ALTERNATIVE POLICY SOLUTIONS

BACKGROUND PAPER

WATER RESOURCES MANAGEMENT IN EGYPT

Assessment and Recommendations

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Water Resources Management in Egypt
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Alternative Policy Solutions is a non-partisan, public policy research project at The American University in Cairo. Using rigorous, in-depth research and a participatory process of consultations with a diverse range of stakeholders, we propose evidence-based policy solutions to some of the most difficult challenges facing Egypt. Our solutions are innovative, forward-looking and designed to support decision makers' efforts to introduce inclusive public policies.

Abstract

Uneven water distribution, misuse and pollution of water resources, inefficient irrigation techniques, and access to the River Nile's water, are some of the other major challenges confronting Egypt's water security. The enormous challenges facing the water sector in Egypt require the mobilization of all resources and the management of these resources in an inclusive manner. In order to confront the prevailing problem of water scarcity, Egypt endorsed several policies to achieve both integration and decentralization of water management to the lowest possible level. It is believed that conventional scenarios are no longer adequate for meeting the challenges at hand. There are necessary changes to be made in the way water resources are being allocated and managed. Accordingly, alternative policy solutions that cope with the country›s strategic plan of 2030 and describe how Egypt will safeguard its water resources in the future, both with respect to quantity and quality, and how it will utilize these resources in the best way from a socioeconomic and environmental perspective, are essential. Common prerequisites for the success of any of these alternative solutions include the availability of reliable data and information, the provision of proper explanation for the prevalent situation of water resources management in Egypt, and critical analysis of previous and current government plans and strategies.

In view of all above, this background paper represents the corner stone for formulating a comprehensive water policy document that sheds light on the water status in Egypt in the future, based on the prevalent status with respect to the availability of water resources, demand for water, and the institutional and legislative frameworks governing water management.

Keywords: Water Resources Management; Water Policy; SWOT Analysis; Water Vision.

1. Introduction

In Egypt, the paucity of water resources represents the most formidable obstacle impeding the pursuit of national ambitions vis-à-vis the development of water share per capita, which has dropped far below the threshold of water poverty. The main source of water in Egypt is the River Nile (comprising 93% of its conventional water resources and 97% of its fresh surface water resources). Egypt is unique among nations in terms of its absolute dependence on water from a single, determinant source. The 1959 Nile Waters Agreement with Sudan allocates 55.5 billion cubic meters per year to Egypt. Egypt attaches great importance to its water resources and is cognizant of the importance of the preservation and proper management thereof, and is working on the development of additional resources. This includes the desalination of seawater and brackish groundwater, which come on top of the list of strategic options for filling the widening gap between water resources and needs of different sectors.

With population growth on the rise, issues involved in water management become harder and financial investments for enhancing efficiency of usage and developing water resources increase. Also, with the increasing severity of water scarcity in the future and the potential impact of climate changes, it is anticipated that problems weighing on the water system will become aggravated unless prompt action is taken to address and solve them in a comprehensive, inclusive manner. In order to confront these problems, scientific, realistic and feasible strategies for water must be developed. Plans and programs should also be devised for water, which are flexible enough to be modified in light of unexpected changes that may occur in the future. The goal of these strategies is to achieve water security for Egypt both in the present and in the future, and to meet future demands of all sectors while focusing on the necessity of changing from a culture of water abundance that has prevailed in the past, to one of water scarcity that is forecasted in the future.

Certainly, most solutions for issues related to development and management of water resources do not necessarily come from the water sector, with all its agencies and institutions. On the contrary, most often, they emanate from other sectors, related directly or indirectly to the water sector. Hence, there is a great need for Egypt to strengthen its water-resource planning and management system, by prioritizing the water sector's problem in its development plans for all ministries and governmental bodies, civil society organizations, and the private sector, with all its technological and financial capabilities. With the current state of water scarcity in sight, this background paper presents a diagnosis of the Egyptian water system, as well as its policies and considerations. The paper aims to delineate the current water resources management system with respect to technical, institutional and legal aspects. The paper also assesses the extent to which Egypt›s water policies are fit for meeting future challenges, and intends to provide an evidence-based evaluation on water resources management at both the national and the domestic level. In this context, we tackle the following research questions:

- What are the drivers and limiting factors of water resources' management in Egypt?
- What are the challenges and opportunities of water resources' management in Egypt?
- What are the shortcomings and loopholes in previous and existing government policies?
- What are the main obstacles hampering the implementation of integrated water-resource management (IWRM) in Egypt?
- Are the existent water-allocation mechanisms suitable under a state of water scarcity?
- What are the guiding principles for Egypt's water vision?

2. Assessment of the Present Water Status

2.1 Water Resources

Egypt lies in a region best described as semi-arid to arid , where most of its renewable fresh water is transported by the River Nile from the Ethiopian Highlands and the Equatorial Plateau. The aggregate available conventional fresh water supply is 59.8 billion cubic meters per year (BCM/y) (Omar and Moussa, 2016), comprising Egypt's Nile water quota of 55.5 BCM/y, nonrenewable deep groundwater (2.4 BCM/y), and coastal scattered winter rainfall and flashfloods of about 1.6 BCM/y on average, in addition to the desalination of seawater and brackish water (0.3 BCM/y). Non-conventional resources include reuse of treated agricultural drainage water, wastewater and industrial wastewater, as well as the shallow aquifer in the Nile Valley and the Nile Delta.

2.1.1 Conventional water resources

Nile River: Its source is the Ethiopian Plateau, representing 85% of the river's yield at Aswan, the Great Lakes, and the South of Sudan, accounting for about 15%. The Nile's annual water yield fluctuates; its natural yield is about 84 BCM/y. It is also characterized by a series of successive high/low floods that may occur for several years at a time, which do not occur in a purely random phenomena. This came to be known as the Hurst phenomenon, after Harold Edwin Hurst who was the first scholar to study this phenomenon.

Given the substantial discrepancy with respect to the river's annual water yield and the succession of droughts and floods; it was not possible to benefit from the whole yield except through the establishment of a reservoir with sufficient storage capacity to hold superfluous water from floods in high-yield years, to be used in low-yield years. The High Dam, with its "century" or continuous storage capacity, is used to strike a balance between the water yield reaching Aswan and water released downstream from the reservoir. The Nile River is completely controlled by the dams at Aswan, in addition to a series of seven barrages between Aswan and the Mediterranean Sea. The live storage capacity required for the High Dam was calculated to be about 90 BCM to ensure annual release of water for both Egypt and Sudan, which is about 74 BCM, alongside losses due to evaporation from Lake Nasser, estimated at 10 BCM/y on average (Allam, 2007). These conclusions transpired following extensive studies conducted by Hurst and his colleagues.

In conclusion, the High Dam's reservoir enabled Egypt to face a series of high and low floods in a highly efficient manner during the past decades. However, given Egypt's severe sensitivity towards its limited water resources originating outside its geographical boundaries; we must be mindful that any future changes in the properties of the yield, or the share—whether in terms of increase or decline—requires a comprehensive re-evaluation of the situation and studying the different methods for maintaining an acceptable degree of tolerance for the risks of floods and droughts. This calls for changing the rules of operation, provision of additional storage capacity, imposing new restraints on quantities released from the reservoir, and/or changing the method of management and distribution of water resources.

Deep groundwater: Groundwater is an important source of fresh water in Egypt. In terms of groundwater hydrology, Egypt can be divided into four provinces: (1) Western Desert, (2) Eastern Desert, (3) Sinai Peninsula, and (4) Northern Coastal Zone. The Nubian Sandstone Aquifer in the Western Desert is the most important and the largest in North Africa. There are substantial quantities in this aquifer in the Western Desert, including the oases of Al-Dakhla, Al-Kharga, Al-Farafra, Siwa, East Al-Owaynat, and Darb Al-Arbe'en. However, the quantity that can be readily economically viable is limited. Groundwater in this aquifer was formed during successive rainy eras and its ability to replenish is currently limited and, as such, it is considered a non-renewable reservoir.

Potential extraction from groundwater in the Western Desert and the oases totals about 3.75 BCM/y with the purpose of maintaining the sustainability of this groundwater storage for 200 years. At the moment, 1.75 BCM/y is utilized, while additional potential for future development plans stands at 2 BCM/y (MWRI, 2010). On the other hand, the Nubian Sandstone Aquifer in the Eastern Desert has relatively limited potential. No detailed studies to assess its water potentials have been conducted, except one for Al-Alaqy valley, which concluded that it was possible to utilize the underground storage at an extraction rate of 0.057 BCM/y. In Sinai, groundwater exists in three aquifers, i.e. the shallow aquifer, the medium-depth aquifer, and the deep aquifer. The total quantity of non-renewable groundwater is 2.4 BCM/y (Omar and Moussa, 2016).

Rainfall and flashfloods: Rainfall in Egypt is very scarce, save for a narrow strip along the northern coastal areas. Annual precipitation rates in the northwestern coast range between 192 mm/y in Alexandria and 102 mm/y in Al-Saloum, and gradually decrease eastwards reaching 80 mm/year in Port Said. They then increase to 100 mm/y in Al-Arish, and climb sharply to 300 mm/y in Rafah. Moving south of the coast, rainfall begins to decline sharply. Some of this rainwater percolates underground, thereby recharging coastal aquifers. As for flashfloods, they are a common phenomenon that takes place in arid and semi-arid regions. They occur as a result of heavy precipitation in a short time. Flashfloods occur in the Red Sea area and in southern Sinai; this water could be used to recharge the shallow groundwater aquifers. Water from flashfloods is utilized by building dams and ground reservoirs for collection and future utilization. Rainwater and flashfloods on the coasts of the Red Sea, Sinai, and the Mediterranean Sea are the foremost sources of fresh potable water for drinking and irrigation for Bedouins and tribes living in these areas. The aggregate quantity of rainwater currently utilized is estimated at 1.6 BCM/y (Omar and Moussa, 2016).

