

# Integrating Climate Action into Water Sector Planning in Egypt: Policy and Program Review

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## Abstract

As a country located in arid and semi-arid regions, Egypt is increasingly vulnerable to the impacts of climate change. These threats are exacerbated by rapid population growth and ambitious urban, agricultural, and industrial expansion plans, leading to water demand magnification, environmental instability, and economic constraints. Recently, addressing climate change impacts has become a major priority for the government and its affiliated institutions across multiple sectors. This study adopts a qualitative policy review approach to examine climate-related programs and initiatives implemented in Egypt's water and wastewater sector between 2018 and 2023. The identified initiatives were analyzed and categorized according to the United Nations Framework Convention on Climate Change (UNFCCC) framework for climate adaptation and mitigation. The findings reveal a significant shift in planning and implementation within the Egyptian water sector toward integrating climate action into sectoral planning. Key actions include the expansion of rural sanitation services from 12.5% in 2014 to 60% in 2023, the increase of seawater desalination capacity from 82,000 m<sup>3</sup>/day in 2014 to about 1.4 million m<sup>3</sup>/day in 2023 with growing reliance on renewable energy, effective sewage sludge management producing clean energy and compost through 6 wastewater treatment plants generating biogas and the environmental reuse of treated wastewater. In addition, more than 1,000 flood protection structures have been constructed, and over 100 Water Safety Plans have been implemented across water supply systems to strengthen utility resilience. Together these measures represent a multidimensional response combining structural interventions, nature-based solutions and governance arrangements to enhance water system resilience.

**Keywords:** Egypt, Climate Change, Desalination, Wastewater, Nature-based Solution.

## دمج العمل المناخي في تخطيط قطاع المياه لزيادة مرونة نظام المياه في مصر

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### الملخص

بوصفها دولة تقع ضمن الأقاليم القاحلة وشبه القاحلة، تُعد مصر من الدول المتزايدة التأثير بآثار تغيّر المناخ. وتتفاقم هذه التهديدات بفعل النمو السكاني المتسارع والتوسع الطموح في مجالات العمران والزراعة والصناعة، الأمر الذي يؤدي إلى تضخم الطلب على المياه وزيادة الضغوط البيئية والاقتصادية. وفي السنوات الأخيرة، أصبح التعامل مع آثار تغيّر المناخ أحد الأولويات الرئيسية للحكومة المصرية والجهات التابعة لها في مختلف القطاعات. تتبنى هذه الدراسة منهج المراجعة النوعية للسياسات بهدف تحليل البرامج والمبادرات المرتبطة بالمناخ التي نُفذت في قطاع مياه الشرب والصرف الصحي في مصر خلال الفترة من 2018 إلى 2023. وقد جرى تحليل هذه المبادرات وتصنيفها استنادًا إلى الإطار المفاهيمي لاتفاقية الأمم المتحدة الإطارية بشأن تغيّر المناخ (UNFCCC) فيما يتعلق بإجراءات التكيف والتخفيف. وتُظهر نتائج الدراسة وجود تحول ملحوظ في أساليب التخطيط والتنفيذ داخل قطاع المياه في مصر نحو دمج العمل المناخي في التخطيط القطاعي. وتشمل أبرز هذه الإجراءات التوسع في خدمات الصرف الصحي في المناطق الريفية، حيث ارتفعت نسبة التغطية من 12.5% عام 2014 إلى نحو 60% عام 2023، إلى جانب زيادة القدرة الإنتاجية لتحلية مياه البحر من 82 ألف متر مكعب يوميًا في عام 2014 إلى ما يقرب من 1.4 مليون متر مكعب يوميًا في عام 2023، مع توجه متزايد نحو استخدام مصادر الطاقة المتجددة. كما شملت الإجراءات تحسين إدارة حمة الصرف الصحي لإنتاج الطاقة النظيفة والسماد العضوي من خلال ست محطات لمعالجة مياه الصرف تنتج الغاز الحيوي، إضافة إلى إعادة الاستخدام البيئي للمياه المعالجة. كذلك جرى إنشاء أكثر من ألف منشأة للحماية من السيول، إلى جانب تطبيق ما يزيد على مائة خطة لسلامة المياه في أنظمة إمداد مياه الشرب بهدف تعزيز قدرة مرافق المياه على الصمود. وتمثل هذه الإجراءات مجتمعة استجابة متعددة الأبعاد تجمع بين التدخلات الهيكلية والحلول القائمة على الطبيعة والترتيبات المؤسسية والحوكومية، بما يسهم في تعزيز مرونة نظام المياه في مواجهة التحديات المناخية.

**الكلمات المفتاحية:** مصر، تغيّر المناخ، تحلية المياه، مياه الصرف الصحي، الحلول القائمة على الطبيعة.

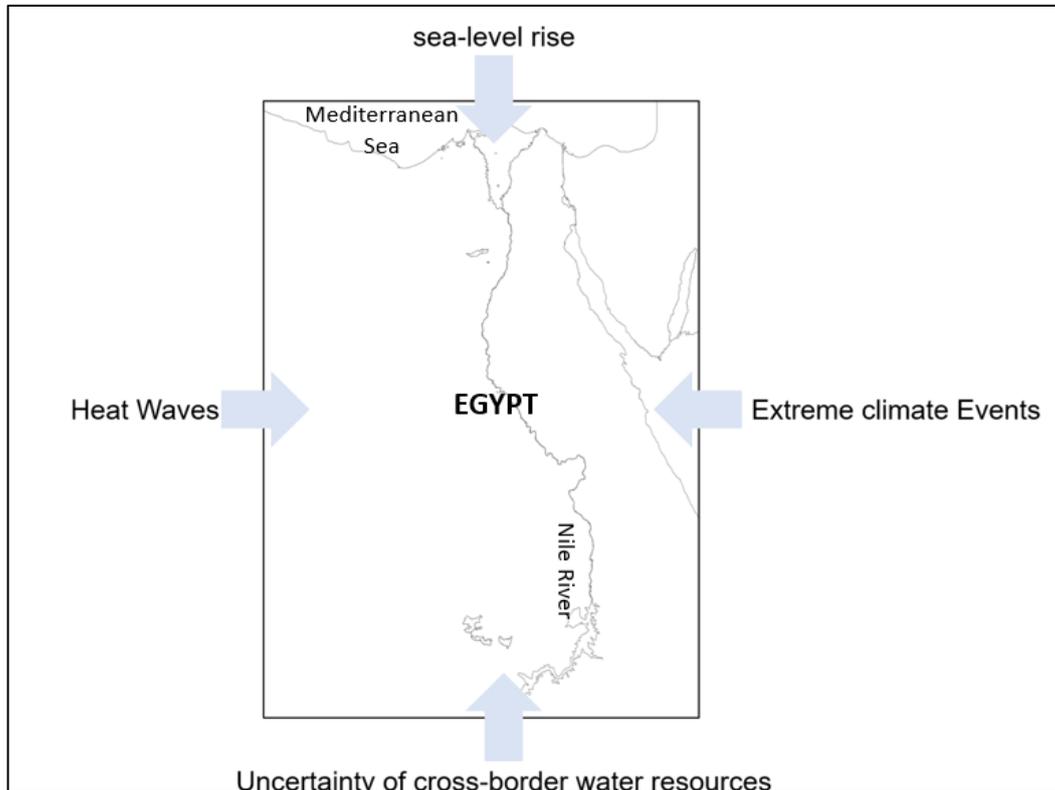
## 1. Introduction

Egypt has experienced rapid demographic growth and expanding urban and economic development in recent years. These changes have increased pressure on natural resources, particularly water resources, which are already limited under arid climatic conditions. Climate change is expected to further intensify water demand and stress on water systems in arid regions (Saeed, 2022). In response, the country has adopted long-term development frameworks such as Egypt Vision 2030, which outlines national strategies and development priorities (Green Policy Platform, 2016). These development trends are also aligned with the Sustainable Development Goals (SDGs), which emphasize sustainable resource management and climate resilience (UN, 2015). In this context, water plays a crucial role in supporting national socioeconomic development, and improving water management practices has become essential for enhancing water use efficiency in arid and semi-arid regions (Jabbar & Jasim, 2023). Furthermore, environmental degradation, water scarcity, and biodiversity loss represent significant constraints to sustainable growth and poverty reduction, increasing the country's vulnerability to environmental risks and hazards while highlighting the importance of environmental protection (Burki et al., 2021).

