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Vision for Future Management of Groundwater in the Nile Delta of Egypt After Construction of the Ethiopian Dams

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Abstract

Many studies and researches have been published discussed water resources in the Nile Delta in Egypt and have dealt with them in different ways, these studies have always been local, and do not cover the entire Nile Delta. Furthermore, most adaptation and mitigation policies and strategies focus only on small and limited areas and do not take into account the common effects that may be seen when examining the Nile Delta from a regional perspective, such as depletion of groundwater levels, pollution, sea level rise, climate change impacts, and expected changes in the future after the completion of the Ethiopian dams. This study aims to develop a future vision for the groundwater system management in the Nile Delta in Egypt, which will take into account the existing issues and challenges, including the depletion of groundwater aquifers, quality deterioration, pollution, and sea water intrusion, moreover the arising future challenges from the completion of the Ethiopian dams and its potential impacts on the Egyptian water resources system, especially, groundwater aquifer in the delta of Nile. Also, this study prompts for reviewing, analyzing the problem and identifying future adaptation strategies that can mitigate the negative impacts of the Ethiopian dams on groundwater water system, and development a capacity for coping with any future effects and impacts. The most important conclusions of this study are; (i) the water policy in Egypt should be modified to overcome the major expected challenges of building the Ethiopian dams, (ii) the agricultural areas at the end of the irrigation canals are expected to be one of the first affected areas by the lack of surface water in the Nile Delta due to the construction of the Ethiopian dams., (iii) the use of groundwater in the Nile Delta is strongly linked to availability of Nile water and any shortage as a result of the Ethiopian dams will be covered by drilling more of groundwater wells, whether legally or illegally, (iv) the basic pillars of the future vision for groundwater management in the Nile Delta are directly related to solve the end user issues such as; fragmentation of ownership agriculture lands, applying new technologies, groundwater wells registration, and groundwater aquifer protection.

Keywords: Groundwater; Management; Ethiopian Dam; Nile Delta; Egypt

Abbreviations:

AMSL: Above Mean Sea level; AHD: Aswan High Dam; BM^3: Billion Cubic Meter; M^3: Cubic meter; GERD: Great Ethiopian Renaissance Dam; Fed: Feddan; km: Kilometer; MM^3: Million Cubic meter; Mg/l: Milligram per Litter; m: meter; M^2: Squire meter; ppm: Part per million; RIGW: Research Institute for Groundwater; TDS: Total Dissolved Solid.

Introduction

Egypt is a part of the arid belt of North Africa and has a semi-arid to arid climate. Due to population growth from 59 million in 2000 to more than 94 million in 2017, and the horizontal expansion in the desert, the demand of fresh water in agricultural, industrial and mining activities have been increased with a continuous decline in per capita share [1]. In 2017, per capita water consumption of renewable water resources in Egypt was about 630 M^3/capita, which fell from 1000 M^3 /capita in 2000. So, Egypt has been included in the list of 10 countries threatened by the need for water by 2025 due to rapid population growth [2]. Since ancient times, the Nile has been the main source of freshwater for the country, which covers all the water needs of the population of Egypt, which inhabited the Nile Valley and the Delta. Groundwater is one of the most important water resources in Egypt [3]. It ranks second after the Nile. Moreover, there are different aquifers of varying importance for different uses, ranging from shallow, renewable aquifers to deep, non-renewable aquifers [4]. Water resources in Egypt can be classified into: Nile River, groundwater and the rainfall. Traditional water resources in Egypt are limited to the Nile, groundwater, rain and flood. More than 96% of Egypt's freshwater resources are supplied by the Nile River, which comes from outside Egypt borders and supplies 11 of Nile basin countries. Egypt fresh water from the Nile River is limited according to the agreement between Sudan and Egypt since 1959. This agreement holds Egypt to 55.5 BM^3 of Nile water annually. Most of the Nile water comes from the Ethiopian plateau through the Blue Nile and Atbara during the flood period from August to December. The tributaries of Ethiopia provide about 86% of the Nile water.