Desalination: Seawater desalination will be one of the most significant approaches for water resources' development in the future. Egypt maintains an auspicious geographical position, bordering the Red Sea to the east and the Mediterranean Sea to the North. This allows for successful implementation of desalination in different areas along the two coastlines, as well as in the Sinai coastal zone. The only remaining element is the high costs involved in desalination. Upon comparing seawater desalination to that of hard water (saline or brackish), where salinity levels range between 1,500-5,000 ppm, we find that it is less costly and has higher economic feasibility. The total quantity of desalinated water is 0.3 BCM/y (Omar and Moussa, 2016).

2.1.2. Non-conventional water resources

In addition to the abovementioned water resources, there are other sources of water that can be used to meet part of Egypt's water requirements. These sources are called non-conventional resources, and include: renewable groundwater from the shallow aquifer in the Nile Valley and Delta; reuse of agricultural drainage water; and reuse of treated domestic and industrial wastewater. The aquifer in the Valley and Delta is replenished with water leaking from the Nile, irrigation networks and agricultural lands. The shallow one exists in the coastal area in Northern Sinai, and is replenished by precipitation and flashfloods. Water in this aquifer exists at a depth of 100 m. The medium-depth aquifer is located in the area of Valleys, in the center of the Sinai Peninsula. As for the Nubian Sandstone Aquifer, which is the equivalent of the Nubian Sandstone Aquifer in the Eastern Desert and the Western Desert, the water depth ranges between 150 m and 350 m from the surface. The quantity of groundwater extracted from the three aquifers is estimated to be 0.145 BCM/y. As for non-fresh (brackish) water, it exists in different formations in most basins (Egypt's coasts, periphery of the Valley and Delta, Eastern and Western Deserts, Sinai, and West Delta). The aggregate quantity of shallow ground water is 6.5 BCM/y (Omar and Moussa, 2016), while total dissolved salts range between 1,500 to 15,000 ppm. This quantity is still within the limits of safe yield, which is estimated to be 8.4 BCM/y (MWRI, 2010).

Reuse of drainage water in the Nile Delta has been adopted as an official policy since the late seventies. The policy calls for recycling agricultural drainage water by pumping it from main and branch drains and mixing it with fresh water in main and branch canals. Agricultural drainage water presently being reused is estimated to be 15 BCM/y (Omar and Moussa, 2016). This quantity includes water reused in Lower Egypt, as well as water taken by farmers directly from drains and reused. In addition, it includes water flowing from drains in Upper and Lower Egypt into the Nile, and quantities of water reused in Fayoum Governorate. It is noteworthy that all wastewater networks in the Valley discharge their wastewater into the agricultural drainage network, then into the Nile. As for the Delta, most of the wastewater flows into drains and, from there, into the Northern Lakes. There is need for continuation and expansion in the area of wastewater and industrial effluent reuse, as this constitutes an important strategic resource for filling the gap between available fresh water resources and spiking demand. However, reuse of domestic and industrial wastewater must comply with environmental and health standards.

2.2 Water Demand

Demand for water is skyrocketing due to population growth, improved living conditions, the increase in cultivated land areas through reclamation of new lands, and the promotion of industrial development. Agriculture, drinking water, and industry account for the largest share of water consumption. Water is also important for the generation of electricity, navigation and the preservation of the environmental habitat, which are considered water users, not consumers. A part of water resources is earmarked for serving tourism, entertainment, and fisheries.

Water uses in agriculture: The agricultural sector is the largest water user and consumer in Egypt. Irrigation water accounts for about 85% of total water requirements. In terms of actual consumption, the share of irrigation water accounts for about 93% of total actual consumption (agriculture, drinking and industry), taking into consideration that actual consumption in agriculture represents 40.4 BCM/y, taking into account evaporation and transpiration. However, the overall volume allocated for agriculture is 68.5 BCM/y, including field application, distribution, and conveyance losses (Omar and Moussa, 2016).

Municipal water uses: Municipal water usage includes water supply for major urban and rural villages. Part of this water comes from the Nile system, either via canals or direct intakes on the river, while the other part comes from groundwater resources. Steady population growth, urban expansion into the countryside, and the introduction of water into rural areas, have led to quantum leaps in the rate of drinking water consumption over the past few decades. The percentage of drinking water coverage nationwide reached almost 100% (96% to be exact). Surface water represents the main source of drinking water, whereas groundwater accounts for 15% of total water supply. Despite the fact that desalination of seawater or brackish water represents a small fraction of drinking water uses on the national level, it is considered a major source of drinking water in some tourist areas alongside the Red Sea and the Sinai coastlines. The aggregate quantity of water released to the drinking water sector is 9.9 BCM/y (Omar and Moussa, 2016).

Industrial uses of water: Industry has developed exponentially over the past few decades. Water requirements for the industrial sector are estimated at 2.4 BCM/y (excluding water used for cooling power stations). Actual consumption of water in industry stood at about 0.85 BCM/y, that is, an efficiency rate of 35% (Omar and Moussa, 2016).

Water uses for Navigation: The navigation sector is considered as a water user, rather than a consumer. The Nile River's main channels and part of the irrigation network are being used for navigation. The construction of the High Dam in Aswan improved navigation conditions in the Nile year-round because of managing the Nile River's discharges in a manner that ensures the existence of an appropriate depth for navigation in both the summer and winter seasons. However, since the mid-1980s, and in light of the increase in water demand for drinking, agriculture, and industry; water discharges have been reduced during the winter, which used to be wasted in the sea. This has lowered water levels during this period (the period of the least water requirements), and caused difficulties in river navigation. Thus, it was necessary to develop and improve navigational courses and use advanced technologies for organizing river-navigation traffic.

Water usage for power-generation: The Nile flows over a distance of about 1,200 km from the High Aswan Dam to the Mediterranean. The total annual hydroelectricity generated by industrial works along the river's course is about 14,632 gigawatt/hour. Hydroelectricity is generated through the power stations of the High Aswan Dam, Aswan Dam 1, Aswan Dam 2, New Isna Barrage, the New Naga' Hammadi Barrage, and Al-Lahoun Regulator at Bahr Yousif. It represents about 8% of total power generated in Egypt, equivalent to about 182,000 GW/hour/year.

Water usage for fisheries: Fish farms have spread extensively in Egypt, given their substantial return in comparison to other agricultural activities. Fish cages are widespread along the Nile and its two branches. Fish farms also exist abundantly in agricultural lands. At present, there are about 300,000 feddans of fish farms along canals, drains, and the Northern Lakes (MWRI, 2010). About 50,000 feddans exist in the cities of Al-Hamoul and Balteem in Kafr Al-Sheikh Governorate, with the remaining area in Port Said Governorate, North Sinai Governorate (in Sahl Al-Hasseneya and Sahl Al-Tina), Sharqiya Governorate and in the Northern Lakes (where more than 50% of fish farms are located). Aquaculture is today the largest single source of fish supply in Egypt, accounting for almost 75% of total fish production in the country, with over 99% produced from privately owned farms. At present, aquaculture production in Egypt is the largest in Africa with about one million tons per annum (Shaalan et al., 2017). Save for a very limited number of isolated exceptions, most aquaculture activities are located in the Nile Delta region. Aquaculture is conducted using a variety of systems, with varying levels of technology. The high rate of return on investment in aquaculture has attracted a large number of small-to-middle level investors who tend to have a more scientific background compared to traditional farmers.

2.3 Water Balance

The current volume of conventional water resources in Egypt is 59.8 BCM/year from the River Nile and from effective rainfall on the northern strip of the Mediterranean Sea; so, as Sinai and from non-renewable deep groundwater from Western Desert so as Sinai. While the total current water requirements for different sectors is 81.3 BCM/year, the gap between the needs and availability of water is about 21.5 BCM/year. This gap is compensated by recycling drainage water and wastewater, as well as the utilization of shallow groundwater (Table 1).

Table 1: Current Water Balance Status (Omar and Moussa, 2016)

Water Resources	Quantity (BCM/year)	Water Demand	Quantity (BCM/year)
Conventional Nile River Precipitation Fossil Groundwater Sea Water Desalination **Non-conventional** Shallow groundwater Agricultural Drainage and Wastewater Reuse	55.5 1.6 2.4 0.3 6.5 15	Agricultural Domestic Industrial Others	68.5 9.9 2.4 0.5
Total	**81.3**		**81.3**

2.4 Water Resources Management

Egypt is unyieldingly committed to developing and protecting its water resources in order to meet the requirements of its entire citizenry. Consequently, the country is managing its water resources system flexibly and dynamically, by considering various technical, institutional and legislative issues. Several ministries are involved in the management of water resources in Egypt. The Ministry of Water Resources and Irrigation (MWRI) plays the lead role in this respect. MWRI is in charge of development and management of water resources, and operating and maintaining dams, weirs, irrigation canals and drainage canals, as well as monitoring water quality. The Ministry of Agriculture and Land Reclamation (MALR) is involved in improving agricultural activities and land reclamation, including water management at the on-farm level. The Holding Company for Water and Wastewater (HCWW) provides water supply and sanitation services. The Ministry of Health and Population (MoHP), the Ministry of State for Environmental Affairs (MSEA), together with the Egyptian Environmental Affairs Agency (EEAA), and the Ministry of Local Development (MoLD), also have cooperative and consultative roles in the sector.