Egypt faces a high risk of natural disasters and is particularly sensitive to the effects of climate change (World Bank Group, 2021). Water resources, agriculture, fishing, health, housing, biodiversity, telecommunications, electricity, tourism, and coastal zones are among the key sectors affected. Natural disasters have caused roughly 1,500 fatalities in the last 20 years, causing 346.7 million USD in economic losses (World Bank Group, 2021; El Kharraz, 2024),

Egypt's water security is threatened by population growth, unprecedented urbanization progress, and limited surface water. These challenges are accompanied by the potential impacts of CC with a different pattern on different areas such as (i) extreme climate events, (ii) sea-level rise, (iii) uncertainty of cross-border water resources which raises concerns and vulnerabilities about climate change trends (El Kharraz, 2024), (iv) waves of heat storm, (v) the effects of rising temperatures (see Figure 1). These circumstances exacerbate existing water stress, potentially impacting both water quality and quantity putting an overburden on already stressed water systems; Consequently,

numerous sectors are significantly impacted. All of these factors forced the Holding Company for Water and Wastewater (HCWW) and other policymakers to adopt a new strategy where the anticipation of climate change is one of its cores (El Batrawy, et al., 2018).



**Figure (1):** The potential climate impacts on water resources in Egypt.

HCWW is considered one of the key actors involved in improving municipal water supply and wastewater services and expanding service coverage across Egypt (HCWW, 2023). In recent years, several initiatives have been implemented within the water and utilities sector that contribute to addressing climate change challenges. These initiatives include infrastructure measures such as seawater desalination, flood protection systems, and wastewater reuse, as well as operational and governance approaches such as Water Safety Plans and improved sludge management. These initiatives aim to mitigate climate impacts or support adaptation to climate change by enhancing the flexibility, resilience, and operational readiness of water systems. This includes diversifying water supply sources, strengthening infrastructure against extreme events, and improving risk management and emergency preparedness within water utilities.

As reported, Egypt's water-, agricultural-, energy-, and health sectors remain very sensitive to climate variability and change in the short and long term (El Kharraz, 2024). This paper aims to review the main programs, projects, and activities that have been taken concerning the response to climate change impacts in the water and wastewater sector in Egypt; subsequently, the paper highlights the main trends of the taken climate actions and categorizes these activities as adaptation measures and /or mitigation measures. Moreover, the paper recommends the proposed interventions (mitigation or adaptation) as a response to climate impacts in Egypt.

Despite the increasing number of programs and projects implemented in Egypt's water sector, many of these initiatives were not originally designed or labeled as climate change interventions. Nevertheless, they contribute directly or indirectly to climate change adaptation and mitigation. However, these efforts are rarely examined within a climate action framework, and their role in addressing climate risks in the water sector remains insufficiently analyzed.

Therefore, this study aims to identify and review major programs and initiatives implemented in Egypt's water and wastewater sector and to analyze their contribution to climate change adaptation and mitigation using an established climate action framework.

## **2. Methodology and Approach**

To explore the concept of climate action in the water sector in Egypt, the authors tried to focus on all of Egypt as a study area; The authors' professional involvement in the water sector and their institutional affiliation with HCWW facilitated access to relevant institutional data and technical reports and deal with many stakeholders (national and international) at different levels (Micro, Meso, and Macro-level) in water sectors, that facilitated the data collection process in a centralized manner. The study team has followed a variety of methods to develop a comprehensive understanding of the study topic: (i) detect all actions that have been taken in the field of water and wastewater sector, (ii) tracking the motivations of executed actives (structure and non-structure), (iii) tracking the governmental policies and statements concerning the climate change response, (iv) reviewing the international cooperation programs (by international doners or concessional loans). Due to the absence of standardized evaluation frameworks for such

interventions, this study adopts a qualitative review supported by a descriptive narrative analysis of relevant policies, implemented programs, and institutional reports.

This study stretched over five years (2018–2023) where the impacts of climate changes became more notable in the water sector in Egypt, hence, the Government of Egypt (GoE) has taken many actions in this regard where these actions intentionally or unintentionally were dedicated to adapt and/ or mitigate the climate impacts. The identified initiatives were classified according to the definitions of climate change adaptation and mitigation provided by the United Nations Framework Convention on Climate Change (UNFCCC, 2007).

Actions addressing climate-related risks such as water scarcity, sea-level rise, or extreme rainfall were categorized as adaptation measures, while interventions contributing to greenhouse gas reduction or renewable energy generation were categorized as mitigation measures.

The findings have determined throughout the identification of the existing program, project, and activities that deal with climate change issues intentionally and/or unintentionally; these findings were classified as adaptation measures or mitigation measures (UNFCCC, 2007). Due to the complexity of this type of study, the outcomes have been assessed either qualitative through the description of the finding and its impact intentionally and/or unintentionally, and a quantitative assessment for which are measurable (For example, Rural sanitation services %, Quantity of desalinated water, Quantity of treated wastewater).

Data were collected from multiple sources including governmental reports, institutional documents of the Holding Company for Water and Wastewater (HCWW), technical reports from the Ministry of Water Resources and Irrigation, international cooperation programs, and relevant scientific literature.

### **3. Results and Discussion**

#### **3.1. Expansion of Sea Water Desalination**

Generally, the seafront of Egypt extends to 2936 km (995 km coastline on Northern Governorates “Mediterranean Sea” and 1941 km coastline on "Red Sea”) makes it eligible with high potential to desalination of seawater. The north coast is characterized

by a high-density population, particularly in the domain of the Nile Delta synchronizes with the governmental plan to expand new urban communities and local touristic cities. other hand, the North-delta is located at the tail of water streams (the endpoint of the Nile River and its other related freshwater streams). Moreover, the North-Delta is subjected to the potential impact of sea rise-level rise (World Bank Group, 2014), which poses a significant threat to water resources and the infrastructure of existing water utilities. In these circumstances, this area is experiencing a severe water shortage in freshwater canals which are the main source for irrigation and Domestic water. to compensate for this shortage, the current applied solution is the intermingled drainage water throughout the mixed pump stations where these canals are classified as "the Stressful canals". That puts an overburden on the WTPs and has a significant impact on the water quality (Yehia et al., 2017).

