresh water resource by almost all sectors (Figure 4) due to its comparative characteristics. The present rate of withdrawal can be augmented by 60% in the Nile system and 70% in fringes. In the desert and coastal aquifers, on the other hand, withdrawals can be increased by more than eight times, based on economic return and technical facilities (essentially the Western Desert). However, the future availability of the resource is determined by the awareness with respect to groundwater protection and the enforcement of protection legislation.

Aquifers have specific characteristics that distinguish them from other water bodies: (i) they can help in removing suspended solids and disease-causing organisms; (ii) they can store water in quantities exceeding those which are or conceivably could be stored in all natural and artificial surface-water bodies; (iii) they can regulate the water temperature and its chemical quality; (iv) they transport water from areas of recharge to areas of need; and (v) they slow-down the natural discharge of water to the surface. As such, aquifers can be utilized as strategic storage reservoirs for water to make up the bulk of the dry-weather flow of streams.

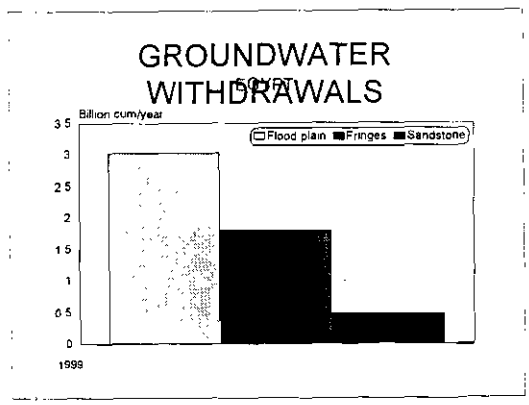


Figure 3. Present (1999) Groundwater Withdrawals

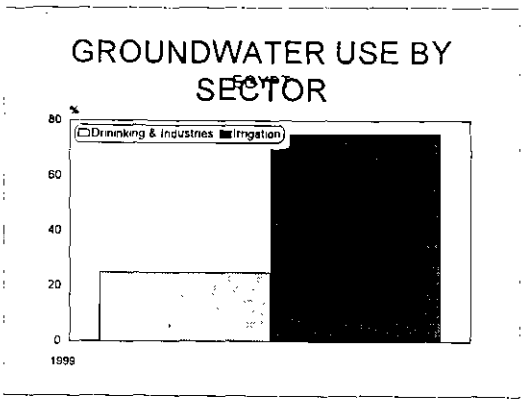


Figure 4. Percent of Withdrawals by Sector

MAIN ISSUES FACING GROUNDWATER SUSTAINABLE USE

Some Issues of Sustainable Development

Identification of development aspects that make development unsustainable has been more successful than the development of remedial measures that reduce or eliminate those undesirable effects. For example, if sustainable groundwater resources development is considered, it is known that pumpage in excess of long-term recharge will result (in the long or short term) in uneconomic (or even in stopping the) development. Similarly, if excessive use of fertilizer and pesticide in agriculture is experienced by farmers, the use of groundwater for drinking will be impaired.

Main issues of sustainable development can be:

1) Short-versus Long-term Considerations: Any plan that does not consider the conflict of short-versus long-term sustainable development and attempt to identify realistic alternatives to overcome the problem, is expected to fail.

2) Externalities: Externalities occur when private costs or benefits do not equal social costs or benefits. Individuals operate primarily on the basis of their own private costs (e.g. cost of sewage/waste disposal, cost of water, etc.) and benefits. If they perceive opportunities which could reduce their costs and/or increase potential benefits, they often take actions which could be beneficial to them but are unlikely to serve the common good.

3) Risks and Uncertainties: For example, the increase in population dictates intensive agricultural production, which is generally accompanied by intensive water development. This may create conflicts among the various uses either due to other economic types of demands and/or due to the reuse of low quality water.

Specific Issues for Egypt

The main issues of sustainable groundwater management in Egypt are diverse. They are a result of institutional, technical, awareness and legislative aspects. Table 1 summarizes the main issues and some examples are given below.

Table 1. Main Issues Facing Groundwater Sustainable Use In Egypt

Aspects	Resulting Issues
1. Institutional (e.g. fragmentation of plans)	1.1 Poor economic return from facilities 1.2 Poor protection of groundwater and water wells 1.3 Overexploitation and loss of investments
2. Technical (e.g. lack of monitoring, unplanned recycling of effluent)	2.1 Over-recharge in some areas and over-exploitation in others 2.2 Pollution from various sources, especially industrial
3. Awareness (e.g.poor understanding of deterioration mechanisms)	3.1 Poor utilization of available groundwater and poor augmentation of the resource 3.2 Groundwater pollution from various sources 3.3 Excessive pumpage resulting in saline intrusion/upconing 3.4 Wastage of groundwater (flowing wells)
4. Legislation (e.g. water wrights, licensing)	4.1 Depletion and loss of investments 4.2 Pollution 4.3 Loss of water wrights

1. Because agriculture is the most spread economic activity, it withdraw the major portion of groundwater and in return it results in the most spread groundwater pollution. Protection of drinking wells (well proper) from agro-chemicals is almost impossible.