2.4.1 Management of the irrigation network

The country has initiated many activities for managing the irrigation network to cope with the ballooning population and its related demand. MWRI distributes irrigation water via the irrigation network (35,000 km) in coordination with the MALR, based on the planned cropping pattern, and a number of projects have been implemented in this respect. The Northern Sinai Development Project included Al-Salam Canal in front of the Damietta Lock and Dam, with the aim of reclaiming 220,000 feddans west of the Suez Canal. A siphon was built in 1997 under the Suez Canal to bring water to the Sinai via Al-Sheikh Gaber Al-Sabah Canal to reclaim 400,000 feddans east of the Suez Canal. The New Valley Project (Toshka) comprises a system of canals surrounding the Sheikh Zayed Canal, fed from Lake Nasser via the Mubarak Pumping Station to irrigate 560,000 feddans in the Sahara. The project commenced in 1997 and the pumping station was completed in 2003, and the entire project is scheduled for completion before 2020. Private investors were planned to complete the tertiary canals that deliver water to farmers. In addition, the MWRI has been implementing various activities for enhancing the efficiency of the irrigation network. The maintenance and lining of irrigation canals thrice yearly is undertaken by irrigation districts on the local level, while maintenance of irrigation infrastructures controlling distribution is being conducted according to a timeframe that heeds the technical condition of infrastructure.

2.4.2 Irrigation improvement project (IIP)

The project began in 1984, but only became a full-pledged program in 1988, with the aim of improving 3.5 million feddans in the Delta by 2017, as well as minimizing water losses in irrigation networks in order to use saved water in reclaiming more land. The program activities at the on-farm level include developing irrigation basins and laser leveling, as well as crop rotation (through the Ministry of Agriculture). Water-user associations are also formed at the level of irrigation ditches and branch canals to participate in operation and maintenance. Several studies (World Bank, 2016 and Oosterbaan, 1999) have assessed the feasibility of irrigation improvement projects, revealing the following findings:

- Developing canals and irrigation ditches saves 7% of irrigation water.
- The improvement project leads to reducing field irrigation costs from 50% to 60%.
- Usage of pipes for watercourses (irrigation ditches and basins) leads to agricultural land savings at a rate of up to 20%.
- Improvement of irrigation increases agricultural productivity by 12%.
- Developing irrigation and using pipelines instead of uncovered irrigation ditches greatly improves environmental costs and reduces pollution problems.

Precision (laser) leveling of areas where field crops are grown and the development of irrigation basins lead to the enhancement of efficiency of irrigation water utilization. The overall, combined impact of the implementation of irrigation improvement projects can theoretically enhance irrigation water usage efficiency and save about 20%. This percentage is divided among the elements of the irrigation improvement system in terms of improving efficiency of conveyance and application. However, on the practical side, the percentage can reach 15% or less.

The total improved area since the beginning of the project up until 2010 is about 510,000 feddans at the main and secondary levels, where 401,000 feddans were improved at the tertiary (mesqa) level (MWRI, 2010). Moreover, 7460 water users› associations were established at the tertiary level and 74 at the secondary level. In cooperation with the World Bank and other donors, the MWRI continued improving irrigation in old lands via the Integrated Irrigation Improvement and Management Project (IIIMP). The IIIMP added about 120,000 feddans to the total improved area, out of the target of approx. 500,000 feddans in Beheira and Kafr El-Sheikh Governorates. Furthermore, the project established 1,530 water users› associations at the tertiary level and 200 at the secondary level (World Bank, 2016).

The strategy of the MALR for sustainable agricultural development up until 2030 adopted the national project for developing and upgrading field irrigation systems for lands in the Valley and the Delta. The project aims to increase agricultural production; improve agricultural quality so as to achieve food security; maximize utilization of land unit and water unit; enhance water usage efficiency by expanding application of advanced irrigation system in the lands of the Valley and the Delta; increase farmers' income; create new work opportunities; bring about sufficiency, equality, reliability, responsiveness and transparency with respect to the distribution of water and the accessibility of water to fields in the right time and quantity; and form water users associations and their participation in the improvement efforts.

Improvement projects, if replicated in all agricultural lands, will lead to a decrease in seepage losses. This would translate into less quantities of reused water from the groundwater stock in the Valley and the Delta, or agricultural drainage water, not just because of the decline in quantities of water discharged into drains, but also due to the increase in the level of water salinity and the concentration of agricultural pollutants. Hence, the real benefit from irrigation improvement is not the quantity of water that can be saved; rather, water quality, as development will reduce fresh water losses instead of reusing groundwater or agricultural drainage water of a less deteriorated quality.

2.4.3 Management of the drainage network

Agricultural drainage in Egypt comes from canal ends, leakage from waterways, or the removal of unused water from agricultural lands by overflows or through the soil. Agricultural drainage water and effluents from municipalities and industries are collected and transported via an extensive drainage network. This system comprises field drains (open drains or sub-surface drains), collector drains, and main drains, which convey the water into irrigation canals and the River Nile, where it mixes with freshwater for further downstream use. The drainage system is largely operated by gravity flow, except for a number of pumping stations in the Northern Delta. Capturing and mixing drainage flow with water from main canals and the River Nile at centralized mixing pump stations is called 'official reuse.' Another type of official reuse is called 'intermediate reuse,' where water can be mixed from smaller, less-polluted drains with lower-order irrigation canals. These types of reuse are planned and managed by the MWRI with an impressive track record.

2.4.4 Management of drinking water and wastewater services

Egypt has been following a successful policy for drinking water supply, which includes the expansion of service delivery, the introduction of modern technology in operations and maintenance, as well as management, and increasing the private sector's participation in activities, which are unessential to its mission. The total number of water treatment plants is 2,175 with a capacity of 25.3 MCM/y. The total length of the drinking water network is 165,000 km, with a coverage reach of 96 %, while the total number of wastewater treatment plants is 400, with a capacity of 10.62 MCM/y. The total length of the potable water network is 45,000 km, with a coverage reach of 56%. The government has been supplying safe potable water to the entire population in 222 cities and to the majority of 4,617 villages. Sanitation services in Egypt are less developed compared to water supply services. Sanitation coverage is more than 95 % in urban areas and less than 15% in rural areas. The low coverage in rural sanitation, in combination with sub-optimal treatment, engenders serious problems of water pollution and degradation of health conditions because the majority of villages and rural areas directly discharge their raw domestic wastewater into the waterways. Only 0.7 BCM/year of treated wastewater is being used in irrigation, of which 0.26 BCM (secondary treated) and 0.44 BCM (primary treated) are used to cultivate forests and some crops. Another 2.95 BCM/year is pumped to drains and canals in Cairo and the Delta. The total land allocated for wastewater reuse projects is 88,000 feddans in different governorates (Abdel-Wahab, 2015). Industrial wastewater is particularly tied to small and medium industries, which is discharged into waterways and sewerage networks.

2.4.5. Institutional framework for water management

The government has been taking its first steps towards changing the institutional environment, roles and functions of the different water organizations. The government has been strengthening the decentralization, privatization and participatory approach within the water boards and water users' associations. The MWRI established 39 integrated irrigation and drainage management units (integrated handasat) in Qena, Aswan, Sharqiya, Gharbiya, Beheira, and Kafr El-Sheikh. The number of these units was supposed to reach 104 in 2012, but due to the recent developments in the country, this target has not been achieved until date .The MWRI has restructured its role to include establishing integrated water districts at the local level. Ten districts were established in Fayoum, Qena, Aswan, Gharbiya, and Beheira that represent 30% of the target (Bahaa el-Din, 2012). The concept of cost recovery for construction, operation and maintenance was applied to ensure sustainable development.

2.4.6 Legal framework

There are a number of main laws of relevance for water resources management, including laws on irrigation, drainage and water quality. Irrigation and drainage laws include:

- Law 12/1984 on Irrigation and Drainage;
- Law 213/1994 on Farmers' Participation and Cost-Sharing.
- Laws and decrees for environmental protection include:
- Law 93/1962 on Discharges into Open Streams and its amendments in the years 1962, 1982, and 1989;
- Law 27/1978 on the Regulation of Water Resources and Treatment of Wastewater;
- Law 48/1982 on the Protection of the River Nile and its Waterways from Pollution;
- Law 4/1994 on Environmental Protection.

3. Challenges Facing Water-Resource Management in Egypt

Given its location in the belt of arid regions, Egypt is extremely sensitive towards its limited water resources, which flow into the country from beyond its geographical boundaries, as it depends on the Nile as the main source of water. The other sources, on the other hand, do not exceed 5% of these resources. Water resources management, including water quality management and environmental protection, is the main concern with respect to sustainable development. The water resources system in Egypt has been grappling with many problems and challenges, chiefly:

- **Limited availability of supply resources:** Surface-water resources originating from the Nile are already fully exploited, and shallow groundwater resource are being brought into full production. Effective rainfall on the northern strip of the Mediterranean Sea and the Sinai, and non-renewable deep groundwater from the Western Desert as well as the Sinai Peninsula are very limited and rare resources. The total water supply is 59.8 BCM/y, while the total current volume of water requirements for different sectors is 81.3 BCM/y. Water resources available at hand cannot compensate ballooning demand for water.
- **Obstacles against improving water-use efficiency in different sectors:** The MWRI has been executing a number of projects for reducing seepage losses from canals and drains, infiltration losses from agricultural lands and aquatic weeds in canals. However, the implementation of some projects needs a diversion of canals into other routes, which penetrate the agricultural lands owned by farmers. This requires engaging in negotiations with a large number of farmers. The high costs involved in these projects constitute another obstacle. Moreover, the accuracy of water distribution operations, defective control gates, failed pumps that non-deliver water to the streams ends, and the expansion of rice and sugarcane areas, all reduce the overall efficiency in old lands. In newly cultivated lands, exceedance of the permissible pumping rates of wells, lack of withdrawal control in deep groundwater, dam-

ages in drip irrigation system, and installation of sprinkler systems in inappropriate locations, are also evident. In both municipal and industrial sectors, there exist high losses (50%) in the distribution network and lack of public awareness.