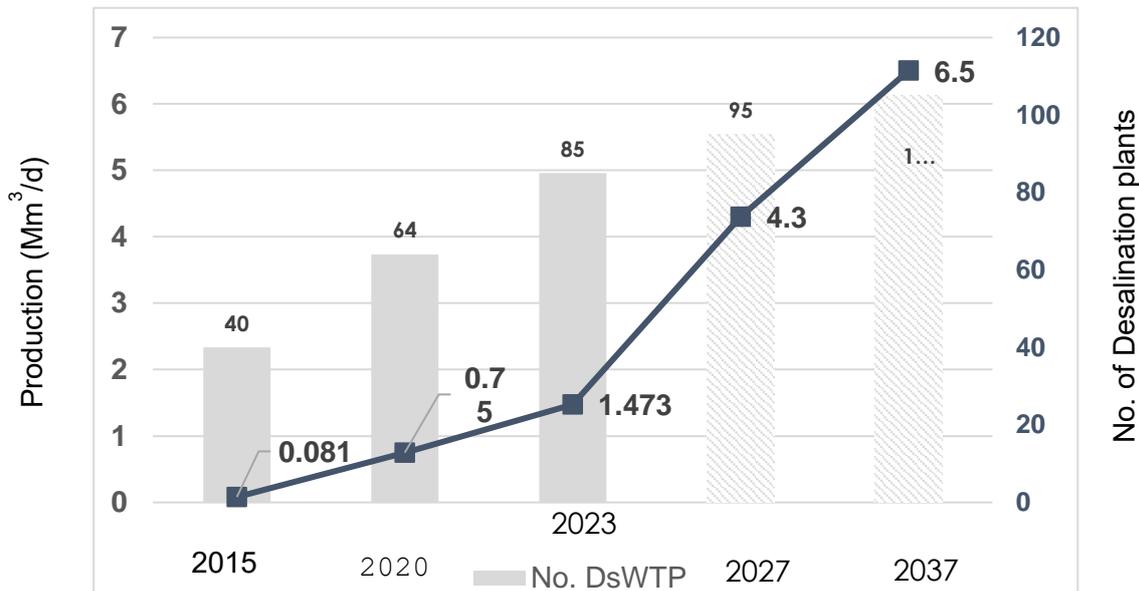
The Government of Egypt decided to diversify the water supply options where the desalination is one from the strategic options in order the tackling the increasing water demand. Desalination is a climate adaptation option as its costs is becoming more competitive than ever, and Egypt could rely on the large coastal areas on the Mediterranean and the Red Seas shores as mentioned above (El Kharraz, 2024).

The desalination in Egypt has a dual role, (i) In terms of Integrated Water Resources Management (IWRM), the desalinated water would contribute to decreasing the gap of water demand, and a great portion of this added water quantity could be considered as wastewater and will be subject to treatment as wastewater which could be reused in different purposes; (ii) in term of climate change confrontation, in addition to its significant role in making water available in an area experiencing water stress for different reasons one of them is the climate change impacts, The Desalination is considered as an adaptation measure for the climate change where the IPCC lists desalination as an “adaptation option” (IPCC, 2014). Subsequently, the rapid expansion of desalination capacity in coastal regions has helped reduce pressure on limited freshwater resources and improve the reliability of water supply systems in areas exposed to climate-related water stress.

Therefore, the GoE has released “The National Plan for the Expansion of Seawater Desalination Plants NPESD”; This NPESD consists of four main pillars that will be

implemented through 6 five-year plans until 2050; These main pillars are (i) Providing water supplies to solve current shortage problems and the future natural population increase for existing communities (old urban communities), (ii) Providing alternative water supplies instead of transporting the drinking water from surface water treatment plants (WTPs) located on the river Nile to the remote governorates (Matruh, Red-sea, Sainai), (iii) Providing alternative water supplies of surface water in areas that rely deeply on the existing WTPs located on the canals that are classified as “stressful canals” particularly in Noth Delta and Suez Canal cities, and (v) Providing the water supplies that are required for new urban development (4th generation cities for example “Alamin and Galala) (Elsaie et al., 2023).

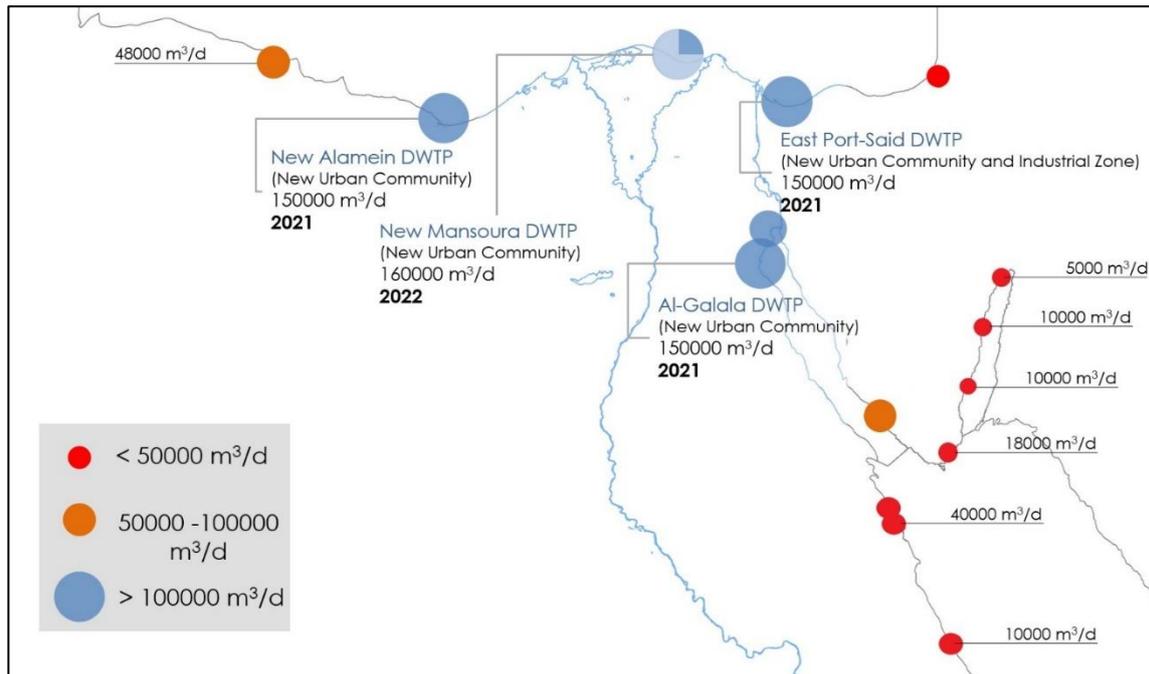
According to Figure (2) and as a response to implementing NPESD, desalination production evolved significantly in recent years from 82000 m<sup>3</sup>/d through 40 DSWTPs in 2014 to about 1400000 m<sup>3</sup>/d via 85 DSWTPs in 2023; that reflects a great commitment of GoE to fulfill its obligations in this track (Elsaie et al., 2023).



**Figure 2:** The evaluation of desalinated water production and the number of desalination water pants in Egypt in recent years.

As known, desalination projects are highly cost compared to traditional water production projects (surface water purification and groundwater extraction) where in Egypt the cost of one desalination treatment plant could reach 4 times the cost of a surface water treatment plant which is equal to the same production capacity; this high cost is attributed to (i) high energy consumption, (ii) other OPEX expenditures, where the OPEX for 1 m<sup>3</sup> of conventional water treatment is 0.104 € While the average OPEX on the desalination treatment is 0.335 € For 1 m<sup>3</sup>, that in addition to (iii) CAPEX expenditures; Moreover, the cost of desalination project are highly variable from place to place relaying on many factors such as (i) the size of desalination treatment plant DWTP (where the large centralized DWTP is lower cost than small one), (ii) the specification of salt water (The Mediterranean sea is low salt content than Red sea consequently, lower OPEX), (iii) the convey of treated water, (iv) the specification of each site such as the sensitive/protected areas and the sea water quality. In addition to the mentioned factors that could be considered as challenges, the finding the balance between the affordable tariff and the overall cost in remain the one of the main challenges of desalination projects in Egypt (Elsaie et al., 2023).

To overcome these challenges that hamper the efforts to execute the desalination projects in Egypt, the GoE has determined 10 parameters to execute the desalination projects; The most remarkable of these parameters are (i) allow the privet sector to invest in desalination projects via BOT approach, (ii) The renewable energy represented in solar energy has a significant role in securing the energy source for the desalination sites in framework of National Plan for Expansion on Seawater Desalination (NPESD); that in order to encourage PPP through obligating the investor to construct a solar plant (equal to the consumption rate) in "Benban Solar Park" in south Egypt and transfer the energy to the national electricity network, (iii) an incentives for the privet sector via offering the land acquisition (this could reduce the capital cost by one third), (iv) expanding in construction of large scale "centralized" DWTPs instead of small scale plants, (v) Oblige international companies that interesting to introduce and invest in Egyptian market to manufacture components locally (Elsaie et al., 2023).



