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The Effect of Climatic Changes on the Coastal Sandy Strip Extending from Gamasa in the West to Ras El Bar in the East, Northeastern Nile Delta, Egypt

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ABSTRACT

The northeastern coastal sandy strip of the Nile Delta extending between Gamasa in the west and Ras El Bar in the east consists of sandy plains, interspersed with scattered, incoherent sand dunes, with a limited extension, between which there are low interlocking and branching gaps, the level of which ranges from zero to -5 meters (and a maximum of -25.0 meters southwest of the port of Damietta) below sea level, with the exception of the area east of Damietta Port, where the chain of southern dunes extends northward to surround the Port from the east and southwest, as well as the area bordering the new city of Damietta from the east.

This coastal strip, which is about 27.5 km long and ranges from 3 km to 4.8 km in width, is subject to the threat of partial sea water intrusion, or partial submersion of subsurface water in the event of a one-meter rise in sea level because about 25% of the total area of this strip does not exceed one meter above sea level. This strip is characterized by a wide human, demographic, tourism and industrial activity. The new city of Damietta, the port of Damietta, and the city of Rasal-Bar are located on it. In view of its tourism importance and its different topography, in this research we explain the different coastal areas of this strip to know which are more threatened than others and the nature of the threat as a result of the increase in sea level as a direct impact of the climate changes that the world is witnessing during this century.

KEYWORDS: *Climate change, Nile Delta, Gamasa, Ras El Bar, Damietta Port, New Damietta*

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1. INTRODUCTION

Climate change scientists have unanimously agreed that the increase in the temperature of the Earth's climate system is a fact that cannot be denied. It is derived from data, statistics and scientific observations published by the Intergovernmental Panel on Climate Change in its six reports (IPCC, 1990- IPCC, 2021), which confirm the increase in the global average temperature of the air, sea and ocean waters, the increase in ice and snow melt rates, and the rise in the global average surface level during the twentieth century. Scientists and experts have also agreed in the IPCC reports that there is strong evidence that current policies to reduce carbon emissions will not be able to reduce these emissions over the next dozens of years. The emission of carbon dioxide gas will increase in proportion to the air by between 25-90% during the period from 2000 to 2030 and thereafter. And that the continuation of these emissions threatens to further global warming in the twenty-first century, at rates greater than what it was in the twentieth century.

The sixth international report on the physical science basis (IPPC, 2021) and the annexes published concurrently with this report on sea level rise and implications for low-lying islands, coasts and communities (e.g. IPCC, 2019) added that the loss of ice mass on a global scale, melting permafrost, decreasing snow cover and sea ice extent in the Arctic is expected to continue in the near term (2031-2050) due to rising surface air temperature. The global average sea level rise (GMSL) is also expected to be

0.39 m (0.26 - 0.53 m) for the period 2081-2100 under the lightest scenario of RCP2.6. As for the RCP8.5 scenario, the corresponding GMSL rise is 0.71 m (0.51-0.92 m) for the period 2081-2100 and 0.84 m (0.61-1.10 m) in the year 2100 (Fig. 1). The likely range extends beyond 1 meter in the year 2100 due to the larger expected ice loss from the Antarctic ice sheet.

In a recent study of the European Environment Agency (2021), the study showed that a rise in global mean sea level will increase the frequency of extreme sea level events in most locations. Increases in tropical cyclone winds and precipitation, and increases in extreme waves, along with relative sea level rise, also exacerbate extreme sea level events and coastal hazards. Future changes in the Earth's cryosphere are expected to affect water resources and uses, and changes in floods, avalanches, landslides and land destabilization will increase risks to infrastructure, cultural, tourism and recreational assets. Future shifts in fish distribution and decreases in fish abundance and fishing potential due to climate change are also expected to affect the income, livelihoods and food security of marine resource-dependent communities. It is also expected that the deltas and coastal cities rich in resources will experience moderate to high levels of risk after 2050 under the current adaptation

All the scientific reports issued by the United Nations organizations (the Intergovernmental Authority on Climate Change "The World Bank, the United Nations Environment Program)" and scientific non-governmental organizations, universities, Egyptian and international research centers and news agencies have unanimously agreed that the Egyptian Delta is considered one of the most threatened sites by marine invasion as a result of the increase in global sea level. These risks combine with the side effects left by the construction of the High Dam to make the delta in imminent and certain danger. The situation is, thus, dangerous and requires quick treatment, and any delay means more losses. The threats arising from these risks will persist for several decades and perhaps for a few centuries, even assuming the success of the United Nations in stabilizing the concentration of greenhouse gases in the atmosphere in the near future. This is due to the fact that the Earth's climate system needs centuries to stabilize. On the other hand, the current international policies adopted to reduce the rate of emissions of these gases will not be able to reduce these emissions during the next tens of years.

In a scientific study of the World Bank (Dasgupta et al., 2007) on about 84 developing countries, with the aim of knowing the effects of sea level increase on these countries - especially the effects on population, land, agricultural activity, populated cities, wet areas, and economic losses in case of increase in sea level from one meter to five meters. It has been concluded that the impact of this rise will be more harmful in the Middle East and North Africa than in all other developing countries of the world, and that the Arab Republic of Egypt is the developing country most vulnerable to losses in the event of a one meter rise in sea levels. These losses are concentrated in the Nile River delta where they affect about 12.5% of the total cultivated area and including the displacement of about 10% of the total population of the Republic from their lands and cities.

In a study by Daoud and Mohamed (2008) at the Survey Research Institute in Egypt to assess the risks of sea level rise on the Egyptian delta using the SRTM 3 elevation model, the authors concluded that the area of areas prone to drowning in the delta ranges from 292 km² (about 2% of the delta area) to 2023 km² (about 17% of the area of the delta) according to the sea level rise by an amount ranging from 25 centimeters to 100 centimeters. Frihy et al. (2010) pointed out that an overall upward trend of relative sea level at different coastal cities in Egypt (Alexandria, Abu Qir, Rosetta, Burullus, Damietta and Port Said). fluctuates between 1.8 and 4.9 mm/year.