In 2011, the Ethiopian government announced a plan to build a hydroelectric dam on the Blue Nile, 45 km east of its border with Sudan, called Great Ethiopian Renaissance Dam (GERD). It will create a 74 BM^3 lake [5], It is expected that the construction of this dam will affect Egypt's share, which will lead to a reduction of the discharge of Aswan High Dam. The reduction in outflow of Aswan High Dam has a negative impact on water supply, irrigation system efficiency, hydropower stations and navigation and. It is also reported that Egypt is vulnerable to severe droughts even under current conditions (without building the Ethiopian dams). Thus, the historical system of Nile flow over a seasonal and annual time scale will be significantly alter, allowing a high degree of flow regulation in the Blue Nile and the Nile. As such, the Ethiopian dams has the potential to exacerbate water stress in Egypt if it works unwisely without the participation of Sudan and Egypt [6]. The negative effects on Egyptian water resources are dominant. In contrast, water policy and management in Egypt should be modified to overcome the major challenges of building the Ethiopian dams. Otherwise, Egypt will face many severe environmental, economic and social problems if Ethiopian dams are completed without the full coordination between the Egyptian and Ethiopian government's [7].

Many studies and researches have been published discussed water resources in the Nile Delta and have dealt with them in different ways, most of these studies focus on surface water and groundwater using several tools and procedures for the characterization, classification, assessment and analysis, but a few studies have investigated the current status of groundwater on the Nile Delta, and these studies have always been local, and do not cover the entire Nile Delta. Furthermore, most adaptation and mitigation studies focus only on small and limited areas and do not take into account the common effects that may be seen when examining the Nile Delta from a regional perspective, such as depletion of groundwater levels, pollution, sea level rise, climate change impacts, and expected changes in the future after the completion of the Ethiopian dams [3,8-13].

This study to develop a future vision for the groundwater system management in the Nile Delta in Egypt, which will take into account the existing issues and challenges, including the depletion of groundwater aquifers, quality deterioration, pollution, and sea water intrusion, moreover the arising future challenges from the completion of the Ethiopian dams and its potential impacts on the Egyptian water resources system, especially, groundwater aquifer in the delta of Nile. Also, this study prompts for reviewing, analysing the problem and identifying future adaptation strategies that can mitigate the negative impacts of the Ethiopian dams on groundwater water system, and development a capacity for coping with any future effects and impacts.

Numbers of important hydrogeological criteria and parameters have been reviewed, analyzed and evaluated to develop the future groundwater management vision in the Nile Delta, such as: (i) the quantitative status of groundwater in terms of aquifer thickness, depth to water, groundwater abstraction, and natural recharge, (ii) Groundwater quality status in terms of pollution, salinity and seawater intrusion, and (iii) Potential direct effects and impacts of the Ethiopian dams on Egypt water system and its impacts on groundwater status in delta of the Nile in Egypt. Moreover, this vision to be more reliable, and can be executed; some site visits has been done to the Nile Delta in Egypt to explore how the water end users (Farmers) do now to face existing water shortage and their thinking regarding the future issues regarding Nile water shortages.

Materials and Methods

Sakr et al. found that the salinity of groundwater is changing with changing surface water levels of the canals, also, he mentioned that after 1984, the groundwater salinity started to increase due to extensive abstraction and reduction in the water flow of the Nile, and when the Nile flow increased in 1990, the salinity of groundwater reduced again to its former levels [8]. However, in 2000, the salinity of groundwater increased again due to extensive abstraction. Al-Tahlawi et al. [3], summarized the most environmental problems in the Nile delta as pollution of surface water, northern lakes, and the shallow groundwater layers and aquifers due to the disposal of primary or non-treated waste water, and solid waste disposal, as well as the over pumping on the desert fringes caused decline of groundwater level. Mabrouk et al. [9] mentioned that; the salinization analysis of the aquifer with all the hydrological dimensions is very complicated, and it is severely impaired by the lack of continuous monitoring data. Highly populated regions like the Nile Delta faced with a persisting issue of seawater intrusion require groundwater aquifer management based on prediction of future conditions that can be provided by groundwater modeling accompanied with continuous monitoring. Abdel-Shafy, et al. [10] concluded that; a result of the extensive use of the pesticide, herbicide and fertilizers in the delta of Nile; the groundwater aquifer has been contaminated.