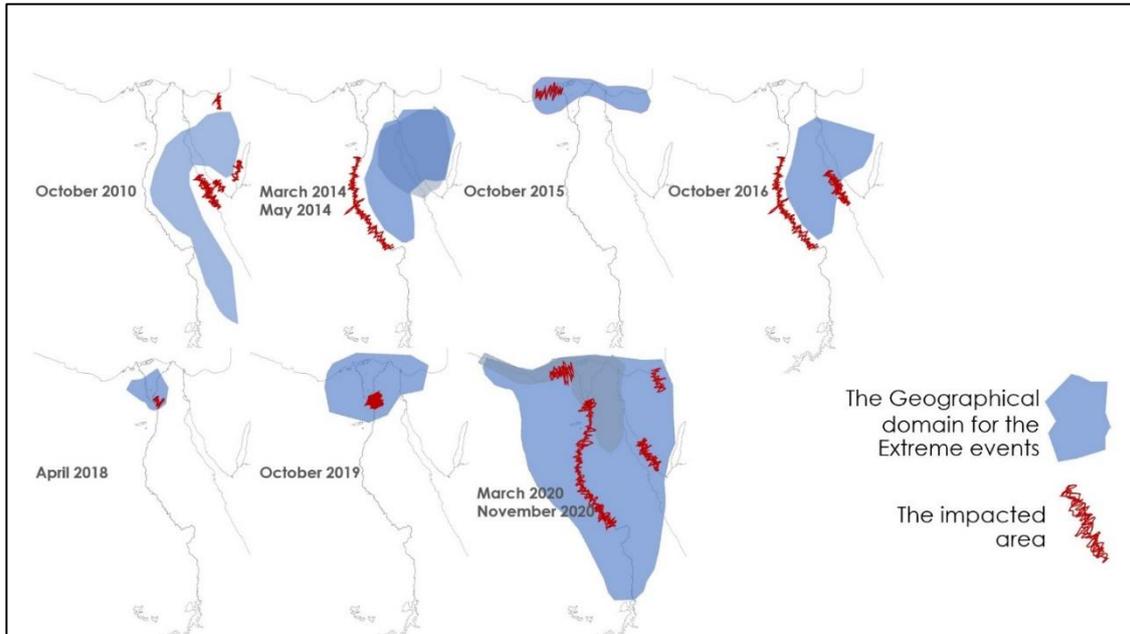
**Figure 3:** The change in design approach in the capacities of New Desalination water plants (in blue) and the old Desalination water plants (orange and red).

### 3.2. New approach Infrastructure

Many areas in Egypt became prone to heavy rain in repeatable patterns, which led to the formation of torrents in wadis (valleys), and storm surges in coastal areas such as Alexandria which consequently caused flash floods (Negm. 2020). Extreme climate events as a result of climate variability have an impact on both water supply and sanitation systems efficiency; so, the water utilities and also the sanitation systems become more stressed (European Environment Agency. 2024).

The high variability and uncertainty of rainfall call for a robust and flexible strategic approach that considers a portfolio of measures to reduce both the chance and the consequences of flooding. In this regard, “an anticipatory flood plans” has been developed in many areas across the country; these includes many aspects that could be mentioned as following: (i) governance and managerial level such as the assembling the steering committees from related entities to deal with the extreme events, (ii) Engineering aspect, (iii) Rehabilitation, restoration, and exploitation of the natural wetlands" in the confrontation efforts.

In this regard, the areas that are likely to be vulnerable to extreme climate events could be divided into (i) coastal areas, inland areas, as well as (ii) Inside cities, out-side cities, as well as (iii) old urban communities, or New-urban communities (4<sup>th</sup> generation cities) as showed in Figure (4).



**Figure 4:** The Geographical domain of Extreme Climate Events and the impacted areas during last decade.

### 3.2.1. Alexandria region (inside Cities)

This coastal area extends for about 60 km from the Rosetta branch of the river Nile in the east to El-Max Bay in the west including the Alexandria governorate. It is one of the oldest cities on the Mediterranean coast and is an important tourist, industrial, and economic center. About 40% of all Egyptian industry is located within the governorate of Alexandria. The area is characterized by lowlands, waterfront, and beaches. The lowlands (figure 5) on which the city of Alexandria originally developed are vulnerable to inundation, water logging, increased flooding and salinization under accelerated sea level rise (Yehia et al., 2017).

In recent years, this coastal area (Alexandria city and the neighboring region) experienced an unexpected severe rainfall event, Figure (6) shows that the precipitation rate has tended to increase, especially in the last decade. These circumstances put an overburden on both water resources and infrastructure (water supply and sanitation systems). on October 2015, this high precipitation rate led to a devastating flood that has

been described as “the worst flooding of Alexandria City over the past decades (Zevenbergen et al., 2017). That motivated the authorities to set up a comprehensive anticipatory flood management plan. The main feature of this comprehensive plan could be summarized as the following:

- The development of a suitable hydraulic model that is able to determine flood heights, extents of inundations, rate, rise and duration of inundation for floods of different probabilities representing the actual conditions and future scenarios.
- Working on upgrading and improving the existing urban hydraulic network of canals and drainage infrastructure (irrigation system, and drainage/sewage network) along the city and its neighbouring vicinities; that represent in a number of projects (9 projects) that targeting the separation of rain water drainage system from the sewage network, retain and store exceedance rainfall, and reuse the harvested water (Ahram Gate, 2022).
- Improve the current wastewater system, including upgrading and rehabilitating Wastewater Treatment Plants (WWTPs) and the pump-stations (91 pump stations).
- Develop an emergency plan for the operation of the drinking WTPs during the extreme climate event targeting to ensure the safe drinking water supply (i.e. based on the approach of the water safety plan) and optimize the water demand to avoid dumping the sewage network; this emergency plan was set with coordination between the company of drinking water and the company of sanitation (Ahram Gate, 2022).
- The formation of a steering committee includes all water stakeholders in the Alexandria Region to engage in a broad discussion, leading to an agreement on the level of acceptable flood risk. This communication emphasizes a better understanding of the risks, the costs of failure and inaction, and the multiple benefits to accrue from integrated mitigation measures.
- Rehabilitation, restoration, and exploitation of the natural wetlands and swamp represented in Lake Maryout after decades of deterioration through a better understanding of these natural wetlands' role in the extreme events confrontation effort; Where Lake Maryout acts as a large extra retention reservoir by pumping the water out before it rains (Zevenbergen et al., 2017).