The present author (Ouda, 2010, 2011, 2012a, 2012b.) has published an extensive study aimed at determining the quantitative and qualitative size of the certain risks that will face the Egyptian coasts as a result of the global rise in sea level as a direct effect of the certain rise in the earth's temperature during this century in order to identify the weaknesses in these coasts, and the traditional defensive policies that must be followed to avoid or mitigate these risks based on updated information from NASA's Shuttle Radar Topological Mission SRTM 4). The study concluded by identifying the risks that threaten the Egyptian coasts, the sources of threat, and determination of wet and dry low-lying land areas exposed to the risks of marine encroachment as a result of the global rise in sea level by a maximum of one meter during this century. The study also included a proposal for traditional and non-traditional means of defense.

According to Ouda's studies (2010, 2011), the dry and wet coastal lands of the Egyptian delta (including the Tina Plain , northwestern Sinai) that are subject to marine invasion in the event of a global sea level rise of a maximum of one meter during the current century range from 4147 km² in size to 17% of the

total area of the delta as a minimum (which is the threatened coastal lands whose level does not exceed sea level) to 5,920 km², or 24.2% of the total area of the delta as a maximum (which is the threatened coastal lands whose level does not exceed one meter above sea level). The low-lying, dry and wet coastal lands exposed to the dangers of sea level rise include cities, villages, manors, roads, bridges, dunes, sandy hills, and dry lands whose level rises more than a meter above sea level, with a total area of 2113 km².

These high areas will be subjected to complete sea blockade and isolation as isolated islands within the invaded areas; In addition to the damage to agricultural and industrial projects and public utilities established on these lands as a result of the naval blockade. Therefore, the total affected areas in the delta as a result of the sea level rise by a maximum of one meter will be 8,033 km², which is equivalent to 33% of the total area of the Egyptian delta (Fig.1).

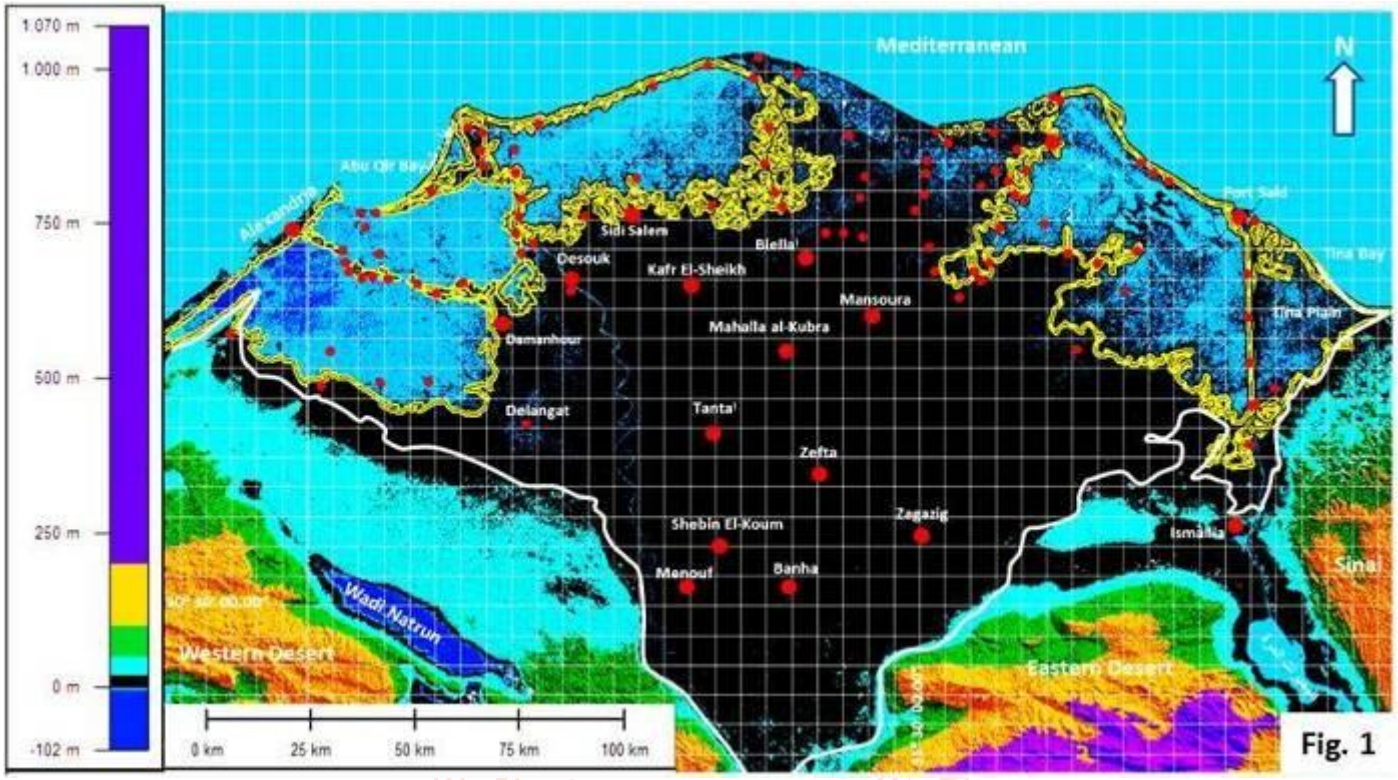


Fig. 1: Simple Topography of the Nile Delta in case of sea-level rise by a maximum of one meter - showing the limits of areas threatened by direct invasion from the sea, indirect invasion through the northern lakes, or immersion by water leaking from the sea or the Suez Canal through the sandy subsurface soil (After Ouda, 2010, 2011). The white line is the limit of the natural Delta. Yellow lines are the limits of threatened low-lying dry and wet lands (blue areas south of sea shore). The total area of these lands is 5938 square kilometers, representing about 24.28 % of the total area of delta. In addition, ~ 2075 square kilometers made up of cities, villages, roads and sand ridges and dunes situated more than a meter above sea-level are threatened by the siege and isolation as separated islands within the endangered areas. Thus, the total area which becomes at risk as a result of rising sea level by a maximum of one meter in the Nile Delta is equal to~ 8033 square kilometer, representing ~ 33% of the total delta area. The black areas are dry lands with a level ranging from 1 to 20 meters above sea level.