Molle et al. [14] wrote a report providing a general discussion of the Nile delta water balance with availability and accuracy of data. They reviewed in detail the different conditions of the water balance and examine the quantitative values which provided by the literature. They also pointed out that the flow to the delta of Nile consists of rainfall, surface water and groundwater flow from the Nile Valley, and the outflow occurs through evaporation from water bodies, crops evapotranspiration, and the flow to the sea, also they concluded that the Nile aquifer is mainly renewed by recharge from waterways and irrigated fields, with the possibility of exchanging water with adjacent aquifers and sea and discharging them to lowlands, waterways and wells. Wagdy [11], explanted how Egypt would protect its water resources in the near future, in terms of quality and quantity, and how it would use these resources in the best way from a social, economic and environmental aspects. Mabrouk et al. [9] have shown a gap in the studies which focus on the sustainability of groundwater resources and environmental protection in the delta of Nile in Egypt, as well as they categorized and analyzed the most related researches and studies on climate change and the challenges that face groundwater aquifer system in the Nile Delta. El-Nashar [4] stated that the management of available groundwater resources in Egypt needs a comprehensive approach, combining both supply and demand sides. Also he recommended urgent actions to use the groundwater in the water stressed regions, as well as stated that the development activities must now be balanced by management mechanisms to achieve a sustainable utilization of groundwater resources.

Barbary [12] evaluated the Nile low flow effects during the period of low demand on the operation of drinking water system and electrical power stations along the Nile from Aswan to Cairo. Also, Sadek [13] evaluated the effects of implementing the Ethiopian dams and new agriculture projects on water share of Egypt. She concluded that the Nasser Lake discharge may reduce by 5 BM^3/year. In addition, the water level upstream of Aswan High Dam will decrease. Ismail [15] investigated numerically the effects of the Aswan High Dam outflow reduction on irrigation system along the Nile from Aswan to Cairo. He tested some scenarios for flow reduction downstream of Awan High Dam between 0 and 25%, also, during this study; Nile water levels were computed to evaluate the effects of flow reduction on the irrigation pumps. Ramadan et al. [7] evaluated the environmental effects of Ethiopian dams on the water system of Egypt. Using a hydrological model; they found that; (i) impounding of the Ethiopian dams at normal flow from the Blue Nile within 6, 3, 2 years will cause a decrease on the storage of Nasser Lake by 13.28, 25.41, 37.26 BM^3/year (ii) impounding of the Ethiopian dams at min of average flow from the

Blue Nile within 6, 3, 2 years will cause a decrease on the storage of Nasser Lake by 25.96, 37.81, 45.105 BM^3/year, (iii) and impounding of the Ethiopian dams at min flow within 6, 3, 2 years will cause a decrease the Nasser Lake storage by 44.39, 54.41, 55.13 BM^3/year.

Bastawesy et al. [16] presented some hydrological scenarios of the Ethiopian dams to calculate and assess its water storage and impacts on the net yearly discharge at downstream countries. Also, they mentioned that the Ethiopian dams effects on downstream countries will be more clear for Egypt because it relies on the Nile water, moreover they found that; the completion of the Ethiopian dams could cause a negative effects during a low flood seasons. Consequently, the net annual discharge of the Blue Nile downstream could be minimal, and the Nasser Lake could also struggle to sustain the required water of Egypt. Mulat and Moges [17] evaluated the effects of the Ethiopian dam on the performance of Aswan High Dam using the Mike Basin river basin simulation model. They concluded that if the dam will be filled in 6 years, the yearly outflows from the dam during the impounding stage will never be lower than 28.9 BM^3/year which represents about 58% of the mean flow. Fahmy et al. [6] studied the Impacts of the Ethiopian Dam on different water usages in Egypt based on the conclusions witch were deduced from their numerical simulation; it was found that: reducing Egypt water share more than 15% induces superficial effects on the drinking water stations., and up to 10% induces no effect on the irrigation, and industrial pump stations, also, their recommendation was; More reliable water management policy for Egypt water resources should be developed to deal with possible future water shortage. According to Abdelkader et al. [18], Nasser Lake water storage may compensate the problem of Ethiopian dam for about 70% of the filling periods in most studied scenarios. Based on their results and conclusion; the best acceptable scenario for filling the reservoir of the Ethiopian dam is 10 BM^3 / year or less in 7.8 years. This amount of water will be sufficient to generate energy with less impact on the Nile countries, also they stated that; the agricultural land will be affected and millions of households will be dispersed because of the low water share of the downstream countries, especially in Egypt. Armanuos et al. [19], concluded that; due to the existence of the upper clay layer which reduces the amount of water which reaches to the groundwater in the shallow aquifers in the Nile Delta, the effect of increasing abstraction on groundwater level is more significant than decreasing the water depth of the water canals.