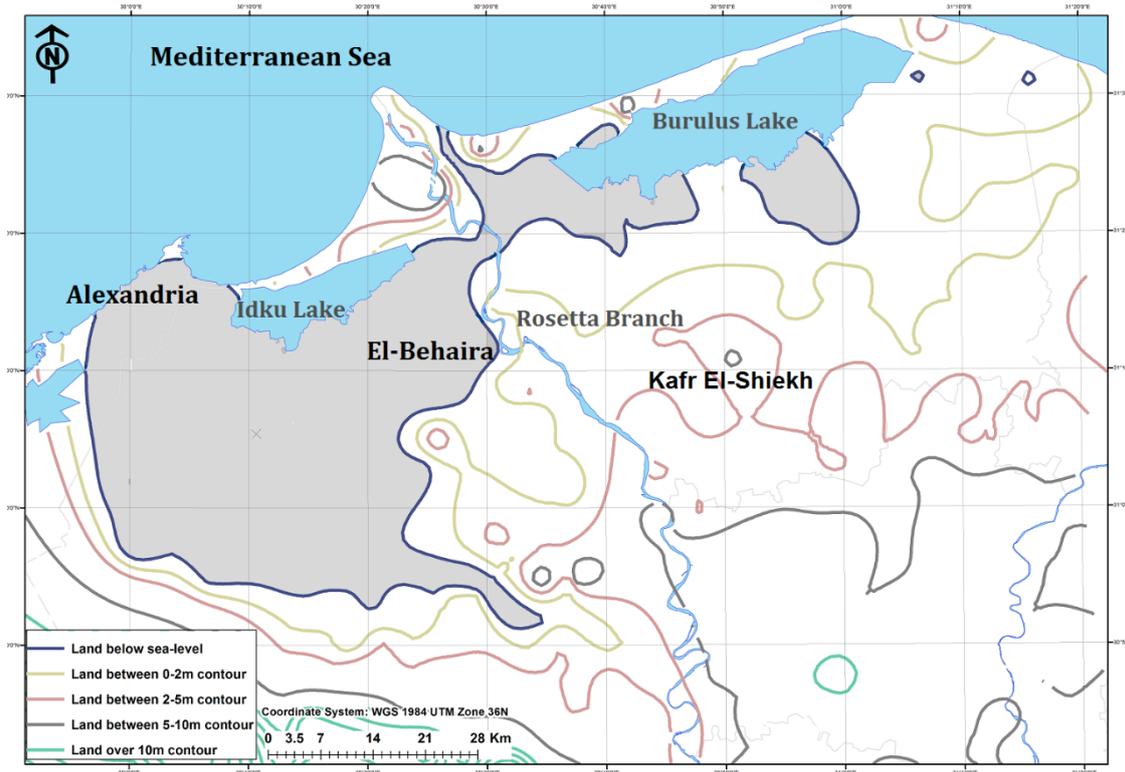
- HCWW, represented by Alexandria sanitation company, purchased many evacuation trucks and other equipment to deal with the aggregation of water and clean the pipes as well (HCWW, 2023).

These aforementioned measures worked to increase the resilience of the hydraulic systems of the city of Alexandria during many extreme climatic events that have struck the city significantly in recent years.

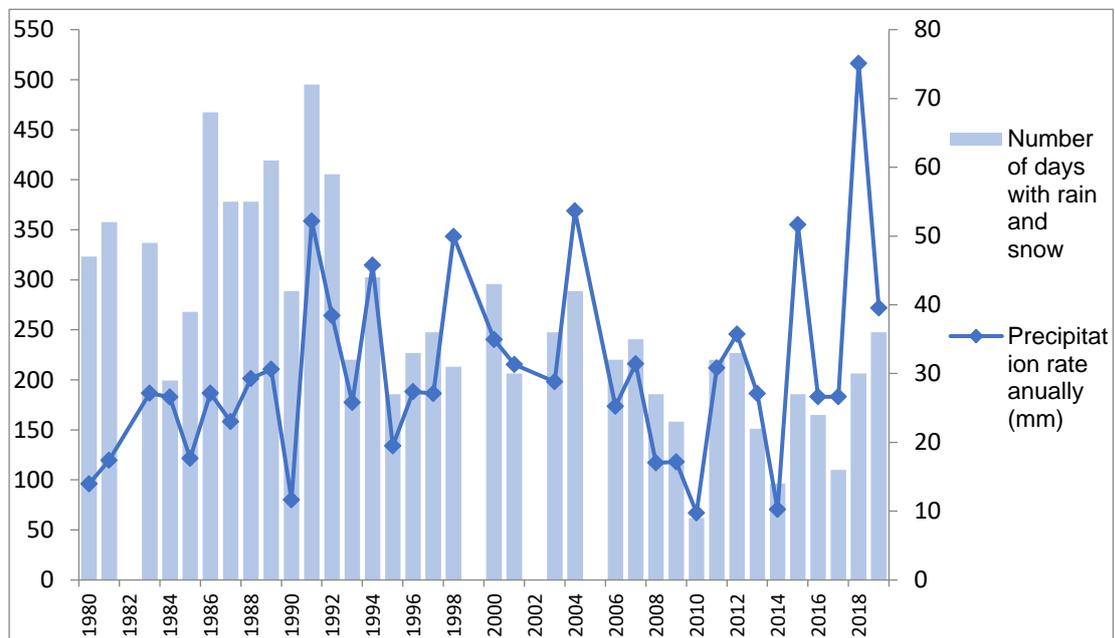
### **3.2.2. The mountainous areas (outside cities)**

As mentioned above, the heavy rainfall and torrents became more frequent and the devastating impacts became more notable (Figure 4); The flash floods resulting from the torrents in the mountainous areas have increased property damage to infrastructure and personal loss with the expansion of urbanization and the development of human activities at the edge the mountainous regions and at the remote urban agglomerations at the end of the watersheds drains (to the seas or the Nile River) (Yehia et al., 2017).

Furthermore, another side effect of these flash floods could happen particularly in areas near the watersheds that drain into the Nile River (for example Wadi Qena and Wadi Degla) where a significant influence on the raw water turbidity of the River Nile is more evident; An unexpected increase in turbidity levels of the Nile River that had a direct impact on WTPs operation that has led to a shutdown of all the surface drinking water plants, both conventional and compact located downstream for some time; Where the sustainability of water supplies along these areas are greatly threaten during these extreme climate events (Figure 7) (Yehia et al., 2017).



**Figure 5:** The low-lands below sea-level in Alexandria region



**Figure 6:** The increase in the probability of flash floods due to changes in rainfall patterns in the Alexandria region.



**Figure 7:** Satellite Image by Landviewer illustrate the impact of Extreme Climate Event (torrents and flash floods) 2015 in the mountainous area – Upper Egypt on the water quality of Nile River (Turbidity).

These circumstances forced the GoE represented the Ministry of Water Resources and Irrigation MWRI to take a group of steps that would mitigate the potential threat of flash floods on the existing infrastructure and the environment in the vulnerable areas; these actions include the implementation of long-term, seasonal, and proactive actions and represented in the following:

- constructing about 1,084 facilities include Levees, embankments, flood-walls, dikes reservoirs as a long-term measure to protect against the threat of flash floods in the vulnerable areas (MWRI, 2023).
- A forecast center monitors the amounts and locations of rainfall three days before it occurs and provides it immediately to decision-makers in ministries, relevant authorities, and governorates (MWRI, 2023).

Prior to the implementation of these flood protection structures, flash floods frequently caused damage to infrastructure and settlements in vulnerable areas, particularly in mountainous catchments. The construction of approximately 1,084 flood protection structures, including levees, embankments, and retention reservoirs, has improved the capacity to retain and regulate floodwaters and reduce the destructive impacts of sudden runoff events. However, no significant or abrupt changes have been

observed in the water quality of the Nile River as a direct result of these interventions. The main contribution of these structures lies in reducing flood risks and improving the management of stormwater and runoff before it reaches sensitive infrastructure and water supply systems.

### 3.3. Sewage Sludge to Clean energy.

- Municipal wastewater sludge is an inevitable by-product from biological wastewater treatment processes, which usually requires high costs for proper handling, disposal, and treatment – often accounting for ~30–40% of the capital cost and ~50% of the operating costs of the entire WWTPs (Andreoli et.al., 2007).
- Over the past 4 decades, the increasing amounts of excess sludge from municipal WWTPs represent a challenge toward achieving the sustainability of the drinking water and sanitation sector in Egypt; resulting in serious environmental pollution due to the uncontrolled use of non-stabilized sludge. Currently, about 4 million tons of dry solids is produced annually; In the next few years and as a response to the massive expansion of sanitation services and sewage treatment, it is expected to produce a huge amount of sewage sludge as a byproduct of the treatment process (Wahaab et al., 2020).
- Many strategies that have been developed in order to draw the best scenario to rationalize water use and maximize the reuse of wastewater. However, all of these strategies neglect to conceptualize sewage sludge management and reuse (Wahaab et al., 2020).
- The treatment, disposal, and management of municipal wastewater sludge would have a multidimensional role concerning climate change within the Egyptian environmental context where:
  - a) The prevention of sludge discharge into the water streams (i.e. the drainages canals) would reflect directly and/or indirectly on the (i) improving the health of the environment “adaptation”, (ii) biodiversity conservation, (iii) rehabilitation of surface water courses “adaptation”, and finally (v) the maintenance of public health “adaptation”.
  - b) Reuse the stabilized of sludge in (i) production of compost for the agriculture “adaptation”, and/or (ii) maximize the reuse of this sludge; particularly, in the field of Biogas production (to generate green energy),

and to reuse as a compost for the new reclaimed agricultural land in many areas in Egypt (for example: Toshka, New-delta Noth-sinai) “mitigation and adaptation”.