2. The lack of comprehensive monitoring and enforcement of legislation is adversely affecting the sustainability of groundwater.

3. Due to the shortage of fresh water, agricultural and domestic drainage water is being recycled irrespective of the adverse impact on groundwater, especially in the rural areas where shallow groundwater is the main source of potable water.

4. Both decision makers and the public lack the proper understanding of degradation mechanisms, resulting in a continuous degradation of this precious resource.

5. In the desert oases, flowing wells are either uncontrolled or poorly controlled, resulting in water wastage and deterioration of agricultural lands.

GROUNDWATER MANAGEMENT/DEVELOPMENT IN EGYPT-OPPORTUNITIES AND CONSTRAINTS

Distinction of Groundwater Management/Development Regions

It is worth here mentioning that groundwater development is restricted to the aquifers that are not yet fully developed. Accordingly, the Nile aquifer system is excluded since it does not represent a new water source.

Distinction of groundwater management/development regions, as made herein, is based on global similarities in the general characteristics of the basins with respect to opportunities and constraints.

Figure 5 illustrates, schematically the possible distinctive groundwater management/development regions. An inset map of the Nubian sandstone aquifer is included because it overlaps with other surface systems (carbonates and alluvium).

Within the Nile aquifer system and fringes, five regions are distinguished:

1) The northern Delta affected by or vulnerable with respect to sea water intrusion.

2) The north-middle Delta, being an intermediate zone with essentially upward groundwater flow.

3) The middle delta with marginal groundwater quality and highly productive aquifer, but the clay thickness is considerable.

4) The southern delta and most Nile valley where the aquifer is of high productivity and the clay thickness is moderate or absent.

5) The fringes (including the Moghra) where the aquifer productivity is marginal and the clay cap is almost absent.

Among the other aquifer systems, the following distinction is made:

1) The Nubian sandstone is generally more productive in the middle-southern portion of the Western Desert than in the rest of the country, being affected by sea water intrusion near the coast.

2) The carbonate aquifer system is of medium to low potential.

3) The coastal aquifers, being of low potential, also need specific techniques in the development.

4) The fractured rocks of low potential.