Later, updated studies were published by the present author Ouda (2022a; 2022b) on the coasts of the Egyptian Delta in order to determine the quantitative and qualitative size of the certain risks that will face these coasts. The studies included Neighborhoods at risk of drowning in Alexandria in light of climate change, coastal threat sources and means of protection (Ouda 2022a). They also included the sandy belts of the four lakes in the northern Delta (Manzala - Burullus - Mariout - Idku) in order to determine how these lakes and their surrounding plains will be in the event of an increase in the global sea level (Ouda, 2022b). The later study included the coasts extending northwest of the delta from Abu Qir in the west to Idku in the east, north of the delta from Rosetta in the west to Gamasa in the east, and northeast of the delta that extends between Damietta in the west and Port Said in the east. The study included areas of dry and wet coastal lands threatened by marine invasion, coastal threat sources and the traditional defensive policies that must be followed to avoid all these risks.

The present research aims to complete the risks that threaten the northeastern coastal part of the Nile Delta. It concerns with the study of the quantitative and qualitative size of the risks that will face the eastern sandy belt extending along the northeastern coast of the Nile Delta from Gamasa in the west to Ras El Bar in the east and its surrounding plains, with a length of about 27.5 km, including the port of Damietta as a result of the global rise in sea level during this century. The study includes the coastal threat sources and the traditional defense policies that must be followed to avoid all these risks.

The study is based on the consideration that the maximum remainder increase in the global average sea level (GMSL) during the twenty-first century is 100 centimeters, based on the sixth report issued by the Intergovernmental Panel on Climate Change (IPCC), and the supplements published concurrently with it in December 2019-2021. As for what was mentioned in the scientific report of the World Bank directed to developing countries (Dasgupta, 2007) that the maximum sea level rise during this century could reach 300 centimeters, or what was mentioned in a study of the European Environment Agency (2021) that the rapid disintegration of the ice cover in Antarctica may lead to a sharp rise in the global sea level to 2.3 meters in 2100 - we don't work with it. Such a sharp increase in sea level is not expected by the Intergovernmental Panel to occur in this century, but rather during the next two or three centuries as a long-term effect of climate change - due to the greater ice loss expected from the Antarctic ice sheet. This is if emissions are not controlled so that the concentration of carbon dioxide in the atmosphere reaches 660-790 parts per million.

2. Methods of Study

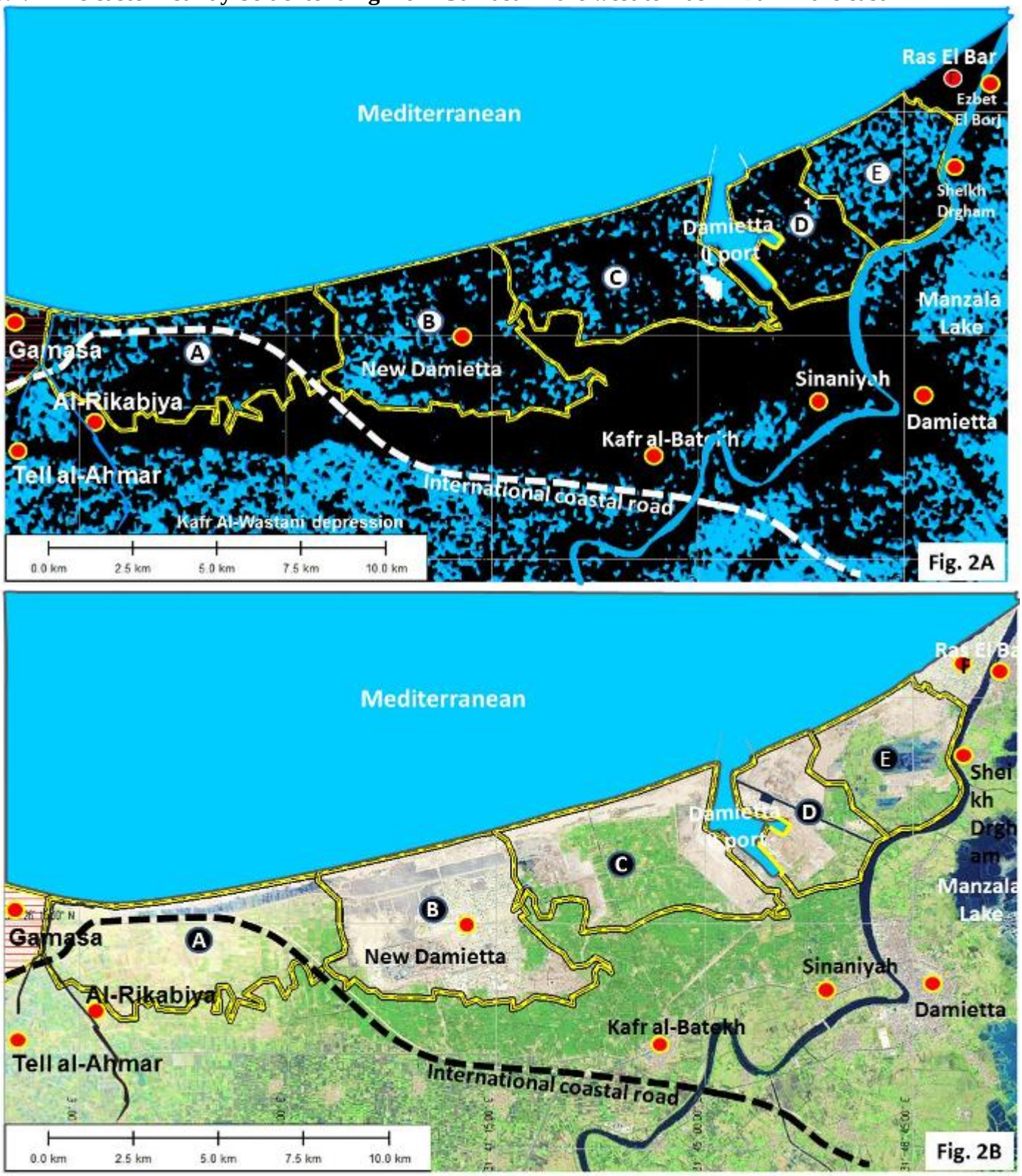
In this study, modern international mapping programs have been used, the most important of which is the Global Mapper (versions 9-13) program to design detailed topographic and contour maps of the delta coasts and to determine the damaged and safe areas in relation to sea level based on the information and digital data for ground elevations received from the Shuttle Radar Topographic Mission (SRTM) of NASA. This shuttle has built a high-resolution World-Wide Elevation Data (3-arc- second Resolution) system for most of the Earth's land surfaces. The fourth improved version of this information released in 2008 by CGIAR-CSI was used.