Based on the aforementioned, the main alternative is to use the sewage sludge to produce biogas which is consumed to produce the energy that compensate a considerable portion of energy needed in the treatment process; nowadays, Egypt has 6 mediums to large scale WWTPs that produce a biogas on-site which supplying from 50% - 60% of energy consumption in those WWTPs (Wahaab el al., 2020; Decent Life initiative, 2019; EIB, 2020; EIB, 2022).

In this track, GoE has taken tangible steps toward safe managing and disposal of municipal wastewater sludge to eliminate the risks of the non-stabilized sludge in land reclamation, minimize the potent greenhouse gases emissions, and recover value-added products (such as renewable energy, soil conditioners, and nutrients); these determined steps represented in the following:

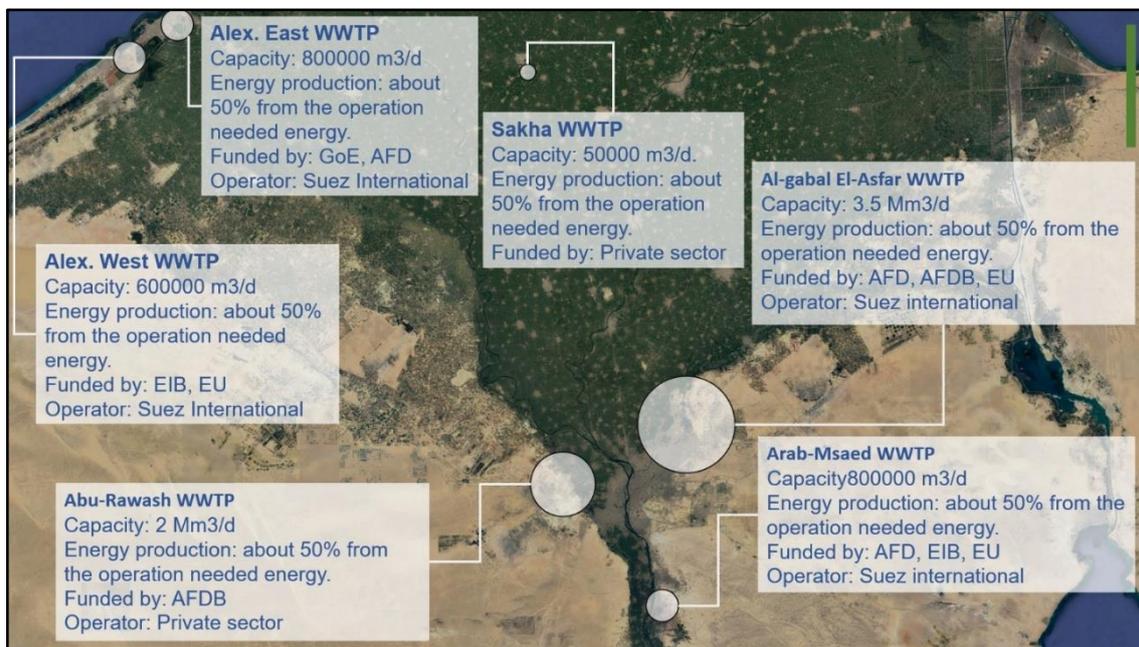
(i) The Ministry of Environment (MoE) in cooperation with all related entities has released “Egypt National Climate Change Strategy 2050” which encourages the scaling-up of biogas production from the wastes particularly the municipal wastewater sludge in order to generate clean energy “electricity power” instead of its generation from fossil sources (Wahaab el al., 2020).

(ii) GoE embarked a great investment in field of municipal wastewater sludge treatment and management particularly the production of bio-gas to generate clean energy; that achieved throughout a portfolio of actions that rely on a cooperation with international partner and doners (for example: Agency France De Development (AFD), European Union (EU), European Investment Bank (EIB), European Reconstruction and Development Bank (ERDB), and African Development Bank (AFDB)); Nowadays Egypt has 6 medium to large scale WWTPs that produce a biogas on-site which supplying from 50% - 60% of energy consumption in those WWTPs (see Figure 8) (EIB, 2020), (EIB, 2022).

(iii) Public-Private partnership (PPP) is an approach that the GoE has adopted to operate these sludge treatment sites in order to sustain the operation of these sites; that attributed to the sophisticated process that needs high qualified labor to manage where the area of

expertise is relatively new for the wastewater operators in Egypt, therefore the GoE directed toward the houses of expertise in this field to operate these assets. In this regard, the GoE has contracted with firms which considered the house of expertise in this area globally to operate and maintain these sludge management sites.

Currently, about 7 Mm<sup>3</sup>/d from municipal sludge have been digested, stabilized, and managed to produce the bio-gas to generate clean energy; otherwise, the digested sludge was used to produce the composter to fertilize the new reclaimed cultivated lands within the framework of the national mega-project for agriculture expansion in Egypt to secure the food production.



**Figure 8:** The WWTPs that have Biogas production form municipal sludge.

### 3.4.Rehabilitation or reuse wastewater stabilization ponds in biodiversity conservation

The Rift Valley-Red Sea Flyway (RVRSF) is the second most important flyway for MSBs in the world, with over 1.5 million birds comprising 37 species migrating twice each year between their breeding grounds in Europe and West Asia and wintering areas in Africa. Between 50-100% of the global or regional populations of some of these species pass along this route and through narrow "bottlenecks" in a frame time of just a few

weeks. Due the biannual movement and characteristics of the birds involved they are highly vulnerable to human threats particularly from hunting, energy infrastructures, waste management developments, and certain agricultural practices. Soaring birds are vulnerable; both along their migratory routes and at stopovers, reasons include habitat destruction due to agricultural expansion and intensification, overgrazing, inappropriate tourism development, industrial expansion, urbanization with an improper management of waste-disposal facilities (Noby et al., 2020). All are widespread threats to soaring birds. Twenty-seven (69%) out of the 37 MSBs species found in the RVRSF have an unfavorable conservation status and also present are the local populations of globally threatened and vulnerable species.

Wetlands are crucial habitats to birds, during both breeding and migration seasons. Millions of Western Palearctic birds cross over 2000 km over desert every year to reach their wintering grounds in Africa (Noby et al., 2020).

With its unique location between three continents of Europe, Asia and Africa, Egypt is considered one of the most important migration flyaway in the world (along the Red Sea coast and the Great African Rift); Therefore, Egypt is considered a bottleneck, as it witnesses high traffic of these migration in a global context (Ministry of Environment, ARE., 2024).

Despite these facts, the flyway of MB in Egypt is a vast arid landscape with minimal natural wetlands, Swamps, and other natural habitats that are used as a stopover for the MB; This natural limitation of habitat is synchronized with massive urbanization and tourist activities in areas that were considered formerly a natural habitat for the MB (Noby et al., 2020). The deterioration of aquatic habitats and natural wetlands induced a selective force against endemic and aquatic birds that made both endemic and migratory birds become increasingly dependent on alternative man-made aquatic habitats. Therefore, the man-made/artificial wetlands particularly the Wastewater Stabilization Ponds (WWSPs) have a great value for the Migratory Birds (MBs) where it acts as natural habitat along the migration corridors, especially those that are located in a sever arid region, where these Wastewater stabilization ponds and its annexes (the woody forest and the aquaculture) are mainly used as stopover and wintering sites by some bird species (Noby et al., 2020).