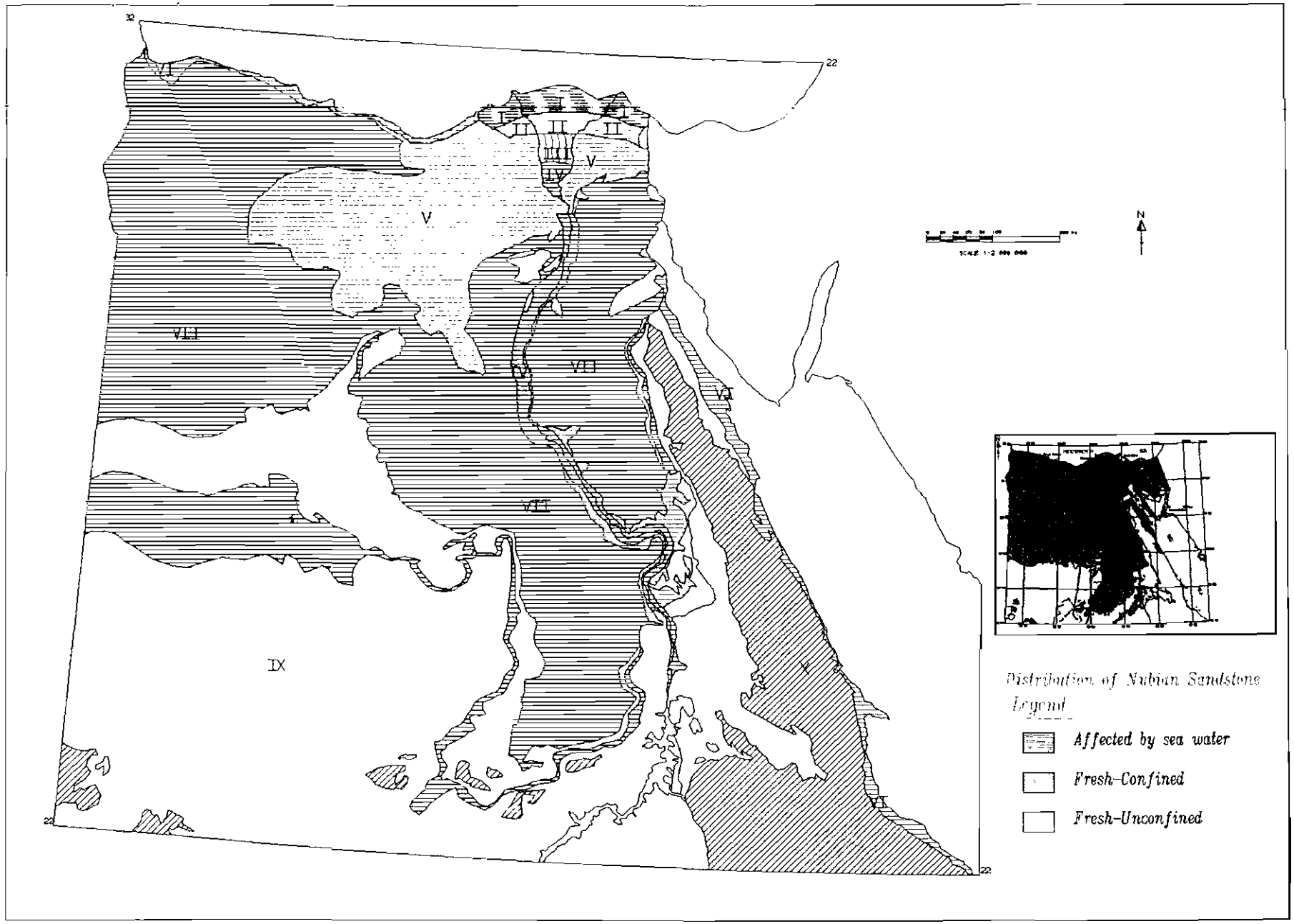

32
22
I
II
III
IV
V
VI
VII
VIII
IX
N
Distribution of Nubian Sandstone
Legend
Affected by sea water
Fresh-Confined
Fresh-Unconfined

Figure 5. Distinctive Groundwater Management/Development Regions in Egypt

Opportunities and Constraints

Opportunities for and constraints facing the development and management of groundwater differ, generally, from one region to another. Table 1 summarizes the relative (qualitative) management/development opportunities and constraints for the various classes.

Opportunities

1) Opportunities for groundwater development exist only in the desert regions where groundwater is still under-developed. This may apply to the Nubian sandstone, the coastal aquifer systems, and the carbonate.

2) Within the Nile system and fringes, groundwater management opportunities are based on the water allocation: (i) priorities to be given to water use sectors, based on economic return; (ii) conjunctive use of groundwater with other resources is an important management practice for water saving; and (iii) the aquifer system can be treated as a treatment and storage reservoir to make for the drought periods (Figure 6). This will help increasing the economic return from the overall water resources management of the country.

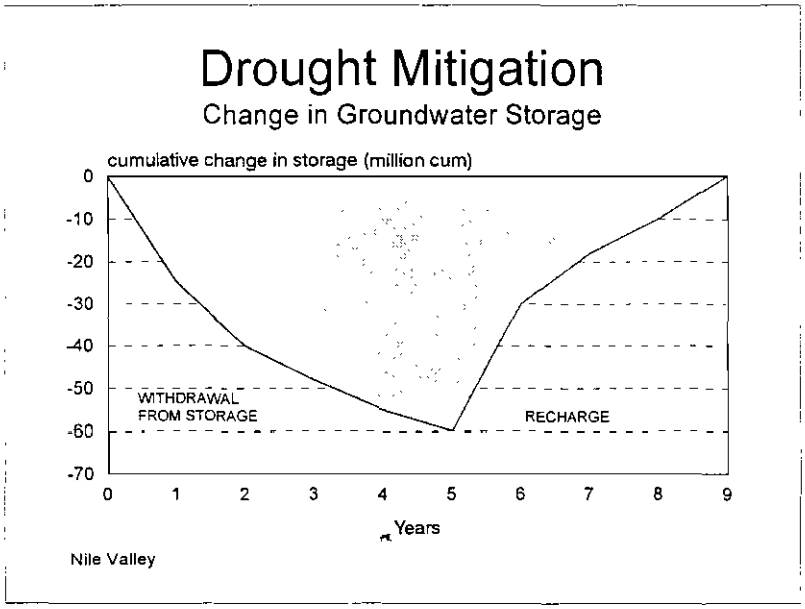


Figure 6. Groundwater Management for Mitigation of Drought

3) The management of groundwater in the coastal aquifers needs to be combined with rain water harvesting, aiming at increasing the opportunities for satisfying fresh water needs to the coastal communities. Retrieval of fresh water, on the other hand, needs specific technology (e.g. scavenging), thus providing more space for recharging fresh water and supplying fisheries with proper water quality.