The current human uses of the threatened lands in question have been determined through precise and direct electronic projection of modern satellite images on topographical maps designed with high accuracy. Worldwide high resolution color imagery from Digital Globe, and satellite images from Landsat 7, Google Earth Pro, and Google Maps were used. Also, GIS programs available to determine locations were used, such as The USGS Digital Elevation Model (DEM), USGS digital Raster Graphic (DRG) data, USDA National Agriculture Imagery Program (NAIP), Digital Chart of the World, Egypt. This is in addition to field visits to some threatened neighborhoods along the northern coast of the Nile Delta and its beaches.

This study included detailed topographic maps of the northeastern coastal part of the Nile Delta extending from Gamasa in the west to Ras El Bar in the east and its surrounding plains, with a length of about 27.5 km, including the port of Damietta and then put them in the case of sea level rise and the sources of their threat. The satellite images corresponding to these topographic maps, represented by the lines of the new beach in the event of sea level rise, the threatened lands, the sources of their threat, the effect of sea level rise on human uses of threatened land spaces, are all given in order to determine the size of the gaps that permeate the coastal threat sources and to determine the appropriate means of protection of defense lines.

3. Results and Discussion

3.1. The eastern sandy belt extending from Gamasa in the west to Ras El Bar in the east



Figs. 2A-2B: Fig. 2A: A brief topography of the eastern sandy belt in the north of the Delta extending between Ras al-Bar to the east and Gamasa to the west along the Mediterranean coast - in the event of a maximum sea level rise of one meter. The black areas are lands and sand dunes whose level rises more than a meter above sea level, while the blue areas are depressions whose levels often range from -2.5 meters below sea level to one meter above sea level. These depressions are under threat either by direct invasion from the sea due to their direct contact, or by partial immersion in the event of seawater infiltration into the subsurface sandy soil. The yellow lines are the boundaries of the coastal areas from A to F which are mentioned in the text. Fig. 2B – Landsat 7 satellite image of the same eastern sandy belt in the northern delta, whose topography is given in Fig. 2A - showing the land uses of the coastal plain. From now and ongoing the geographic North is oriented north of the figure.

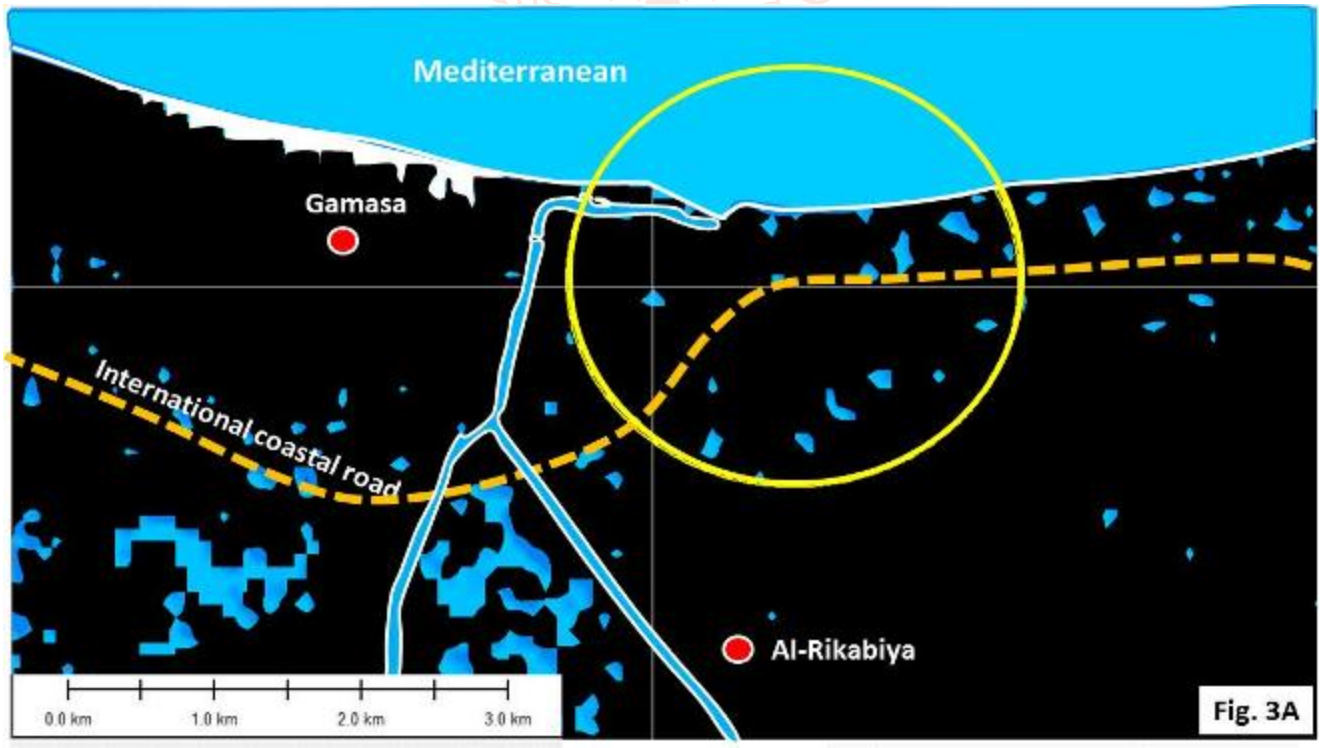
This belt extends in a northeast/southwest direction, and is opposite to the direction of the sand belt that extends from Al-Burj to Gamasa. Hence, it lacks the characteristic of sand dune accumulation along the shore line that characterizes its predecessor. Rather, the migrating dunes gather from the northwest at a distance of 3.5 km to 5 km south of the beach line. It is located in a longitudinal chain that extends in an east-west direction from Al-Rikabiya in the west to Damietta in the east, with a length of 22.6 km and a width ranging between 1.5 km in the east and 3.75 km in the west. It is characterized by the density and cohesion of dunes without any gaps between them, and their levels often range between 5.0 meters and 8.0 meters (minimum 3 meters and maximum 10 meters) above sea level. The danger of this depression lies in its being submersible if the groundwater level rises as a sequential effect of the global sea level rise, due to its proximity to the coast and its wide extension.