Although there is much evidence that WWSPs and their annexes have a growing role in the effect of the stopover decision of the migratory birds and attract high numbers of birds, their functions as stopover, wintering, and conservation sites are not well understood particularly in the collective mentality of the operators, decision-makers of the wastewater utilities.

In recent years, there has been growing recognition of the function and importance of Nature-Based Solutions (NBS) as an alternative or supplement to conventional wastewater treatment systems. Treatment wetlands and Wastewater stabilization ponds (WSPs) are NBS often used in decentralized wastewater treatment systems, and they are often a viable option for remote areas that do not have access to centralized systems.

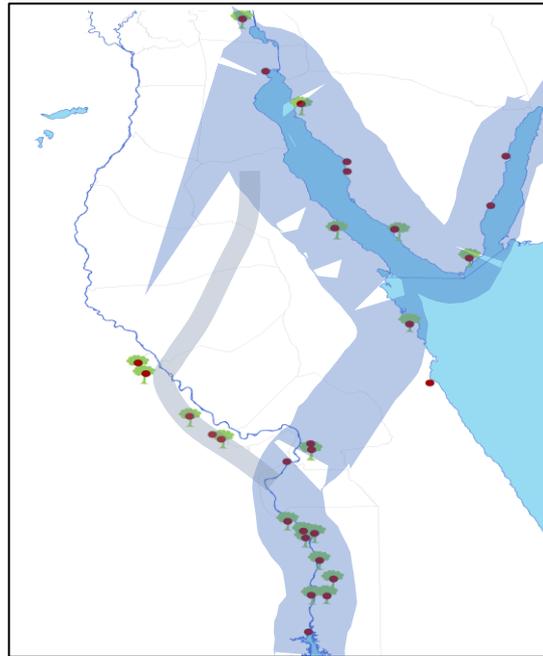
It is worth mentioning that, HCWW has numerous WWSPs (natural stabilization ponds "> 25 sites") located along the flyway of MBs; this section of flyway in Egypt is considered a severe arid region; which are considered as a stopover for the Migratory Birds. Thereby, these WWSPs and their “woody forest” have a significant role as an ecological model (i.e., a temporary rest site for drinking, feeding, and bathing) for MBs. Whilst invariably, the optimization of these kind of Wastewater Treatment Plants (Stabilization ponds) is an important water management challenge (MEDWAYCAP, 2023).

In this regard, HCWW has expanded its scope in terms of environmental protection under the stresses of climate change as an adaptation measure to include the conservation of biodiversity, HCWW has been involved in a partnership with the Egyptian Environmental Agency (EEAA) in activities aimed to conserve the migratory soaring birds in the framework of an international project funded by UNDP and bird life international.

In order to sustain this cooperation and partnership With EEAA in a field that is considered relatively far away from the main scope of HCWW; Both entities have signed a protocol of cooperation in the field of conservation of soaring birds that stopover in the WWSPs along the flyway in Egypt; that was on the sideline of the CPO 27 which held on Sharm-Elsheikh in 2022.

In light of this protocol of Cooperation, there are a group of findings have been detected and defined as measures targeting the conservation of the migratory birds such as:

- Rehabilitation of WWSPs located along the MBs flyway (example: Sharm El-sheikh WWSP); that was reflected significantly of the treated water quality hence a significant decrease in the mortality rate has been recorded of the MBs (Figure 9).
- A decision has been taken to keep a temporary lagoon filled with treated wastewater from Ras-ghareb WWSPs, This lagoon formed aquaculture that attracted many species of endemic birds and migratory birds; Moreover, another decision has been taken to cultivate a woody forest annexed to the Ras-ghareb WWSPs in order to emphasize the site as a stopover and attraction of the migratory birds; that was in the framework of an active water management plan maximize the water reuse in environmental purposes (Figure 10).
- Other site, The wastewater treatment site in Hurghada is consist of (i) a new tertiary mechanical treatment plant with a design capacity 90000 m<sup>3</sup>/day and extended aeration as adopted technology and a slow filter is annexed to the WWTP, (ii) old wastewater stabilization pond; Where the reuse the old WWSPs that were out of services through re-supply the old WWTP (the stabilization pond) with reclaimed water from the new WWTP (Mechanical WWTP) in order to be as an attractive site and creation of a wetland to be a suitable habitat for the MBs.



**Figure 9:** The WWSPs located along the Migratory Birds flyaway in Egypt.



**Figure 10:** The formation of an aquaculture that is used as a habitat and stopover for endemic and migratory birds.

### 3.5. Water Safety Plan implementation

These large investment in water and wastewater infrastructure need to a wide approach to grantee the good governance and sustainable management for those assets.

The HCWW has adopted the WSP as a holistic approach not only to mitigate the potential risk upon the public health but as a participatory way to reinforce and create a resiliency among the key actors in water sector. This study states that there are tangible impacts on the performance and homogeneity in water sector in different areas at different levels and various dimensions as a response of WSP approach implementation. It has become more pronounced throughout (i) institutionally creates WSP units at HCWW and its affiliated companies, (ii) inclusion of WSP in the legislations, (iii) develop framework of WSPs in water sector, (iv) Stakeholder collaboration agreement, and (v) assess of technical requirements (Decent Life initiative, 2019).

The concept of WSP based on risk assessment and mitigation, climate change as a major risk that threaten the water resources globally must be taken into consideration and for the water utilities to be prepared for such events (Roeger and Tavares, 2018).

In practical terms, the WSP approach enhances the adaptive capacity of water utilities by establishing monitoring systems and early warning procedures for critical operational parameters such as water levels, turbidity, and temperature. These measures allow utilities to respond proactively to climate-related events such as heat waves or fluctuations in river levels before they affect water supply safety or reliability.

WSP application in Egypt have started since 2012 under the umbrella of EU project. The main objective of a WSP is to ensure water quality for human consumption using good practices in water supply systems. These include the minimization of contamination in water sources, the reduction or removal of contamination during the treatment processes, and the prevention of post contamination during storage and distribution. Thus, a WSP reflects an organized operating system of water quality management in which four basic stages can be identified (Yehia et al., 2024):

- System Evaluation – process analysis and risk assessment encompassing the entire supply system, from the water source to the consumers' taps;

- Operational Monitoring – identifying and monitoring critical control points in order to mitigate the identified risks;
- Management Plans – development of effective management control systems as well as operational plans to meet routine and exceptional operating conditions;
- Assessment validation - Determine and validate control measures reassess and prioritize the risk

To nationalize the concept of WSP, HCWW has developed national guideline for WSP implementation. Teams have been formalized in 25 affiliated companies with the participation of stakeholders from Ministry of Health, Ministry of Environment, Ministry of Water resources and Irrigation and Ministry of Defense. NGOs are also a participant in these teams. Through these teams HCWW succeeded to certify more than 100 water supply system for WSP.

Risks for water resources due to climate change are enormous, affecting both availability and quality: Water Scarcity and Droughts; Altered Water Cycle; Increased evaporation and Water Quality Degradation:

Water quality degradation can arise from nutrient runoff from increased rainfall can carry fertilizers, sediments, and pathogens into water bodies. Warming water temperatures contribute to harmful algal blooms, affecting aquatic ecosystems and human health. Algal blooms reduce oxygen levels, harm fish, and make tap water unsafe to consume.

Form practical application of the WSP in Egypt to mitigate possible risks from climate change is to protect the water intake via installation of warning color meter that measure the level of Nile river water and give different level of warning according to a color code as follow (Safe level “green color” - warning level “yellow color” - critical level “red color”) to facilitate the communication process, Figure 11.



**Figure 11:** Level control procedures to ensure the safety and sustainability of the service

HCWW has settled a group of procedures and measures to ensure water safety during periods of low water flow. Accordingly, a set of procedures are implemented and classified as follows:

- Regulatory procedures (through the Supervisory Committee for Water Safety and Security).
- Operational procedures (executive work teams for water safety in conjunction with branch managers).
- Corrective actions (through the guidance of the Safety Oversight Committee).