- **Water quality deterioration:** Surface water in Lake Nasser maintains good water quality, but then onwards the quality deteriorates from South to North. The River Nile is characterized by its self-purification process. The quality of water released from the HAD showed little degradation; it remains remarkably clean from chemical pollution until it reaches the Delta. The TDS level in the Nile gradually increases from 150 ppm at Aswan to 250 ppm near Cairo (Abdel-Wahab, 2015). Water pollution in the Nile Delta is also manifest, especially in the Rosetta branch of the River Nile, due to the disposal of agricultural drainage mixed with municipal and industrial wastewater. As a result, the MWRI has stopped a number of drainage reuse stations. The Northern Lakes, as well as Lake Quarun and Wadi El-Rayan in Fayoum, are also sinks of agricultural drainage, as well as municipal and industrial wastewater. Groundwater contamination in the Delta region is evident due to wastewater leakage and salt intrusion. The degenerate water quality greatly undermines agricultural productivity, not to mention exacerbating aquatic ecosystems.

- **Population increase and increasing demand:** Egypt's freshwater resources are under constant, increasing pressures due to population growth. The improved standards of living lead to increased consumption of the limited freshwater resources. The country's intensification in undertaking horizontal agricultural projects engenders an overexploitation of water. The per capita freshwater share has drastically declined from 1,972 m3 in 1970 to about 570 m3 in 2018, and is expected to fall to 390 m3 by 2050.

- **Uncertainty of climate change impacts:** The uncertain climate change impacts on the Nile flow, temperature, evaporation and evapotranspiration is another problem in Egypt, since it is as an arid country relying on the Nile River, which provides 97% of its water resources. It is predicted that climate change will alter the Nile's flow at the entrance of Lake Nasser in Dongola Station, where the flow will range from -25 to 14% of the current flow (Strzepek and McCluskey, 2007). The average increase is 14.3% of current flow and the the average decrease is 11.8%. The change in water quantity will jeopardize the agricultural sector in terms of cropping pattern and food security.

- **Construction of dams on the Nile tributaries:** Any construction will impact downstream discharges during the process of filling the reservoir, bearing in mind whether the filling process would start in a wet or in a dry hydro-climatic period. This is alongside the implications of different reservoir operation strategies on discharges flowing into Egypt. The Great Ethiopian Renaissance Dam (GERD) is now under construction as the largest hydroelectric power plant in Africa, with a storage capacity corresponding to approximately 1.5 years of the mean discharge volume of the Blue Nile. Liersch et al. (2017) reported that there will be an impact during a six-year filling period on irrigation management of the High Aswan Dam (HAD) in Egypt. Accordingly, the filling of the GERD may adversely affect Egypt and agricultural water demands might be higher than the available water supply.

- **Complexity of the hydropolitics in the Nile basin:** The hydropolitical situation and conflicting interests of other countries in the basin is driving Egypt to exert political and diplomatic efforts.

- **Inequitable water access:** Deterioration in water shortages and water quality have been steadily exacerbating equitable water access to irrigation water and sanitation services to Egypt's population. The evaluation of water equitability in Egypt mainly depends on the water quantity, which is believed that water needs for farmers, all urban and most rural households are satisfied. However, there remains a lack of extensive evaluation of the equitable access for the water resources system, which should comprise the criteria of sufficiency, accessibility, acceptability, and affordability. In addition, domestic water networks in many areas suffer from leakages causing occasional mixings of agricultural, sewage, and industrial pollutants. Initial assessments indicate positive results for only the affordability criterion, because irrigation water is free of charge and domestic water remains cheap compared to global prices. Conveying potable water across long distances and using untreated water from waterways or underground water may be the only option for meeting domestic demand for water.

- **Self-insufficiency of strategic food crops:** Egypt has not achieved self-sufficiency in strategic food commodities. The current levels of self-sufficiency for wheat and average cereals stand at 42% and 59%, respectively. In spite of its problems in terms of water shortage and the ever-growing population, Egypt must also secure water for food production with focus on self-sufficiency, rather than importing foodstuffs, especially in the wake of US dollar's steep revaluation in recent years.

- **Insufficiency of financial resources:** Governorates' bodies on the local level prioritize immediate solutions or leave farmers reuse drainage water by themselves, while marginalizing and delaying long-term policies due to the lack of financial resources. However, this comes at the expense of equitable access to water with respect to accessibility and acceptability. According to the rapid anticipated changes in water supply, these solutions can never compensate water shortage, even in the short term. Economic risks are critical in light of the high long-term investments required for the overall enhancement of the water system in Egypt.

Challenges to water resources management in Egypt arise from the limitation of traditional and non-traditional water resources, high losses from agricultural and domestic sectors, high population growth and increasing demands, deterioration in water quality, uncertainties engendered by climate change, construction of dams on the tributaries of the River Nile, complexity of the hydropolitics in the Nile basin, inequitable water access, self-insufficiency in strategic food crops, the gap between innovative research findings and upscaling, poor performance, lack of impact of water research institutions, insufficiency of financial resources, and shortcomings pertaining to water management.

4. Previous and Existing Water Strategies, Plans, and Policies

There are several categories of water policies in Egypt. Some represent actions affecting the increase of water quantities available for distribution and use, and others are defined as actions affecting the distribution of given quantities of water. These are listed as follows:

- Policies for development of water resources (Nile, groundwater, rainfall and flashfloods, reuse of drainage and treated wastewater, desalination of seawater and brackish water);
- Policies of rationalization of water utilization;
- Policies of rehabilitation of infrastructure;
- Policies of depollution;
- Policies of adapting to climate change;
- IWRM policies, including institutional, legal, participation, HR, media, and research frameworks.

4.1 Timeline of Egypt›s Water Strategies, Plans, and Policies

Successive water polices since 1975 and up to 1990 adopted an approach relying on development, which focuses on relative abundance of water resources for all uses (1975-1980 Policies). They also adopted the method of allocation, based on the provision of water supplies for non-agricultural purposes, such as drinking, domestic, and industrial uses, as well as electricity and navigation (1986-1990 Policies). The remainder was redirected towards agricultural uses. For example, the method applied in horizontal expansion was to start reclaiming arable land in terms of soil, high productivity, and suitable levels, before gradually moving on to less arable land, and so on. The case for water quality water was also gradual. The start was with surface water, groundwater, agricultural drainage water, treated wastewater, and so on. However, these policies did not pay enough attention to various aspects: environmental (hydrometeorologically and water quality-related), economic (return and productivity per water unit), and social (raising water awareness among the public), as well as the political climate, locally and internationally.

With the onset of the new millennium, water policies developed by the MWRI in 1999, the national water resources plan in 2005, and the strategy document in 2009, adopted the approach of integrated water resources management. It is common knowledge that adopting this approach in developing water policies is characterized by comprehensiveness and flexibility. It also deals with all climatic, hydrologic, environmental, social and economic aspects of water resources. A chronology of these polices from 1929 until today is as follows:

Period 1929-1970: In 1929, an agreement between Egypt and the United Kingdom, on behalf of Sudan, was signed to ratify the historical Nile water rights for each country. In 1933, the Government of Egypt (GOE) implemented a water policy designed to benefit from the extra storage of the Nile water upstream from the old Aswan reservoir after its second capacity-increase. This policy aimed to cultivate an additional 160,000 feddans in Lower Egypt and convert 208,000 feddans from the basin to permanent irrigation, along with the establishment of public open drains in permanent-irrigation areas (Allam, 2007). In 1948, the GOE presented a memorandum to Cabinet to the effect that after 1950 there would be a pressing need for finding additional water resources. The memorandum recommended several Upper Nile projects to increase the river's flow and to avoid flood hazards (Allam, 2007). Land reform in the 1950s rendered the Ministry of Agriculture as an important partner in planning water allocation. The growing emphasis given to the industrial and service sectors also increased the influence of the competent ministries in water policy processes. Following the 1952 Revolution, the HAD project was presented to the GOE and approved. In 1959, an agreement between Egypt and Sudan was reached for the optimal use of the Nile's water as an integral part of 1929 agreement.

Period 1970-1980: Water planning is said to have begun in Egypt in 1933, when a policy was formulated to use the additional storage capacity made available by the second heightening of the old Aswan Dam and the Gabal El-Awlia Dam in Sudan. This plan introduced programs for land reclamation, conversion of some basin irrigation to perennial irrigation, and increases in the areas under rice cultivation. This policy was first revised in 1974, and again in 1975, when a new plan was drafted to accommodate the extra volume of water resulting from the erection of the HAD (Hvidt, 2000). In 1975, the Ministry of Irrigation (MI) established a policy aimed at rebalancing the water status through the rationalization of crop-water applications, in light of studies and field experiments. The additional demands were to be satisfied by the reuse of drainage water, expansion of groundwater utilization—especially in the Nile Delta region—and the optimal exploitation of rainfall on the northern coast. In 1977, the Ministry of Irrigation began preparing the National Water Master Plan (NWMP) in collaboration with the German Development Bank (KFW) and UNDP. The NWMP aimed to devise plans to satisfy water demands over a period of 20 years (1980-2000) (Allam, 2007). In 1981 came the first attempt to create a master plan for all water use in Egypt. It was implemented in the early 1980s under the auspices of the UNDP and the International Bank for Reconstruction and Development (IBRD).

At the time, the MWRI pointed out that the objective to be achieved by this effort for introducing new scientific techniques was using mathematical models to design future plans for water development, and for ensuring efficient use of this resource. The resulting plan, the 'Arab Republic of Egypt's Master Plan for Water Resources Development and Use' was a first step intended to lead to improved planning capabilities within the sector. The main objective of the plan was to implement planning tools that will make it possible to plan the development and use of water resources with greater precision in the future (Hvidt, 2000).