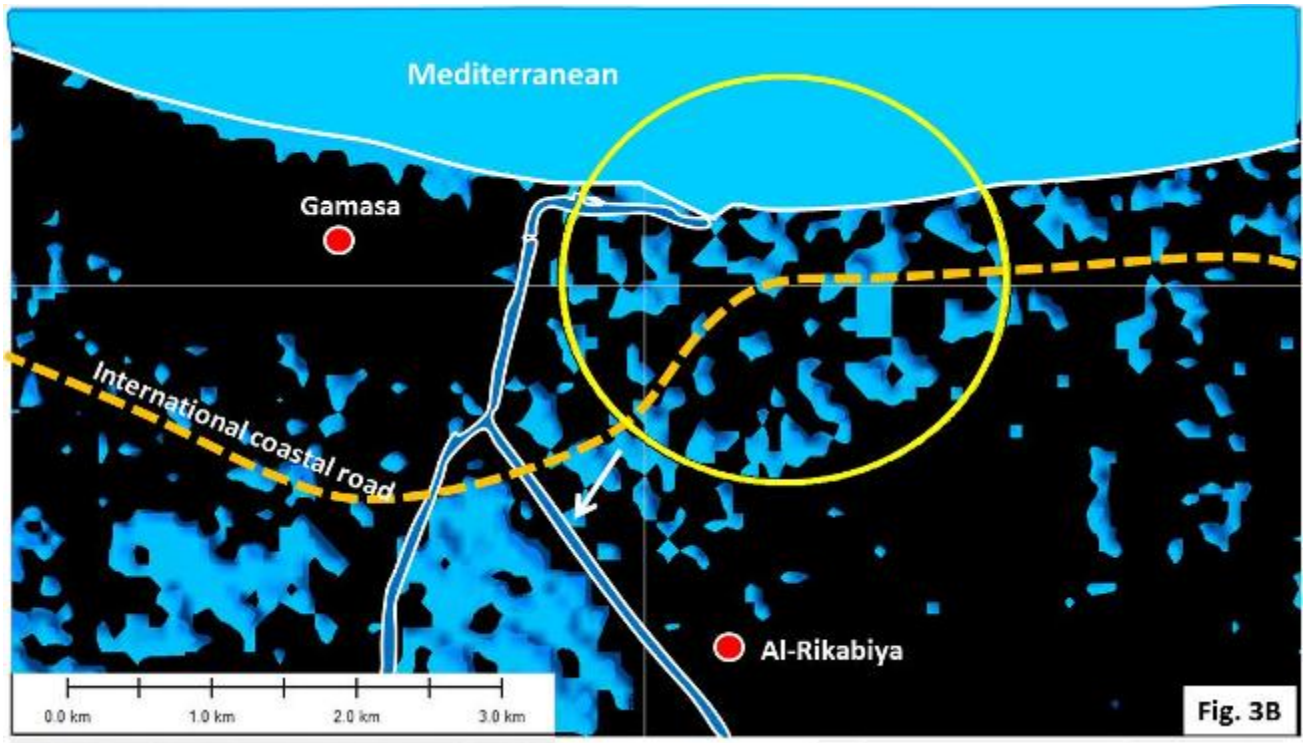
As for the north of the dune chain towards the sea, the coastal strip consists of sandy plains, interspersed with scattered, incoherent sand dunes, with a limited extension and a level ranging between one and 5 meters above sea level, and interspersed with low, interlocking and branching gaps, the level of which ranges from zero to -5. meters (and a maximum of -25.0 meters southwest of Damietta port) below sea level - with the exception of the area east of Damietta port where the chain of southern dunes extends northward to surround the port from the east and southwest, as well as the area bordering the new city of Damietta from the east.