Evaluation of groundwater statues

The area of Nile Delta is about 22,000 km^2. It represents two-thirds of Egypt's agricultural land moreover it is the most fertile area in Egypt [20]. The Nile Delta is located 20 km north of Cairo (latitude 30°) and the length of its base in the Mediterranean is about 245 km. The length of the right branch of Damietta is about 240 km. The length of the left branch (Rashid) is about 235 km. The elevation of the land surface in the Nile Delta is above sea level, with the exception of a few sites in the northern part. The Nile Delta groundwater aquifer covers about 3 million acres of fertile lands. The Damietta and Rashid flow are less than half of the original water flow to the north via the water network which consist of more than 10,000 km of canals. Consequently, this massive surface water network interacts with groundwater aquifers in the delta of Nile [21,22].

Many factors contribute to the deterioration of the quality of groundwater resources in the Nile Delta aquifer, which include: groundwater over pumping to meet growing needs, pesticides from agricultural lands and disposal of wastewater. Among these reasons, seawater intrusion is the main cause of the degradation of aquifer quality. The direct leakage from the Nile, the extensive network of irrigation canals and the excess water from irrigation water are the main sources of groundwater recharge in the Nile Delta. Estimated total annual recharge of groundwater is about 6.70 BM^3 [20].

Groundwater aquifer in the Nile Delta: Egypt Contains eight hydrogeological units, as shown in Figure 1. The Nile Delta aquifer is a semi-confined aquifer system, where, the thickness of the groundwater layers is varying from place to another, with average about 190 m, increasing gradually to the north to reaches about 350 m at city of Tanta. At the Western part of the Nile Delta the aquifer thickness varies from 120 m to 220 m, decreasing gradually towards the East. The total thickness of the groundwater aquifer increases from Cairo northward to about 1000 m at the Mediterranean coast [3], the most permeable water bearing strata has been found at depths between 55 and 150 m from land surface. The base is a clay aquiclude with a slope of about 4 m/km, which is about 40 times the average slope of the ground surface [23].

The Nile Delta depot consists of sand and pebbles in the Pleistocene period, and turns into fine sand and clay to the north, the aquifer is semi-confined in the floodplains of the Nile, which covered by the Holocene silt, fine sand and clay. In the northwestern part of the region, a limestone parasitic layer acts as a semi confining layer outside the floodplains, the thickness of this layer ranges between 0 and 20 m. The semi-confined layer is missing at the desert fringes, where the aquifer becomes phreatic and responds to the hydraulic pressure and the free water table fluctuates on the basis of pumping, and recharge events.

The transmissivity reaches its minimum values in the Nile delta southwestern where it ranges from 2000 to 3000 m^2/day and reaches to maximum values in the middle and southeastern area, where it ranges from 9000 to 15,000 m^2/day [24]. The hydraulic conductivity of the Nile Delta aquifer is relatively high and ranges from 70 to 100 m/day, and the effective porosity over the whole area ranges between 12% and 19% [25], and total porosity varies between 25% and 40%, where the groundwater aquifer is composed of gravel and coarse sand.

The lateral and the longitudinal dispersivity for the groundwater aquifer in the Nile Delta equals 10 m and 100 m, respectively, and the saline water of the Mediterranean Sea intrudes the aquifer at a depth from 175 to 225 m. The average freshwater thickness is about 200 m, the major alluvial aquifer is generally of good groundwater quality, with salinity values of less than 1000 ppm. Which increases toward the north due to the effects of seawater intrusion from the Mediterranean Sea, in the northern Delta, the salinity ranges from 5000 ppm to 35000 ppm, [26]. Apart from the two Nile branches (Rosetta and Damietta branches), the Delta area is dissected by extensive networks of canals and drains [20], these water networks play an important role in relation to the groundwater flow regime and salinity.