1980-1990: In 1982, the MWRI reset its water policy according to the results of the NMWP. The new policy decided that extra water was needed to satisfy future water demands. The policy also showed that this additional water could be secured through Egypt's share in the first phase of the Jonglie Canal, and by expanding the reutilization of drainage water. In 1994, however, the MWRI and the General Authority for Land Reclamation prepared a comprehensive and ambitious plan intended to expand the country's agricultural horizon by 1.28 million feddans up to 2025.

1990-2000: The government launched three megaprojects to increase irrigation on 'new lands' located in the Toshka area (New Valley), on the fringes of the Western Nile Delta, and in Northern Sinai. All these projects require substantial amounts of water that can only be mobilized through higher irrigation efficiency on already irrigated 'old lands,' as well as the reuse of drainage water and treated wastewater (Water, 2013). In October 1997, the MWRI prepared a draft of the 'Water Resources Strategy of Egypt until 2017.' Hence, the strategy also analyzed the projected water balance in 2017 through the completion of the first phase of the Jonglie Canal, an increase of groundwater utilization and water reuse practices, and a reduction of the areas of high-water requirement crops (Allam, 2007). Until today, none of the Nile basin countries have endorsed the 1959 agreement between Egypt and Sudan, albeit there have been many technical cooperation programs between Egypt and these countries. At present, both the Council of Ministers and the Technical Advisory Committee are working to set up the legal framework necessary for regional cooperation among countries sharing the Nile Basin (Allam, 2007). In 2003, the MWRI launched a program to support improved environmental and water resources management focusing on the decentralization and integration of water resource management at the irrigation district level. The introduction of Integrated Water Management Districts (IWMD) was adopted as a strategic solution. A typical IWMD is an independent government irrigation operation and maintenance organization, at the district level, that has sufficient manpower, materials, and financial resources to operate and maintain all water resources under its jurisdiction. However, the implementation of an integrated water management at the district requires integration of staff, facilities, stakeholders, information, users, and water resources. Moreover, an effective information management is a must for the appropriate operation of IWMD, along with relevant databases as supportive tools (Wagdy 2008).

Then, the National Water Resources Plan (NWRP) project commenced in 1998, and the plan was produced in 2005 for the target year 2017 by the MWRI, in cooperation with all line ministries. Its main objectives was to describe how Egypt will safeguard its water resources in the future, both with respect to quantity and quality, and how it will use these resources in the optimal way from a socioeconomic point of view. The NWRP (2005) tried to tackle the obstacles that impeded previous policies through focusing on the plan's implementation, and this could be achieved during the process of selecting measures. Special attention was given to measures that could be implemented in terms of costs, necessary institutional capacity, and public support. The NWRP (2005) provided lists of measures for facing future challenges.

The measures are categorized under four main pillars: developing new water resources, using available water resources efficiently, improving water quality management, and creating an enabling environment for enhancing implementation. The NWRP (2005) relied on the numerical models to quantify the effects of different measures. The second phase of the NWRP started in 2007 for the monitoring and evaluation (M&E) of the plan implementation. Data was assembled from various organizations, stored in the NWRP's M&E system, and aggregated to the level of measures. The M&E system included data flows from partner ministries to the NWRP unit within the MWRI, using a web interface. However, partner ministries maintain their individual M&E systems. Problems of data flows, transparency, and conflicts of interest have fragmented the evaluation process. In addition, the national plan did not take into account the decentralization process.

Therefore, the NWRP supported decentralized planning. The national plan has been the basis for developing three pilot water resources plans (GWRPs) for the governorates of Fayoum, Qena and Beheira. The GWRPs were developed in 2012 for the five-year period. The support of planning on the governorate level included establishing Water Resources Units in a number of pilot governorates, and providing the necessary financial, technical, and logistical support. An evaluation of GWRPs measures concluded that only a few measures achieved their progress target indicators, while the majority either failed to achieve these indicators or yielded undefined values.

The NWRP developed a Decision Support System (DSS) based on the RIBASIM7 and ASME models to provide a full picture of the water balance at HAD. However, the calibration and verification processes failed to convince water experts due to the large disparities between simulated and field values. Therefore, it did not show the future situations according to expected developments and different management measures.

The 2050 water strategy (2010) aimed to ensure long-term water security for Egypt through some policies that balance supply and demand, which recognize the limited water resources and the expected move from water poverty to water scarcity. It is based on six pillars: (1) reduction of water losses in the upper Nile and developing groundwater resources, (2) water conservation in all sectors, (3) rehabilitation of the national irrigation and drainage networks' infrastructure, (4) combating water pollution, (5) adaptation to climate change impacts on water resources, including rising sea levels, and (6) targeting advanced and effective water resources management system that creates a feeling of ownership for all stakeholders. The strategy explained how different groups of measures impacted water demand and shortage.

The strategy was similar to previous policies and failed to produce innovative or cutting-edge measures, nor has it succeeded in presenting subsequent M&E process or indications of progress. The strategy briefly considered possible impacts of climate change and presented some adaptation measures for the Nile flows, on the coastal zones, and on precipitation rates at the coasts. However, it did not include a vulnerability assessment for the aforementioned impacts.

Egypt has been developing its Vision 2030, which plans to instill an efficient and effective government administrative body, characterized by professionalism, transparency, responsiveness, and accountability, offers quality services, and able of increasing citizen satisfaction, and potently contributes to the achievement of Egypt's developmental goals and in improving the wellbeing of the Egyptian people.

Egypt's Vision 2030 targets 12 pillars: Education & Training, Knowledge, Innovation & Scientific Research, Heath, Economy, Culture, Social Justice, Transparency & Efficiency of Governmental Institutions, Energy, Foreign Policy and National Security, Domestic Policy, Urban Development, and the Environment. Although water has not been included as one of the target pillars; however, the 2030 Vision focused on reforms that are extremely necessary for effective management of water resources in Egypt.

Such reforms included: i) a unified planning law (national, regional and local planning) and (economic, social, and spatial), ii) a unified database (new base map, unified registry, zip codes, etc.), iii) electronic unified monitoring and evaluation system adopted by all government institutions, iv) Result-Based Management (RBM), v) administrative reform: new civil service law, vi) reform of the System of National Accounts (SNA), and vii) governance, transparency, and accountability.

Recent Evolution of Egyptian Water Policy

1977 - Horizontal Expansion Policy: An ambitious plan to increase the national cultivated area by about 2.8 million feddans from 1997 to 2000, of which 0.50 million feddans were to utilize deep groundwater in the New Valley.

1981 - National Water Master Plan (NWMP): To implement the 1977 policy, the NWMP took a 20-year planning horizon and evaluated alternatives for water supply augmentation and water conservation in agriculture, municipal use and industry.

1982 - Water Policies to Implement the NWMP: MWRI reset its water policy according to the results of the NMWP, based on a goal of making an additional 11.7 BCM of water available to satisfy future water demands.

1994 - Horizontal Expansion Policy: An agreed upon comprehensive and ambitious plan of horizontal expansion to 2025 that set total targeted agricultural expansions through 2000 at 2.2 million feddans, comprising: 1.7 million feddans irrigated with Nile water, agricultural drainage, and the groundwater aquifer of the Nile Valley and the Nile Delta; 0.3 million feddans using deep groundwater water; and 0.2 million feddans using treated wastewater. An additional 1.0 million feddans were planned for development during 2000-2025.

1997 - Draft Water Resources Strategy of Egypt up to 2017: Based on a water balance analysis examining all sources in 1995/1996, and totaling approximately 73 BCM, with 61 BCM used in agriculture and 12 BCM in other sectors. The strategy lays out plans for meeting alternative 2017 water demand scenarios, the maximum being 97.8 BCM.

Policies considering the IWRM approach

2000 - Main Features for Water Policy towards 2017: Prepared by MWRI for the development of water resources.

2004 - National Water Resources Plan (NWRP): MWRI, along with line ministries, prepared this plan. Its main objectives were to describe how Egypt will safeguard its water resources in the future, with respect to both quantity and quality, and how it will utilize these resources in the optimal fashion from a socioeconomic point of view.

2005 - Integrated Water Resources Management: Prepared by the World Bank to support the IWRM principles in Egypt.

2010 - Water Strategy for 2050: MWRI developed the strategy, which aimed at ensuring long-term water security for Egypt through some policies balancing supply and demand that recognize the limited water resources and the expected move from water poverty to water scarcity.

2012 - Three Governorates Water Resources Plans (GWRPs) for Fayoum, Qena and Beheira: The pilot governorates' plans have been established for strengthening the decentralization concept.

Ongoing - Egypt Vision 2030: Targets 12 pillars; Education & Training, Knowledge, Innovation & Scientific Research, Heath, Economy, Culture, Social Justice, Transparency & Efficiency of Governmental Institutions, Energy, Foreign Policy and National Security, Domestic Policy, Urban Development, and the Environment.

4.2 Critique of Implemented Water Strategies and Policies

Egypt has been managing its water resources system by considering various policies for a long time. The policies towards developing new water resources did not achieve advancements in terms of the Nile River's water due the transboundary complexity; one of the examples being the cessation of the Jounglei project. Due its paucity, policies for the exploitation of rainfall water still fall short of impacting the overall system. Although the country has been focusing on desalination for many years, yet progress has not yet been achieved. However, utilization of deep groundwater for new agricultural areas and reuse of drainage water for water shortage compensation have been clearly established.

Regarding the rationalization of water uses, various policies have been allocated for on-farm improved water management, land irrigation timing, leveling of lands, aquatic weeds in waterways, and sugarcane and rice areas in old agricultural lands. Other policies were suggested to pumping rates of deep groundwater, sprinkler and drip irrigation systems in new agricultural lands. Further policies were also suggested to perform automatic daily surveying for distribution leaks and managing pressures effectively in the domestic and industrial water distribution systems. Egypt has also directed part of available funds for the construction of main barrages for enhancing the regulation and distribution of water, and has also been establishing policies for the rehabilitation of irrigation canals and related infrastructure. Nonetheless, distribution conflicts between water users and the overall performance of agricultural, domestic and industrial sectors ensure that the policies for the rationalization of water uses still face many obstacles hampering implementation.