This coastal strip, which is about 27.5 km long and ranges from 3 km to 4.8 km in width, (Fig. 2A-2B) is subject to the threat of partial sea water intrusion, or partial submersion of subsurface water in the event of a one-meter rise in sea level, as about 25 km 2 of the total The area of this strip (101 km2 after deducting the area of Damietta port that it crosses) does not exceed one meter above sea level. This strip is characterized by a wide human, demographic, tourism and industrial activity. The new city of Damietta, the port of Damietta, and the city of Ras al-Bar are located on it. In view of its tourist importance and the difference in its topography, we explain the following to the different coastal areas of this strip to know which are more threatened than others and the nature of the threat as a result of the increase in sea level:

3.1.1. A- The coastal area extending between the resort of Gamasa to the west and the new city of Damietta to the east

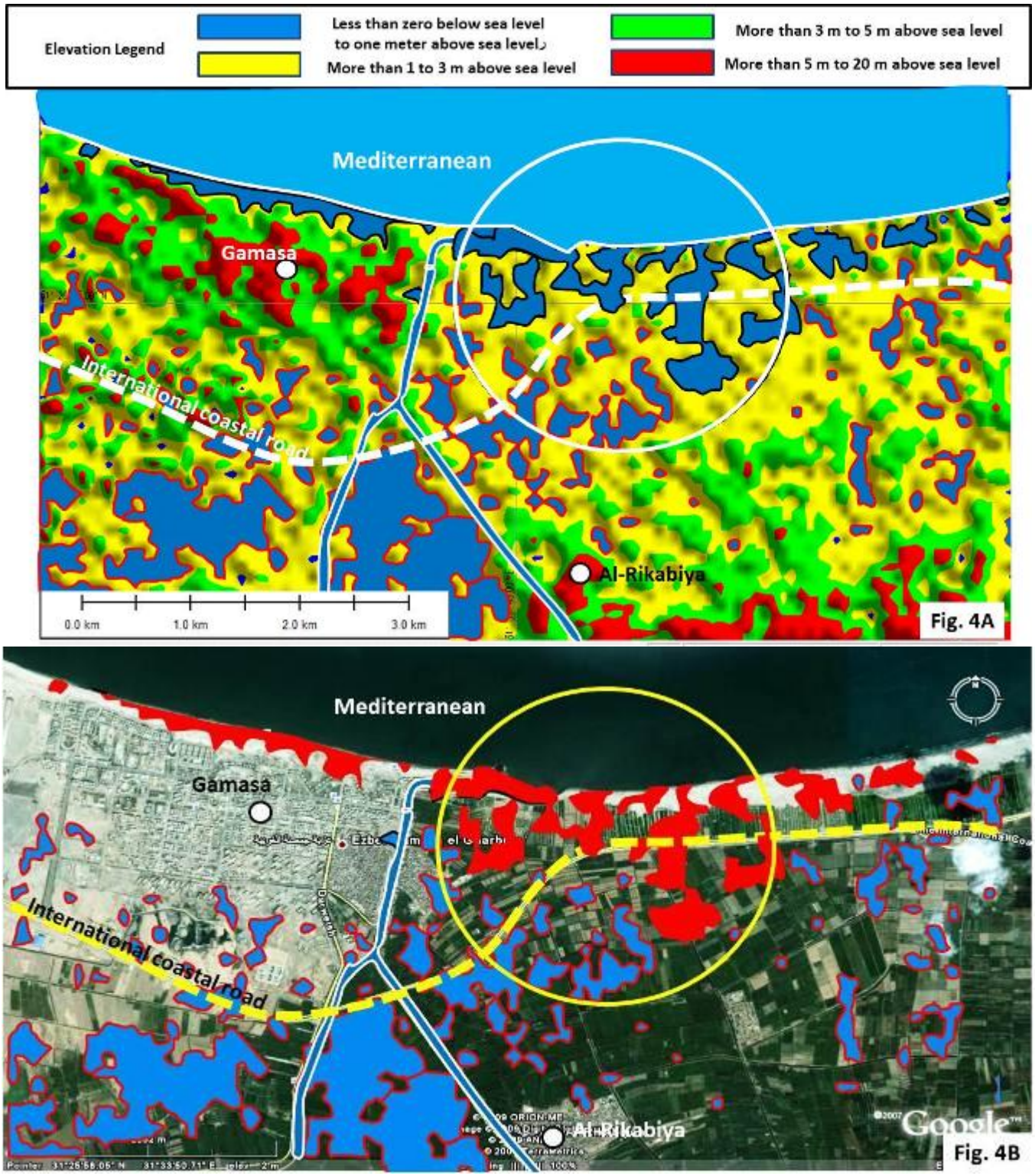
This area extends south of the beach line with a length of 7.6 km and an average width of 3.3 km with a total area of about 25.5 km² (Figs. 3A-3B). The area is dotted with dunes and sandy hills whose level rises more than a meter above sea level by 82%, interspersed with depressions ranging from -1.0 meters below sea level to +1.0 meters above sea level by 17.5%. Some of these depressions are far from the shore line and not directly connected to the sea, and therefore are not threatened by direct invasion if the sea level rises, but rather they may be partially submerged if the groundwater level rises as a sequential effect of sea level rise. While others are located directly south of the beach line and directly connected to the sea, extending inland to form a large gap that is qualified to serve as a sea passage between the sea and the southern plains.