In the Nile delta; the interaction between the aquifer system, Nile branches and the channels varies spatially based on internal and effective conditions, in some locations, the levels of the surface water bodies are below the groundwater levels, making the Nile branches and the canals as drains. Groundwater depth ranges from 1 to 2 m in the north, from 3 to 4 m in the center and 5 m in the south [9], while the land elevation gradually slopes from about 18 m at the Delta apex to about 5 m (AMSL) near Tanta, sloping down to the sea by 1 m per 10 km on average [27]. Moreover, the Nile Delta slopes from east to west, with Damietta branch being about 2 m higher than Rasheed branch,

Figure 2 shows the aquifer thickness in the Nile delta, while Figure 3 shows water level contour map.

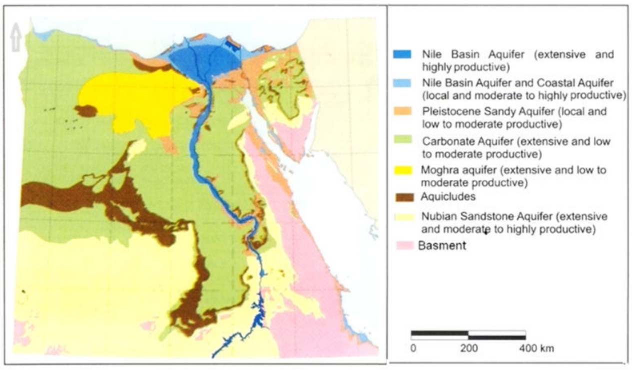

Figure 1: Hydrogeological map of Egypt and RIGW/IWACO [39-41].

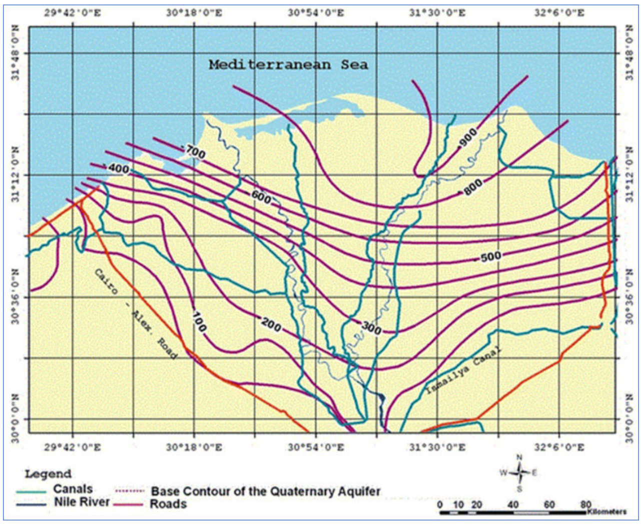

Figure 2: The total aquifer thickness in the Nile delta after [42].

Groundwater abstraction: In the Nile delta; the total groundwater abstraction rate in 1980 was estimated at about 1.6 BM^3/year, and the net recharge rate to the Quaternary aquifer was estimated at about 2.6 BM^3/year. In 1991 the abstraction reached around 2.6 BM^3/year and the numbers of wells have doubled from 5600 wells in 1958 to 13000 wells in 1991 [28]. In 1999, the groundwater abstraction reached around 3.02 BM^3/year while, in 2008, the groundwater abstraction for drinking and irrigation in the Nile Delta was estimated at about by 4.9 BM^3 [29]. In 2011 the total number of groundwater wells was 11,120 wells in the west Delta, 2,887 wells in the central and 8,898 in the eastern part of the Nile Delta, i.e., a total of 22,905 [30], in 2016; the estimated discharge from groundwater aquifer in the Nile Delta was about 7 BM^3 [14].

In the Nile Delta; the groundwater abstraction increases linearly by about 0.1 BM^3/ year, except the period from 2003 till 2010 where the abstraction increases dramatically by rate of 0.2 BM^3 per year, this demonstrates the need to control abstraction in Nile Delta otherwise, the aquifer will be surely threatened with severe depletion, salinization and deterioration. Figure 4 shows the trend of groundwater abstraction in the Nile Delta. The leakage towards the groundwater aquifer due to irrigation water and canals network infiltration was estimated between 0.25 and 0.80 mm per day in the southern and central parts of the Nile Delta [31]. These estimation has been used for a long time to estimate the annual recharge rate of 6.78 BM^3/year [32]. However, the leakage towards the groundwater aquifer is not known with proper accuracy.