With respect to the sanitation sector, the development in rural areas lags significantly behind compared to urban sanitation. This is partly due to the lack of a clear institutional framework, as well as information, training and involvement of users and stakeholders. For treated wastewater reuse, the current situation is unconducive to its development because of the unclear institutional situation, extremely restrictive standards, lack of technical training, additional treatment costs and distribution networks, insufficient information to potential users, and uncertainty about the quality of distributed water. Regarding sewage sludge, the role of institutional managers and users, as well as their mutual relations, remains unclear. Participative management in the sanitation sector in Egypt remains underdeveloped, and the potential for the private sector to participate is relatively limited. The multiplicity of sanitation strategies is engendered by the absence of a single, agreed upon National Water strategy. For industrial discharges, the institutional framework for industrial wastewater discharges is inadequate. Discharge standards by type of activity and the principle of 'the polluter pays" are not applied. No efficient financial incentive programs are in place for the depollution of industrial discharge.

Egypt has exerted efforts towards prevention, remediation, and control of pollution sources; however, the pollution indicator and its hazardous impacts continues to exist. Although a new number of wastewater treatment units are built every year, yet operation and maintenance problems are hindering advancement.

Many policies focused on climate change impacts and adaptations, and highlighted relatively generic policies and measures in addressing pertinent water risks and adaptations. These policies considered vulnerability assessments for different sectors, followed by a sensitivity analysis and a prioritization for adaptation measures and policy constraints. These policies also included predicted impacts on the Nile flow variations, coastal zones, and agricultural productivity.

Water allocation in Egypt is based on demand without considering the economic value of water. For the irrigation sector, there have only been a few trials to apply the concept of cost recovery. The MWRI has been successful in converting surface drainage systems in many areas to subsurface systems. The costs of installation have been recovered by users, who have been aware of the system's importance. In addition, few active WUAs have recovered the costs of lining and maintenance activities for a number of mesqas serving their lands. However, the current situation of public awareness, community participation, privatization, decentralization and legislations, prevent the generalization of the concept of cost recovery. The tariff on sanitation is insufficient and does not cover operational costs, which creates difficulties for HCWW. The possibilities for the private sector to participate are relatively limited, and need to be facilitated.

Various policies have been put in place for strengthening the enabling environment. Institutional, legislative, and awareness policies have been devised to support the coordination, privatization, and participatory approaches. The policies also included socioeconomic issues and supported economic tools. The policies dedicated more focus to crisis management. IIP is one of the major projects focusing on the expansion of on-farm improved water management in the West Delta region, aiming to improve irrigation on 500 thousand feddans, reclamation of 170 thousand feddans, and the rehabilitation of infrastructure serving 250 thousand feddans. This project is a public-private partnership designed as a hybrid scheme, based largely on the design-build-operate (DBO) model.

Egypt has changed its planning vision from sectoral planning to the coordination approach following the IWRM principles in 1992. The existence of a water deficit, water quality deterioration, and inequitable water access are testament to the continuation of several obstacles facing enabling the environment for the implementation of water policies on the national and governorate levels. The evaluation of equitable access to water within governmental authorities is considered solely as a quantity issue, but has never been extensively evaluated in terms of sufficiency, accessibility, acceptability, and affordability.

This background paper conducted a follow-up process of different measures from various previous and existing policies. The follow-up process divided these measures into three categories:

1. Measures that proved good progress: These measures having base and target values and achieving observable progress. Examples of measures are presented from Fayoum GWRP - 2017 (Table 2). This can be found in Measures No. 2, 3 and 4.

2. Measures that have achieved no/poor progress: These measures having values, albeit their actual current values are very far from their targeted values. This can be found in Measure No. 1.

3. Measures having undefined base and/or targeted values: These measure cannot be evaluated, since there are no values for measuring how much progress has been achieved. This can be found in Measure No. 5.

The evaluation processes concluded that the measures with achieved targets (Measures 2, 3, and 4) were only fully implemented by one stakeholder. The other Measure (5) has not been evaluated because there was no available data about targeted plans of different stakeholders.

The background paper also conducted an evaluation of a number of measures' indicators on the transboundary, national, and governorate levels to assess their suitability and applicability, according to the so-called SMART criteria. SMART criteria is a management tool for project managers and program managers to help them set their goals. Recently, however, it has been extensively employed in the field of monitoring and evaluation. SMART criteria guide setting reasons for failure/success of measures and activities. SMART criteria stand for; S: specific, the indicator clearly and directly relates to the outcome, and is described without ambiguities, and parties have a common understanding of the indicator, M: measurable, the indicator is preferably quantifiable and objectively verifiable, and parties have a common understanding of the ways of measuring the indicator, A: achievable, the required data and information can actually be collected, R: relevant, the indicator must provide information which is relevant to the process and its stakeholders, and T: time-bound, the indicator is time-referenced, and is thus able to reflect changes, and can be reported at the requested time. Table 3 illustrates an analysis for some selected measures' indicators.

Table 3 illustrates an analysis for some selected measures' indicators from previous policies and plans. The indicator "Maintenance of canals and drains" has fulfilled all five SMART criteria. The indicator has a direct and clear impact on the water velocity via canals and drains, and accordingly, on the efficient use of existing water resources that was one of the targeted outputs of the plan. As a result, the indicator is considered Specific (S). The length of canals and drains is quantifiable and its method of measurement is understandable and wellknown to the Irrigation District. Therefore, the indicator is considered Measurable (M). In addition, required data and information are available at the Irrigation District, so the indicator is Achievable (A). The indicator has a direct relation to the tasks and responsibilities of the Irrigation District, which is in charge of regular weed control in canals and drains, manually and mechanically, and hence the indicator becomes Relevant (R). The indicator is also Time-bound (T) because this activity is being implemented regularly and has fixed beginning and ending times. Since the indicator has fulfilled all SMART criteria, and the responsible stakeholder has been capable of successful implementation, the progress of this indicator reached 100% of the target.

It is obvious that the indicators 'Jonglei Canal in Sudan' and 'North and South Bahr Ghazal' for the measure 'Increase the Nile water supply through continuation of cooperation among the Nile basin countries' comply with only three out of five SMART criteria. The indicators have direct and unambiguous impacts on developing new water resources, and are hence classified as Specific (S) indicators. The lengths of canals were quantifiable and their method of measurement is understandable and wellknown to the MWRI, which makes the indicators Measurable (M). In addition, the required data and information are available, so the indicators are considered Achievable (A). Due to the complexity of hydrosystem in the Nile basin, the indicators do not provide sufficient relevant information, which represents an obstacle towards being Relevant (R). Due to the complexity of hydrosystem in the Nile basin and high investments, both projects have no time-schedules, and are accordingly considered not Time-bound (T). Therefore, the indicators did not achieve any progress.

Table 2: Progress in Fayoum GWRP 2012 - 2017

Measure	Progress Indicator	2012	2017 (Target)	2017 (Actual)	Observations
Improving drinking water availability and reduce losses	No. of installed water meters				Unknown values
	Percentage of losses (%)	33	20	30	Poor progress
	Percentage of safe drinking water coverage in rural areas (%)	95	100	95	No progress
Maintenance of canals & drains 3 times a year	Canals length maintained (km)	1,398	1,398	1,398	100% is achieved
	Drains length maintained (km)	1,063	1,063	1,063	100% is achieved
Applying modern irrigation techniques in new lands	Area of new lands applying modern irrigation (feddan)	45,000	45,000	45,000	100% is achieved
Drainage reuse & expanding intermediate reuse	Volume of Reused Drainage Water (BCM/year)	0.6	0.7	0.8	200% is achieved
Minimizing pollution of courses from industries	No. of industries required treatment			40	Unknown values
	No. of units with treatment			24	Unknown values

Table 3: Progress Analysis of Some Examples for Different Measures

Measure	Indicators	Achieved Progress	Nature of Measure	SMART	Observations
Increase in the Nile water supply through continuation of cooperation among the Nile basin countries From (NWRP 2017)	Jonglei Canal in Sudan, North and South Bahr Ghazal	0% of targeted indicator has been achieved	Political and investment on the transboundary level	S: √ M: √ A: √ R: X T: X	Complexity of hydrosystem in the Nile basin such that high investments are the reason behind being realistic and time-bound
Maintenance of canals & drains 3 times a year (From GWRPs for Fayoum, Qena, El Behira 2017), (NWRP 2017)	Length of maintained canals and drains	100% of targeted indicator has been achieved	Planning and executive on the national & governorate level	S: √ M: √ A: √ R: √ T: √	It achieved target, because SMART criteria are achieved, only one stakeholder is responsible, hence no conflict of interests

The evaluation processes of existing policies conclude that only a few measures have defined indicators' values for base and target years, and accordingly, can be evaluated. However, other measures cannot be evaluated due to lack of data and targeted plans of different stakeholders. This is an indication that there is a lack of interest in the coordination approach, a lack of standardized and unified M&E and data flow systems, and a lack of recognition with detailed impacts and significance of measures.

4.3 IWRM

The world has been supporting Integrated Water Resources Management for decades. IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems. The Dublin Principles are general guidelines for IWRM, which have been carefully formulated through an international consultative process during the International Conference on Water and the Environment in Dublin, (1992). The four Dublin Principles comprise:

1) Fresh water is a finite and vulnerable resource.
2) Water development and management should be based on a participatory approach; involving users, planners, and policymakers at all levels.
3) Women play a central part in the provision, management, and safeguarding of water.
4) Water has an economic value in all its competing uses and should be recognized as an economic commodity.