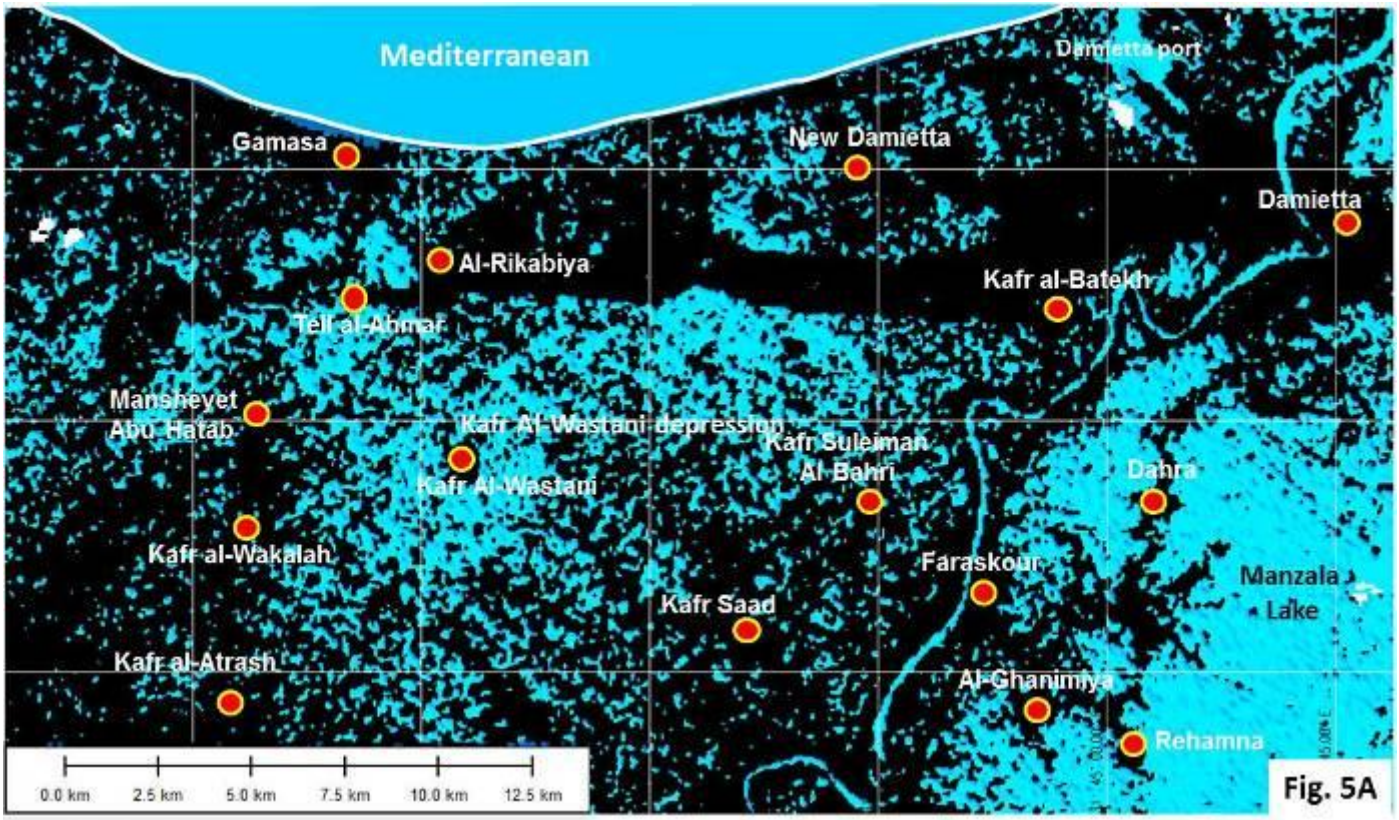


Figs. 3A-3B: Fig. 3A: A brief topography of the coastal strip of the resort of Gamasa and the area east of Gamasa between Qlabcho in the west and the new city of Damietta in the east on the Mediterranean coast - as it is the current situation. The continuous white line is the current shoreline. Black spaces are lands that rise above sea level. The blue areas south of the beach line are depressions below sea level. The white space that represents Gamasa beach is excavated from the sea and dried for the purpose of exploitation as an artificial beach. Note that the most threatened coastal sites in the event of sea level rise are the Gamasa artificial beach and the coastal area east of Gamasa indicated by a yellow circle. Fig. 3B: A brief topography of the same coastal strip in the event of a maximum sea level rise of one meter. The continuous white line is the current beach line, including the shore line of the Bahr Sindila Drain. Black spaces are lands that rise more than a meter above sea level. The blue areas south of the beach line are depressions whose level does not exceed one meter above sea level. Note the large expansion of the areas of the depressions along the shoreline and its extension to the south, compared to the current situation in Fig. 3A. Note also that the coastal depressions east of Gamasa (east of the Bahr Sindila Drain), whose outline is defined by a yellow circle, are isolated from the southern triangular depression located west of Al-Rikabiya by a thin ground corridor that does not exceed 1.5 meters above sea level (the location indicated by the white arrow). An increase in sea level greater than a meter will result in the invasion of this corridor, and from there to the southern depression (Kafr Al-Wastani depression), which extends from the village of Manshiyet Abu Hatab - Kafr Al-Wakalah in the west to Kafr Abu Suleiman Al-Bahri - Kafr Al-Batikh in the east.

The last type of depressions is concentrated in the area located directly east of the mouth of Bahr Bassandila, which extends between the coast in the north and Al-Rikabiya in the south (around the intersection of 31º 23.75` longitude and 31º 26.25` latitude) with a length of approximately 3 km and an area of 7 km² (Figs. 4A-4B). It is an area partially exploited as salines, and it is subject to direct invasion in the event of an increase in sea level by one meter, or 33% of its area (2.32 km²). This area poses a potential danger to the agricultural depression located south of the sand belt (Kafr al-Wastani depression (Figs. 5A-5B) in case the sea level rises between 1.25 and 1.5 meters.In case of direct marine invasion, and because of the presence of a corridor lower than this level in the southern part of this region (Fig. 3B), between the Al-Rikabiya canal and Bahr Bassandila at Tal Al-Ahmar (south of Ezbet Gamasa Al-Sharqiya), it is expected that this low corridor will act as a waterway between the aforementioned coastal region and the southern depression. The more we go east from the previous region towards the new city of Damietta, the gaps in between the depressions decrease and the level of the plain increases relatively. Some of these depressions are close to the shore line and are threatened with partial submersion due to sea water seeping into the subsurface soil in the event of an increase in sea level - but its effect is limited geographically, while others are relatively far from the shore line, and all of them do not constitute a danger to the coastal region and can be treated by filling them in and raising their levels to more than a meter.