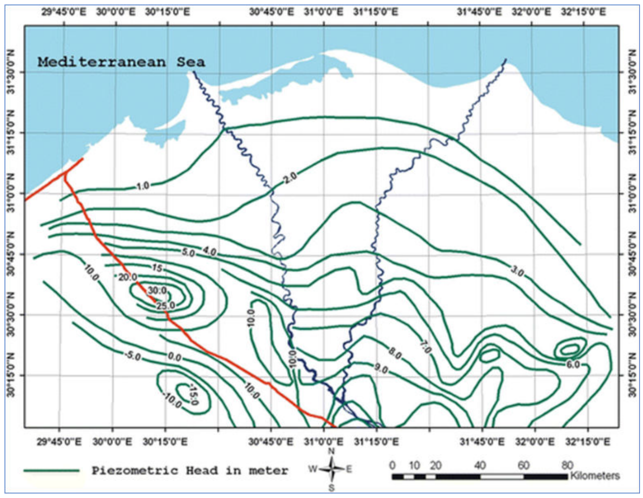

Figure 3: Water level contour map in the Nile Delta after [42].

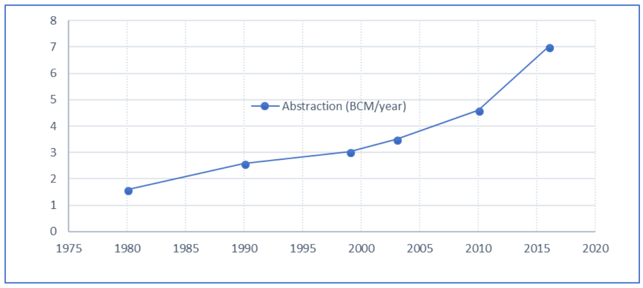

Figure 4: The trend of groundwater abstraction in the Nile Delta.

Existing groundwater challenges: Many factors contribute to the quality deterioration of the groundwater aquifer in the Nile Delta which includes;

- Wastewater from domestic and industrial sectors, agriculture pesticides due to the interaction of surface water and groundwater.
- Seawater intrusion, mixing with the El-Mohgra aquifer and up coning of saline water, were the salinity of the groundwater in the Nile delta as a total dissolved solid (TDS) ranges from 430 ppm at the central and south parts to 24407 ppm at the northwestern Nile Delta, it increases gradually north- and westwards [10].
- Over pumping to meet the growing domestic demands and agricultural development, so, a rapid depletion in groundwater level have been observed, this indicates that the groundwater abstraction is much higher than the aquifer recharge in the Nile Delta, moreover, the groundwater is expected to be more saline

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and the quality will be deteriorated, if the current extraction rate of groundwater will continue in the future [33].

- On the edges of the Nile Delta and in the shallow groundwater aquifers; the pollution is more severe [34]. With intensive fertilizers application on the agricultural area; the nitrate occasionally is from 70 to 100 ppm and it is expected to increase with time, in addition, groundwater pollution resulting from surface water may pose a problem [35].

Evaluation of the Ethiopian dams impacts

Based on the previous hydrological studies results [6,7,17,19,36], this analysis was thus initiated in order to provide us with an approximate estimation of the potential impacts of decreasing the outflows of the Aswan High Dam due the construction of the Ethiopian Dam, on the water shortage for agriculture and other usages, consequently, the potential impacts on groundwater in the Nile Delta to face this expected water shortage, which could be used as a key criteria during develop the vision for the future groundwater management in the Nile Delta.

Some different operational scenarios have been tested using mathematical modelling to forecasting the impacts of constructing the Ethiopian dams on Egypt water resources and its consequences, Ramadan et al. [7], Table 1 presents the impounding of the Ethiopian Dam scenarios impacts on decreasing storage of Lake Nasser, from Table 1, the active storage of Nasser Lake had a decrease between 13.28 and 55.138 BM^3/year.

Scenario	6 years	3 years	2 years
	(BCM/year)	(BCM/year)	(BCM/year)
Normal	13.287	25.413	37.263
Min average	25.963	37.814	45.105
Min	44.398	54.415	55.138

Table 1: Impounding of GERD scenarios impacts on decreasing storage of Lake Nasser.