4) Groundwater in the carbonate shows good potential for various types of economic development, especially with respect to medicinal tourism (RIGW, 1997).

Table 2. Groundwater Management/Development Opportunities and Constraints-By Region

ID	Location	Aquifer System(s)	Management/Development Opportunities	Constraints
I	North Delta	Pleistocene	* Aquaculture	* Sustainability questionable.
II	North-Middle Delta	Pleistocene	* Aquaculture * Tube-well drainage * reuse alone or in conjunction with fresh water	* Economy
III	Middle Delta	Pleistocene	* Municipal * Agriculture * Regulation and flexibility of water management	* Proper Design and protection measures against pollution. * Salt water intrusion.
IV	South Delta and Nile Valley	Pleistocene	* Municipal * Agriculture * Tube-well drainage * Regulation and flexibility of water management	* Proper Design and protection measures against pollution. * Operational, economy.
V	Fringes	Plio-Pleistocene and Moghra	* Municipal * Agriculture in conjunction with fresh water * Tube-well drainage (possible)	* Sustainability. * Possible induced poor quality water.
VI	North-West Coast and South-East Coast	Coastal	* Drinking (skimming or scavenging) * Aquaculture	* Rainwater harvesting for augmentation and sustainability/economy. * Retrieval technology.
VII	North-Western Desert	Carbonates	* Medicinal tourism * Specific Agriculture and Aquaculture	* Proper exploration/investigation for sustainability. * Exploitation technology/economy. * Impacts on adjacent groundwater.
VIII	South-Middle Western Desert	Nubian sandstone	* All purposes * Stage development	* Economy of development. * Special management suitable for deep/free flowing water. * Sustainability.
IX	North Western	Nubian sandstone	* Specific Agriculture and Aquaculture	* Salt water intrusion * Impacts on adjacent groundwater.
X	Eastern Desert	Various	* Drinking	* Salt water intrusion/sustainability

Constraints

With respect to the physical and economical aspects,

1) The main constraints facing the development and management of the non-Nile aquifer systems (with the exception of the coastal aquifers) are the sustainability and economy of such developments.

2) Those concerning the coastal aquifers, on the other hand, are mainly technical and economical.

3) Management of the Nile aquifer system and fringes is confronted by various constraints, namely, pollution from surface activities for the major part of the systems; and salt water intrusion in the coastal regions.

4) Lack of protection measures due to the lack of monitoring systems and historical information concerning the hydrological and quality changes.

The main constraints related to human aspects are the lack of awareness of both the public and the decision makers with respect to integrated water management and pollution mechanisms.

CONCLUSIONS AND RECOMMENDATIONS

1. Groundwater in Egypt has always been considered a secondary source of water, and, thus has been given very little attention in the past. *More attention is needed in the future to ensure a positive role of groundwater in all sectors.*

2. One of the main requirements for the economical development of the country is population redistribution away from the crowded Nile valley and delta, where groundwater is the main source of fresh water. *In this respect, the Nubian sandstone aquifer can play an important role in the development stage and final sustainable economic development.*

3 For a long time, the use of groundwater within the Nile system was only restricted to supplemental irrigation and partly to municipal water supply, which rendered the development/management uneconomical. *Groundwater development and management should be carried out in the framework of integrated water management to ensure the sustainability of projects. Moreover, water resources allocation, e.g. resources among sectors, should be considered at the planning stage.*

4. A set of opportunities are foreseen for the economic development and management of groundwater. These depend on the regions and aquifer systems and their characteristics. The main opportunities include, among others: (i) fisheries based on brackish groundwater; (ii) medicinal tourism based on the carbonate groundwater; (iii) safe and low cost municipal supply; (iv) conjunctive use for irrigation; (v) tube-well drainage combined with surface water augmentation; and (vi) regulation of Nile flow (mitigation of drought and flexibility of water management).

5. A number of constraints, however, may face the management/development strategies. These include: (i) induced saline water and pollution of groundwater; (ii) economic return from water; (iii) lack of suitable technologies and skills with respect to groundwater development and management; (iv) difficulties facing the enforcement of water wells and groundwater protection laws; and (v) lack of proper awareness and participation in groundwater projects.

6. To enhance the role of groundwater in the sustainable development of the country, thus increasing opportunities and decreasing the imposed constraints, the following additional recommendations are proposed:

- Monitoring should be considered an integral part of the project cycle for timely action.

- Human resources development, including both professionals and operators (technicians) should receive more attention.

- Awareness is an important factor in the success of actions. It should not be restricted to the normal public, but extends to the decision makers.

- Enforcement of water protection legislation, and especially groundwater protection laws, should be given more attention.

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