Accordingly, the GOE went to great lengths to implement IWRM principles. Egyptian stakeholders have been working hand-in-hand to develop a number of strategies and plans on the national level. The relevant line ministries participated in the preparation plans are MWRI, Ministry of Housing, Ministry of Health and Population (MoHP), MALR, Ministry of Environment, Ministry of Finance, Ministry of Planning, Monitoring and Administrative Reform, and the Ministry of Tourism.

Prior to 1992, all water policies targeted technical measures for different sectors, individually. The policies of the irrigation sector presented measures for maximizing various conveyance, distribution, and field application efficiencies. Similarly, in municipal and industrial sectors, special technical solutions on the short and long terms were produced. However, after issuing the Dublin Principles as guidelines for IWRM in 1992, Egypt adopted these principles, except for Principle No. 4; and the GOE changed its water resources planning mechanisms. Egypt has been following IWRM principles and developed a number of policies, namely; The Main Features for Water Policy towards Year 2017, National Water Resources Plan for 2017, GWRP for Fayoum 2017, GWRP for Qena 2017, GWRP for Beheira 2017, and the Water Strategy 2050.

Nevertheless, the water deficit, water quality deterioration, and inequitable access to water and sanitation services indicate that the challenges facing IWRM in Egypt have been much greater than implementation capabilities. The enabling environment has been suffering from lack of interest in the coordination approach, lack of standardized and unified M&E and data flow systems, lack of transparency, lack of quantifying the impacts of measures, fragmentation of institutional and legislative systems, ineffectiveness of public awareness campaigns, lack of political interest, lack of financial resources, and poor decentralization.

4.4 Lessons Learned

Effective water governance is crucial for the implementation of IWRM. Problems in management and governance go beyond technical challenges. In the case of IWRM, institutional reform is necessary, i.e.: correct policies, viable political institutions, workable financing arrangements, self-governing, and self-supporting local systems. Institutions are rooted in a centralized structure with fragmented subsector approaches to water management, and, often, local institutions lack capacity. The following are some of the lessons learned from the present analyses and criticism of previous and standing water policies that have been applied:

- Threats to water resources are recognized at all levels, but communities have limited understanding of cause and effect;
- Interventions should be based on an understanding of water catchment problems and local beliefs, customs, and practices;
- Good results can only be achieved by involving communities in problem identification and solving;
- Stakeholders are more satisfied if decision-making is transparent, but financial restrictions reduce stakeholders' influence;
- Capacity building should be a priority, but it requires patience; learning is imperative for effective engagement;
- Local authorities often lack resources, while regional and central institutions lack management direction;
- Willingness to pay depends on expected improvements;
- More cognizance is necessary with respect to the economic and social value of water. The return on water unit (m3) should be maximized, while using economic instruments to increase water efficiency. However, the social value of water must always be highlighted and safe potable water must be a priority for all;
- Rain-fed agriculture in downstream countries must be better supported to increase productivity and improve quality, in order to meet food requirements. There should also be support for establishment of constructions for rain harvesting in semi-arid areas in order to meet water demand for drinking, grazing lands, and limited irrigation agriculture;
- Reducing excessive extraction from deep groundwater layers;
- Critical areas liable to flashfloods, including categorization of valleys and their areas based on the degree of risk, and defining safe areas for different developmental activities lack reliable data and information;
- Efforts to encourage and provide financial and technical support to civil society organizations and community associations to establish, operate, and maintain wastewater treatment plants are insufficient;
- The coordination between the National Water Research Center, universities, and related research centers with competent ministries and entities to come up with cost-effective technologies;
- More effort needs to be placed into research work to develop varieties of short-season crops, which reduce consumption of water and increase ratios of crop density;
- More emphasis and political are necessary to capitalize on the private sector's participation in solving the problem of fragmented ownership of agricultural lands;
- Setting a per capita share in drinking water, moving forward tariff for consumption categories that go beyond this share, and installing/rehabil-

itating meters for measuring domestic consumption of drinking water, are all measures that must be prioritized in water policies;

- Reviewing estimates of real command areas of canals in light of the high rates of urban encroachment and reconsidering discharges of distribution barrages and canal intakes must be seriously taken into account.

- Reviewing the detailed effects of climate change on economic indicators, namely: agricultural productivity, financial autonomy, consumer-producer surplus, number of jobs, net imports' value, and water marginal value are necessary.

- Vulnerability assessments for different sectors, followed by a sensitivity analysis and a prioritization for adaptation measures and policy constraints, must be conducted;

- Decentralization of water management and sanitation should be studied.

5. Relevant Research Efforts

In general, strategic research is designed to help decide and develop the basic strategic plans. In the field of water resources management in Egypt, few theory-relevant research papers have supported the process of decision-making. The relevant research production contributed in providing reliable solutions. These papers successfully adapted and developed numerical models, and considered reducing water shortages and climate change effects on the economy on the national and governorate levels. The papers used generic models for simulating configurations, institutional conditions, and management issues of Egypt's water resource system, and for the assessment of the impact of different management alternatives, as well as proposed and simulated different futuristic scenarios.

On the governorate level, Omar (2014) investigated the most suitable actions for the future in Fayoum using the RIBASIM (RIver BAsin SIMulation) model. It was used to simulate the conditions in base year 2012 and to evaluate various scenarios in 2017. This evaluation was supposed to enable interested stakeholders to identify and implement relevant actions for minimizing water shortages and controlling volumes of drainage water effluents flowing into Lake Quarun. Three scenarios were formulated: optimistic, moderate, and pessimistic, which represented different implementation rates of the tested actions. The results indicated that water shortage will decrease from 1.85 to 0.59 BCM/y for the year 2017. This decrease in water shortage is a result of high implementation rates of different actions. The study also recommended that water supply release at Lahon Dam needs to be reduced in the period between January and June to save 0.9 BCM of superfluous water, and hence to reduce the volume of drainage effluents and to maintain a safe water level in Lake Quarun. This will protect surrounding areas from over-flooding. Fayoum Governorate was selected in this study due to its suitability to serve as miniature of Egypt, and has similar characteristics with respect to both the natural and the water resources systems. Bahr Yousef is the main water resource in Fayoum, much like the River Nile is to Egypt. Lahon Dam, like HAD, regulates the water supply. Finally, the Fayoum depression is surrounded by desert lands, similar to the Nile valley and the Delta.

Moussa, Omar (2017) predicted a change in water supply from Nile River in 2050 due to climate change, and investigated climate change effects on water resource systems in Egyptian governorates, and set up necessary adaptation measures. The impacts of climate change were considered not only on the national level, but also on the governorate level. Firstly, Global Circulation models (GCMs) were run for investigating the impacts of climate change on surface water at Dongola Station upstream HAD in Egypt. Then, the authors used the Blue M model to predict the expected releases from HAD due to climate change. Finally, they used the Water Balance Model (WB Model) to study the influence of flow changes on water balances of Egyptian governorates, and to conduct sensitivity analyses of adaptation measures. Three governorates were selected: Qena to represent Upper Egypt, Fayoum to represent Middle Egypt, and Damietta to represent Lower Egypt. The results focused on those scenarios of reduction in HAD release. The WB Model showed that Fayoum was the most affected governorate, whereas its water shortage increased in 2050 for the two scenarios. The ratio of drainage reuse to total water supply also increased for both scenarios, and nonetheless, drainage water did not fully cover the shortage. Furthermore, no drainage was discharged into Lake Quarun and Wadi El-Rayan Lake at the system's end, thereby jeopardizing their existence. Damietta would be under high risk of severe water pollution in case of reduced release, since the ratio of drainage reuse to total supply severely increased. The sensitivity analysis proved that modern irrigation systems in the new lands, land leveling, controlling rice and sugarcane areas, and lining the reaches of irrigation canals characterized by excessive losses would lead to minimizing water shortage in the future, and subsequently minimizing drainage reuse.

On the National level, Omar, Moussa, (2016) used the Water Evaluation and Planning (WEAP) model to assess the different scenarios in 2025 by implementing different water-sufficiency measures. Different planning alternatives were proposed and tested in order to design three future scenarios. The findings indicated that water shortage in 2025 would be 26 BCM/y in case of the continuation of present policies. Planning alternatives were proposed for irrigation canals, land irrigation timing, and aquatic weeds in waterways and sugarcane areas in old agricultural lands. Other measures were suggested for pumping rates of deep groundwater, sprinkler, and drip irrigation systems in new agricultural lands. Furthermore, measures were also suggested for conducting automatic daily surveying for distribution leaks and effectively managing pressure in the domestic and industrial water distribution systems. Finally, additional measures for water supply were proposed, including raising the permitted withdrawal limit from deep groundwater and the Nubian aquifer and developing the desalination resource. The proposed planning alternatives would eliminate the water shortage completely by 2025.

Omar (2016) showed the adaptation process of LIBRA game to LIBRA-Egypt, which simplified the process of water resources planning in Egypt and assessed the impacts of different measures on water demand in Egypt. The LIBRA simulation game was developed by UNESCO-IHE (Huen, 2011) to simplify the complexity of water resources management and to simulate the consequent performance of actions of autonomous institutions. Omar (2016) simulated the process of water resources planning in the agricultural sector in Egypt over a period of 20 years. The basic scenario (pessimistic) assumed neither funds nor investments were allocated for maintenance and rehabilitation of canals, saving and modern irrigation technologies, and water infrastructure improvement. The normal and optimistic scenarios assumed two levels of funds and investments. The results proved that funds and investments should reach a specific threshold in order to have potential significant reduction in water deficit and to maximize agricultural water productivity.

Previous research provided reliable and obvious results about quantifying the effects of different measures on future water shortage. However, scientific production is still poor. There is also a lack of valorization of the produced scientific results due to the weak link between researchers and governmental bodies in charge of water resources management. Governmental bodies prefer relying on their previous experiences rather than integrating with scientific research.