During the impounding stage; the annual outflow of the Ethiopian Dam will never be lower than 28.9 BM^3. So, the yearly outflow of the Aswan High Dam will decrease with the same percentage and nine scenarios have been tested considering yearly outflow downstream of the Aswan High Dam ranges between 55.5 and 33.3 BCM and its consequences on agriculture lands [6]. Table 2 presents the impacts of flow reductions downstream of Aswan High Dam on agriculture lands in Egypt, it is clear that there were losses in agriculture lands in the Nile Delta due to flow reductions range from 7.09% to 38.937%. Table 3 shows the lost agricultural areas for a number of possible scenarios for the shortage of Nile water as a result of the construction of the Ethiopian dam. It also shows the amount of water needed to irrigate these agricultural areas, which is expected to be compensated using groundwater wells, which are currently used when there is any shortage of surface water, from Table 3, the required groundwater ranges from 2.85 BM^3 to 15.65 BM^3/year in the worst-case scenario.

Location	Average water duty CM /Fed/year	Current area	Aswan High Dam release (BM^3) sceneries							
		1000 fed	52.7	50	47.2	44.4	41.6	38.9	36.1	33.3
			% losses in agriculture lands							
Upper Egypt	8086.2	1459.94	12.7	17.48	22.6	27.04	31.84	36.63	41.43	46.24
Middle Egypt	7822.2	1470.18	7.09	11.65	16.21	20.77	25.32	29.88	34.43	38.937
Nile Delta	6437	6246.57	7.09	11.65	16.21	20.77	25.32	29.88	34.43	38.937

Table 2: Presents the impacts of flow reductions downstream of Aswan High Dam on agriculture lands in Egypt.

Aswan High Dam Release (BM^3)	Agriculture lands in the Nile delta	% losses in Agriculture lands	Agriculture lands losses in the Nile delta	Average Water Consumption per Fed. Per year	Water needed (MCM)	Water Needed (BCM)
52.7	6.246	7.09	0.4428414	6437	2850.57	2.85
50	6.246	11.65	0.727659	6437	4683.941	4.68
47.2	6.246	16.21	1.0124766	6437	6517.312	6.52

44.4	6.246	20.77	1.2972942	6437	8350.683	8.35
41.6	6.246	25.32	1.5814872	6437	10180.03	10.18
38.9	6.246	29.88	1.8663048	6437	12013.4	12.01
36.1	6.246	34.43	2.1504978	6437	13842.75	13.84
33.3	6.246	38.937	2.432005	6437	15654.82	15.65

Table 3: The shortage of Nile waters in the Nile Delta.

Field visit

A field visit was conducted to the governorate of Menoufia, one of the governorates of the South Delta, at the end-of-canals areas, Farmers suffer from a shortage and pollution of the irrigation water. In the city of Al-Bagour and Ashmoun, which have been visited, the number of groundwater wells has increased by more than five times since 2008, and groundwater levels have fallen more than 10 meters. The groundwater depth in 2005 was about 4 to 5 meters and now it is from 12 to 15 m, this indicates that the groundwater abstraction in the central of the Nile Delta is linked to untimely availability of surface water in the canals (with different factors causing this). The groundwater wells are only used intermittently, and it is not always easy to assess the frequency of use by farmers.

Farmers mostly use groundwater wells during summer (June and July), it has also been observed that the Government have already started to take water abstraction of the groundwater into consideration for allocation of surface water by reducing the amount of surface water which supplies to areas known to have developed conjunctive use of surface and groundwater. This however can drive farmers to increasingly drill more wells and rely on groundwater (depending on the time of the year this surface water reduction is done [37-43].

Conclusions and Recommendation

The preparation of the future vision for the groundwater management in the Nile Delta is based on a number of criteria which area:

1) Egypt currently suffers from a continuous shortage of surface water for irrigation and drinking purposes, consequently it will face many severe environmental, economic and social problems.

2) Many factors cause the quality deterioration of the groundwater aquifer in the Nile Delta including: agriculture pesticides, industrial and domestic wastes, seawater intrusion and up-coning of saline water due to aquifer over-pumping, which reaches about 7 BM^3 to meet the increasing demands.

3) The current use of groundwater in the southern part of the Nile Delta is strategic, which adds flexibility and increases water supply to farmers at peak demands times.