In several water supply systems, the implementation of Water Safety Plans has contributed to improving water quality compliance, with non-compliance rates declining from levels exceeding 5% to less than 3% after strengthening monitoring and risk management procedures (HCWW, 2023, unpublished internal report).

### 3.5.1. Water safety regulatory procedures

- Discussing the issue of safe, warning, and critical levels and dispositions within the work of the supervision committees for water and sanitation safety, in the presence of internal and external partners, members of the committee, issuing a table listing the company's supply systems and the three levels (security - warning - critical), approving it, and distributing it to the various concerned parties.

- Forming a digital communication channel (on a social media application) among members of the supervision committees for water and sanitation safety to ensure effective and rapid communication during crises.
- Classifying the supply systems according to their impact on the decline in the level into three categories in terms of the degree of risk, provided that a statement is distributed to the various concerned parties, which are as follows:
  - ❖ **Class C supply system:** These are stations that are highly affected by low levels, whether in terms of quantity or quality. They are the first to take corrective measures, and a procedure must be put in place for them, such as those described in the corrective measures clause (they are frequently affected by low levels and are next to drains or sources of pollution that lead to the problem being exacerbated, as there are no alternative source).
  - ❖ **Class B supply system:** These are stations that are moderately affected by falling levels and therefore come in the second level in terms of priority (they have recurring problems of being affected by falling levels and there may be sources of pollution next to them, but there are alternative sources for them).
  - ❖ **Class A supply system:** These are stations that are less affected by a drop in the level and therefore come in the last level in terms of priority (the problems of low level do not recur and they also have alternative sources).

### 3.5.2. Water safety operational procedures

- Coordination with the Ministry of Irrigation to calculate the levels in front of each intake, taking into account determining the safe - warning - critical levels through cooperation with the operation and maintenance sector as well as the quality and laboratories sector in accordance with the aforementioned item in the regulatory procedures referred to above.
- Place a measuring ruler next to the outlet, provided that it is numbered in the metric level and also colored with a color code (the safe level “green color” - the warning level “yellow color” - the critical level “red color”) to facilitate the communication process.

- Intensifying the periodicity of collecting follow-up samples to ensure the safety of the water resource and continuous adjustment of doses - follow-up sample every hour, as well as testing the cups for each shift, especially for class “C” stations.
- Installing level monitoring units (level sensitive) and linking it to a warning system for the main stations so that a group of text messages can be sent if levels drop to a minimum through coordination with the projects sector.

These procedures should not be viewed only as operational improvements, but rather as part of a broader climate risk management framework within the water sector. By strengthening monitoring systems, early warning mechanisms, and emergency preparedness, these measures improve the ability of water utilities to respond to climate-related risks such as fluctuations in river water levels, extreme temperatures, and sudden changes in water quality. The Water Safety Plan approach therefore contributes to enhancing the long-term adaptive capacity and resilience of water supply systems under increasing climate variability. In this context, the World Health Organization Water Safety Plan Manual (WHO, 2023) highlights that WSPs provide a systematic risk-based framework capable of incorporating climate variability and long-term climate change risks into drinking water management through the identification and management of hazards such as floods, heat waves, and water scarcity.

### **3.5.3. Water safety corrective actions**

- Implementing an intermediate chlorine injection point (at the exit of the chute), giving priority to class “C” stations.
- Measuring total organic carbon (TOC) and chlorine residues on a weekly basis for all intakes during the period of minimal consumption (winter harvest).
- Finding alternative sources whenever possible (drilling RBF wells - operating underground wells - connecting to an alternative intake) for Class “C” stations in coordination with the company’s projects sector.
- Establish an estimated cost for extending or reducing the intakes to secure them and ensure their operation in the event of a decrease in the level, in conjunction with the company’s advisor for Class “C” stations and through participation with the company’s projects/planning sector.

- Giving priority to implementing water safety plans for Class B and C water station supply systems.

**Overall**

The overall Program/Project/Activates have been summarized in **Table 1**, that in order to build a comprehensive sight on the effort that have been done to mitigate and/or adapt with the impacts of climate changes.

**Table1:** Overall program/project/activaties implemented via GoE to Mitigate and/or adapt to climate changes in water sector.

Program/Project/ Activates	Findings	Action		Classification		Motivation	Comm ents
		Adapta tion	Mitiga tion	Qualit ative	Quantit ative		
Expansion of Sea Water Desalination	(30) Desalina tion Water Treatme nt Plant (WTPs)	√			√	<ul style="list-style-type: none"> <li>• Incre ase water dema nd</li> <li>• Deter iorati on of surfa ce water resou rces</li> </ul>	The baseline year is 2014.
	The National Plan for the Expansio n of Seawater Desalina tion Plants (NPESD )	√		√			
New approach in infrastruct ure	Insid e citie s	Rehabilit ation and Up-grad of (3) WWTPs	√			Extreme Climate Events (i.e. Storm surge, heavy rains, and sea-level rise)	
		Rehabilit ation of (91) Pump stations	√				

	(9) projects (networks).							
	Rehabilitation of Water bodies (Lake Mariout)	√				√		
	Outside cities (1,084) facilities include Levees, embankments, floodwalls, dikes reservoir	√				√	Extreme Climate Events (i.e. Torrents and flash floods)	
<b>Sewage Sludge Management</b>	Egypt National Climate Change Strategy 2050		√	√			<ul style="list-style-type: none"> <li>• Depollution of Water courses.</li> <li>• Decrease traditional energy consumption.</li> <li>• Decrease the carbon footprint.</li> </ul>	
	(6) Sewage Sludge Treatment Facilities (Biogas Production)		√			√		
	Plan for PPP		√	√				
<b>Rehabilitation or reuse wastewater stabilization ponds</b>	Working on rehabilitation/reuse of (3) Wastewater	√	√			√	<ul style="list-style-type: none"> <li>• Biodiversity conservation achieving</li> </ul>	The Wastewater Stabilization ponds along the

	stabilization ponds					SDGs	flyway of Soaring migratory birds.
<b>Water safety regulatory procedures</b>		√	√	√	√		

#### 4. Conclusion

Egypt has become one of the countries strongly affected by climate change, which has become evident in recent years. The threats of these climate changes are represented in different areas (i) uncertainty regarding transboundary water sources (the Nile River). In addition, sea level rise is considered one of the serious threats particularly in the delta regions, which are considered one of the most lowland areas, (ii) along with extreme climate events (i.e. Heavy rainfall, torrents, and flash floods), which have different impacts according the regions features.

This study reviewed major climate-related initiatives implemented in Egypt’s water and wastewater sector between 2018 and 2023. The findings highlight a growing integration of climate action into water sector planning through multiple interventions including desalination expansion, flood protection infrastructure, wastewater reuse, sludge-to-energy initiatives, and the implementation of Water Safety Plans.

These measures collectively contribute to strengthening the resilience of water supply systems by diversifying water resources, improving risk management, and enhancing the capacity of utilities to respond to climate-related challenges.

Although many of these initiatives were not originally designed as climate interventions, their cumulative impact demonstrates the increasing mainstreaming of climate considerations within the Egyptian water sector.

According the regular evaluation of nation’s Sustainable Development Goals (SDG) achievements, the **Figure 11** pointed that, despite Egypt is ranked as Moderate SDG commitment, there is a tangible improvement has been recorded in different goals

such as goal number 6 (Clean water and sanitation), goal number 13 (Climate action), and goal number 15 (Life on land); these goals are related directly and / or indirectly to the impact of climate change. However, there are significant challenges still hamper the progress process which need to address (Jeffrey et al., 2022).

Despite the the adoption of ambitious and credible national plans to face the emerging water challenges resulting from the climate change, there is no holistic plan and/or approach that would ensure the interconnections among these detected plans.



**Figure 11:** Egypt's progress toward achieving SDGs (Sachs et al., 2022).

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