6. SWOT Analysis of Egypt's Water Resources Management System

There are a number of key determinants that must be heeded for the development and management of water resources in Egypt, including political, economic, social, technical, environmental, institutional, and legislative determinants, which will be dealt with in the following sections.

Political determinants: These pertain to the political situation in the Nile Basin countries, their relationship with Egypt and its impact on joint projects to recover losses, and to increase Egypt's share of the Nile water, as well as the political situation of the countries participating in the Nubian Sandstone Aquifer (i.e. Libya, Sudan, and Chad). Demand for freshwater by the Nile Basin countries is expected to soar with the increase in population in these countries, and in light of their ambitions to convey freshwater to rural communities. It is also expected that governments of the Nile Basin countries would attempt to increase food production to meet the needs of their populations, and to export by increasing agricultural land areas, which, in turn, would require increased amounts of water.

Economic determinants: The nonstop increase in the price of cereals prices in international markets has been coupled with population growth at the global, regional, and local levels; enormous costs required for introducing and using desalination technologies; huge investments for meeting demand for water to accommodate the population potential growth in population and industrial, urban and agricultural expansions until 2030; and an increase in debts.

All these factors necessitate a phased transfer to high-yield economic activities, which do not use many water resources. Other economic determinants include food security and the necessity of its accomplishment, which requires the development and optimal management of water resources to open up new vistas before the sectors of agriculture, industry, and tourism to contribute to comprehensive development in Egypt. Hence, land reclamation projects are considered a national, strategic, security-related, inevitable goal for agricultural development because of the large food gap suffered by Egypt, which necessitates that it be narrowed or, at least, prevented from growing wider.

Technical determinants: It is necessary to develop and enhance the technical and administrative level of all staff in the Ministry, and develop their performance and experience to be in line with needs of the upcoming stage, which will witness advances in different technological means. Hence, the importance of benefiting from technologies in providing non-traditional water, developing traditional irrigation methods, using brackish water, harvesting rain, and desalination of seawater, becomes clear. Accordingly, the success of required policies to deal with water scarcity mainly relies on the success of policies pertaining to dealing with the human element and achievement of sustainable human development. The deterioration of both the canals and the drains network, and the need for their rehabilitation, as well as the necessity of the rehabilitation of water constructions and pump stations whose useful lifetime is almost over, are considered among the main determinants for rehabilitating the water system and achieving future objectives.

Environmental and health determinants: These determinants include the issues of the pollution of the Nile, canals, and drains due to wastewater, industrial effluents, and agricultural drainage, as well as excessive utilization of groundwater wells. There are also other phenomena, such as the greenhouse effect, rising sea levels, receding green cover, desertification, biological diversity, and use of crops as biofuel. These determinants require that the environmental dimension must be taken into account when developing different policies to preserve the integrity of the environment, the balance of the ecological system, and public health.

Institutional and legislative determinants: Together with the necessity of applying integrated water management at the national level, global economic development, and local economic open-door, the institutional setup of all agencies in the Ministry must be restructured; allowing for the participation of water users in decision-making and water management. On the legislative front, laws and legislations regulating water resources, as well as relevant laws, help organizational units and cadres in performing their jobs and determine their responsibilities and relationship with others to ensure that set programs are implemented. Therefore, laws and legislations must be amended in line with variables and changes in the expected systems for managing water resources during the next period.

The SWOT analysis summarized below identifies both the strengths and the weaknesses of the water resources management system in Egypt (internal factors), which are based on the evaluation of previous and existent water strategies and policies. In addition, opportunities for future better management system of water in Egypt, as well as the threats that may encounter the improvement of this system (external factors), are revealed from the macro-environment assessment.

Table (4): SWOT Analysis

Strengths	1. Experiences for water resources planning exist; 2. Clear objectives and well-defined targets; 3. Research institutions for development and protection of water resources exist; 4. Water awareness has been rising; 5. Political and public well exist; 6. Numerical models for research in water resources planning process have been developed, adapted and applied; 7. Pilot decentralized planning for a number of governorates; 8. Collaboration with MALR on irrigation improvement; 9. Management and formation of Water Users Associations and Water Boards; 10. Strong donor support for irrigation; 11. Water use improvement and institutional reform in the water sector.
Weaknesses	1. Data flow obstacles among water organizations; 2. Lack of a harmonized, standardized, and unified system for monitoring and evaluating individual measures of the submitted policies or plans; 3. Conflict of interests among stakeholders; 4. Lack of financial resources for policy implementation; 5. Inefficient utilization of numerical models in water planning entities; 6. Decentralized planning on the governorates' level is lagging due to the differentiation of targets between the central ministries and governorates' bodies; 7. Poor governance and institutional systems; 8. Lack of legislative support for water authorities during the process of policies' implementation; 9. Lack of comprehensive evaluation for equitable water access, which is based on sufficiency, accessibility, acceptability, and affordability.
Opportunities	1. Strong political and public support will prompt maintaining unified data and M&E systems; 2. Governmental entities for water planning will attract researchers having relevant numerical modeling expertise; 3. Decentralization and greater control of participants in water user associations will be accepted; 4. Stakeholders will define targeted values for different measures based on quantifying their effects using relevant numerical models; 5. Evaluation of equitable access of water will be undertaken on the national and governorate levels based on four criteria: sufficiency, accessibility, acceptability, and affordability; 6. Water Law under review by the Peoples' Assembly to transfer irrigation management to water users at the branch level.
Threats	1. Continuous population growth, water deficit and water quality deterioration; 2. Complexity of hydropolitics of Nile basin and possibility of Nile flow reduction; 3. Variation of Nile flow due to climate change; 4. Demonstrations and conflicts on the governorate level due to inequitable access, Exclusion of the poor from the WUOs; 5. Lack of willingness in the private sector to participate in the water sector's management; 6. Inactive Water Users Associations.

From the above SWOT analysis, the successful water policy should include four categories, as follows:

- Offensive: policies that use strengths to maximize opportunities;
- Defensive: policies that use strengths to minimize threats;
- Reactive: policies that minimize weaknesses by taking advantage of opportunities;
- Adaptive: policies that minimize weaknesses and avoid threats.

7. Recommendations for the Water Resources Management Vision

7.1 Policy Vision

Water is the most important natural, economic, and life-sustaining resource. Hence, present and future generations must have assured access to adequate, safe, and affordable water to maintain and enhance the quality of their lives. In order to achieve this vision, water must be used and managed sustainably, efficiently, and equitably, while recognizing and preserving the environmental, social, cultural, and economic value and uses of water. Realizing this vision requires the involvement of all stakeholders in Egypt, working in a continuous partnership within an enabling policy, legal, and institutional framework.

7.2 Principles and Specific Objectives

Integration of different aspects of water resources management is widely recognized as key to achieving the overall goal of water security in Egypt. The following principles will guide water-sector stakeholders in laying the foundation for an integrated approach to water resources management in Egypt in the long term:

- Water is a shared resource and appropriate legal frameworks must be established to govern all aspects of water use;
- Water is a limited resource; hence, the allocation of available resources must be on the basis of fair and transparent procedures, which maximize social and economic benefits;
- Priority will be given to basic human needs and maintaining critical environmental processes, upon which economic activities depend;
- Water resources management must take heed of the economic value of water and users are expected to contribute towards the costs of managing and supplying water, according to the volume and quality used;

- Water resources development, utilization, protection, and conservation go hand-in-hand and must be addressed in an integrated manner, which heeds linkages between sectors;
- Water resources planning must involve all relevant stakeholders and must be undertaken on the basis of natural hydrological boundaries. Catchment areas will be the basic unit for planning and managing water resources, and will be clearly delineated;
- Water conservation and protection must be encouraged in all aspects of water resource development and use. The principle of 'the polluter pays' must be applied;
- Water is essential for social and economic development, and it must be equitably developed and managed among the population of Egypt.
- In accordance with the guiding principles outlined hereinabove, the specific objectives of WRM policy can be summarized as follows:
- Ensuring that all Egyptians, including poor and vulnerable groups, have access to basic water and sanitation of acceptable quality and quantity;
- Establishing clear guidelines governing the equity of access to water resources to maximize social and economic benefits for all Egyptians;
- Developing procedures for prioritizing the allocation of water resources for different social, economic, and environmental uses, including during times of shortage, on the basis of social equity, economic efficiency, system reliability, and environmental sustainability principles;
- Conserving available water resources, to manage water quality, to prevent pollution of ground and surface waters, and to promote efficient and responsible development and use of water resources;
- Manage floods and droughts and mitigate water-related disasters;
- Promoting mutual cooperation in planning, management, and utilization of water at the local, regional, and national levels;
- Streamlining institutional and legal frameworks relating to water resources management with clear separation of functions, roles, and responsibilities;
- Establishing appropriate management structures, including mechanisms for inter-sectoral coordination and stakeholder participation;
- Building capacities and develop human resources at all levels;
- Establishing information systems and promote scientific research that will contribute to sustainable development, management, and use of water resources;
- Encouraging local and private resource mobilization and external project financing that supplement and complement public investment in water resource development and management.

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List of Abbreviations and Acronyms

BCM:	Billion cubic meters
BOT:	Build, Operate, and Transfer
EEAA:	Egyptian Environmental Affairs Agency
HCWW:	Holding Company for Water and Wastewater
GCMs:	Global Circulation models
IBRD:	International Bank for Reconstruction and Development
IWRM:	Integrated Water Resources Management
KFW:	German Development Bank
MALR:	Ministry of Agriculture and Land Reclamation
MOHP:	Ministry Of Health and Population
MoLD:	Ministry of Local Development
MSEA:	Ministry of State for Environmental Affairs
MWRI:	Ministry of Water Resources and Irrigation
NGO:	Non-Governmental Organization
NWMP:	National Water Master Plan
NWRC:	National Water Research Center
NWRP:	National Water Resources Plan
WUA:	Water Users Association