4) The use of groundwater in the Nile Delta is linked to untimely availability of Nile water in the canals so, the groundwater wells are only used intermittently, and it is not easy to estimate the frequency of use by farmers. So, any deficit in the Nile water, as a result of the construction of the Ethiopian Dam, mostly will be covered by drilling more of groundwater wells, whether legally or illegally.

5) The negative effects of uncontrolled groundwater extraction can arise rapidly. Potential negative impacts which could be a depletion in the level more than 10 m, increasing salinity levels and the costs of abstraction associated with lower groundwater levels

6) Procedural violations of well drilling in the central Delta are ubiquitous and famers have no motivation to register their wells and go through such complicated procedures and also have to pay for registering their wells.

7) Applying groundwater law remains difficult due to social and economic reasons.

8) Farmers in the Nile Delta already suffer from water supply shortages and abstracting water from wells is twice as expensive as abstracting water from canals.

9) The agriculture lands ownership are small areas and highly disseminated thus the installation of new agriculture technologies and irrigation systems are always costly and met with local difficulties and conflict of interests.

The proposed future vision

The water policy in Egypt should be modified to overcome the major expected challenges of building the Ethiopian dam, where Agricultural areas at the end of the irrigation canals are expected to be one of the first areas affected by the lack of surface water in the Nile Delta due to the construction of the Ethiopian dam. The use of groundwater in the Nile Delta is strongly linked to availability of Nile water in the canals so, any deficit in the Nile water as a result of the construction of the Ethiopian dams, mostly will be covered by drilling more of groundwater wells, whether legally or illegally So, the basic pillars of the future vision for groundwater management in the Nile Delta are directly related to solve the end user issues such as

- Agriculture lands fragmentation.
- Applying new technologies.
- Groundwater wells registration.
- Groundwater Aquifers protection.

Solving the issue of agriculture lands fragmentation:

• Egyptian agriculture in old lands is characterized by small landholdings and is classified by the Ministry of Agriculture and Land Reclamation into four categories as indicated in Table 4.

• The irrigation systems and the use of modern technologies in agriculture in the Nile Delta can only be developed if the necessary action has been taken to address the problem of fragmentation of agricultural lands, either through the formation of agricultural companies or private associations for small farms.

	Size of Landholding (Feddan)			
	Extra small	Small	Medium	Large
Region	<1	1 to <3	3 to <5	≥ 5
North Egypt	29.28	31.99	11.76	26.96
Upper Egypt	42.31	35.89	10.96	10.85

Table 4: Percentage Distribution of Farms by Size of Landholding in Lower and Upper Egypt [43].

Applying new technologies

• The most effective irrigation system and the application of new agricultural technologies are essential to adapt new strategies and policies to groundwater in the Nile Delta, especially for the agricultural sector, which consumes most of it.

• In the case of the applying of medium technologies as protected agricultural systems, the same current productivity can be obtained using only 25% of the amount of water which is currently used.

• The transition from the classical agriculture system to the modern agriculture system will require huge investments, which can be managed through local or external financing or through Agricultural companies. Which will have a huge economic return according to feasibility studies carried out in the project of protected agricultural houses for the project of 100 thousand greenhouses, which the Egyptian government started to implement.

• Urgent action is required to develop the agricultural system in the Nile Delta to address the current and projected shortage of Nile water as well as to preserve the groundwater reserves in these areas.

• Using new technologies such as groundwater modelling and new monitoring devices is essentially required to determine maximum capacity and safe yield of the aquifers in the Nile delta.

Groundwater wells registration

• Farmers already suffer from water supply shortages and abstracting water from wells is twice as expensive as abstracting water from canals.

• An urgent action is required to is required to facilitate the registration and licensing of groundwater wells in the Nile Delta.

• It is necessary to increase farmers' awareness of the need to register wells.

• Some regulations should be established to control and monitor of groundwater abstraction.

Groundwater aquifers protection

• An urgent action is required to complete the sewage treatment system in all the Nile Delta villages as well as operating the solid waste collection system to prevent the contamination of surface and groundwater.

• Using new technologies such as groundwater modelling and automatic monitoring devices is essentially required to determine maximum capacity and safe yield of the groundwater aquifers in the Nile Delta.

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