Figs. 4A-4B: Fig. 4A: Detailed topography of the coastal strip of Gamasa and the area east of Gamasa between Qlabcho in the west and the new city of Damietta in the east on the Mediterranean coast - in the event of a maximum sea level rise of one meter. The continuous white line is the current beach line. The blue areas defined by black lines south of the beach line are the low beach areas threatened by direct invasion from the sea due to their direct contact with the sea. The blue areas marked with red lines are the low-lying areas threatened with full or partial inundation in the event of seawater intrusion into the subsurface sandy soil (depressions near the shoreline) or a rise in the groundwater level as a sequential effect of sea level rise (depressions far from the shoreline). Fig. 4B : Google Earth satellite image of the same coastal strip whose topography is given in Fig. 4A - showing on it the effect of sea level rise by a maximum of one meter. The completely red areas are the low-lying coastal areas threatened by direct invasion from the sea due to its direct contact with the sea, the most important of which are the Gamasa resort beach and the coastal area directly east of Gamasa (marked with a yellow circle). The blue areas marked with red lines are the low-lying areas threatened with full or partial inundation in the event of seawater intrusion into the subsurface sandy soil.



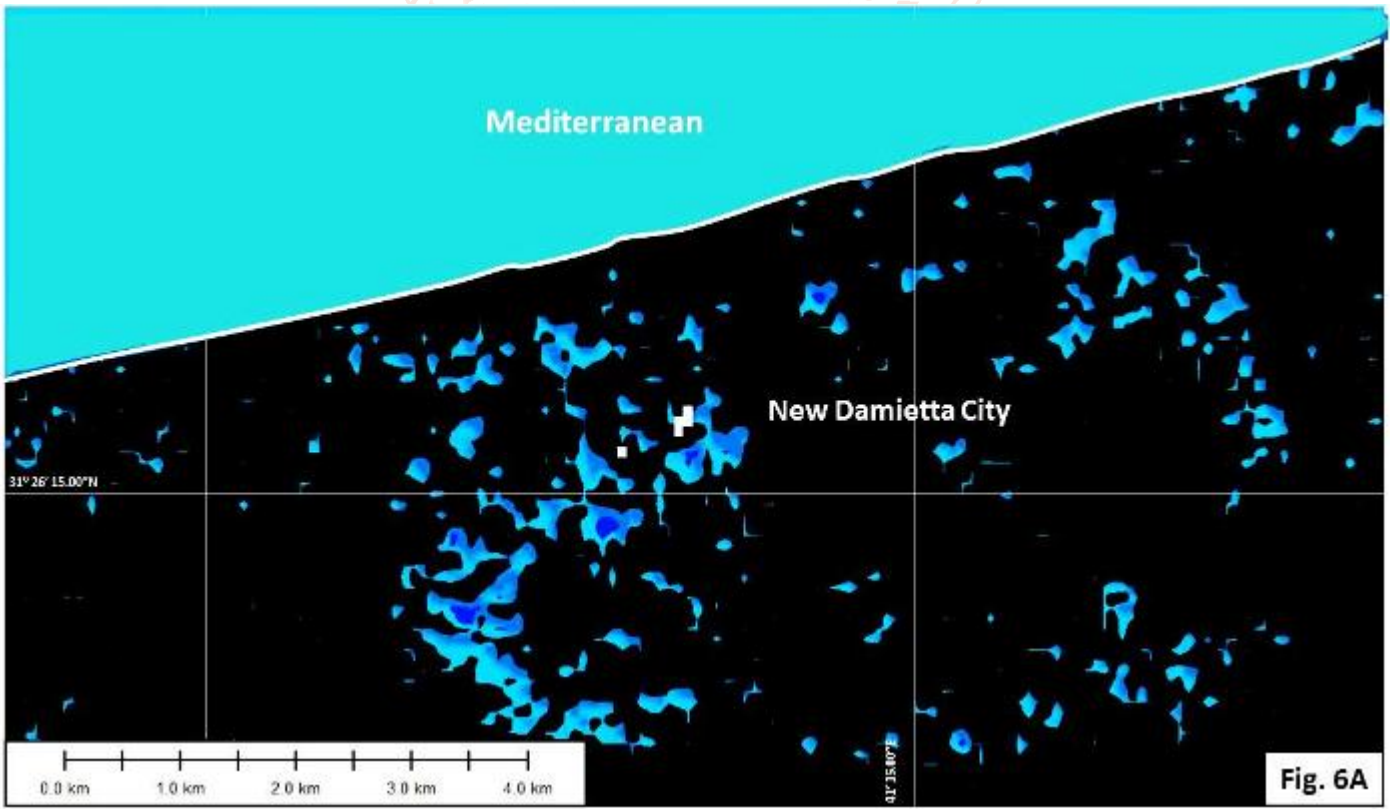
Figs. 5A-5B: Fig.5A: A brief topography of the northern part of the delta extending along the Mediterranean coast from the port of Damietta - Rahamna in the east to Gamasa - Kafr al-Atrash in the west - in case the sea level rises by a maximum of one meter. The continuous white line is the current shore line. Black spaces are lands whose level rises more than a meter above sea level. The blue areas south of the shoreline are submerged low lands (Lake Manzala) or dry lands, with a ground level ranging from -2.5 meters (and a maximum of -7.5 meters, with the exception of some depressions around the port of Damietta, where the maximum reaches -25.0 meters) below sea level) to one meter above sea level. Notice the wide spread of coastal depressions east of Gamasa, around the new city of Damietta, around the port of Damietta, and southwest of Ras El Bar. In addition there is a large transverse depression south of the chain of sand dunes extending from Kafr al-Batikh in the east to al-Rikabiya in the west. This depression (here called the Kafr Al-Wastani depression) extends between the Tal Al-Ahmar-Kafr Al-Atrash line in the west to the West Bank of the Nile River, the Damietta branch in the east. Fig. 5B - A satellite image of the

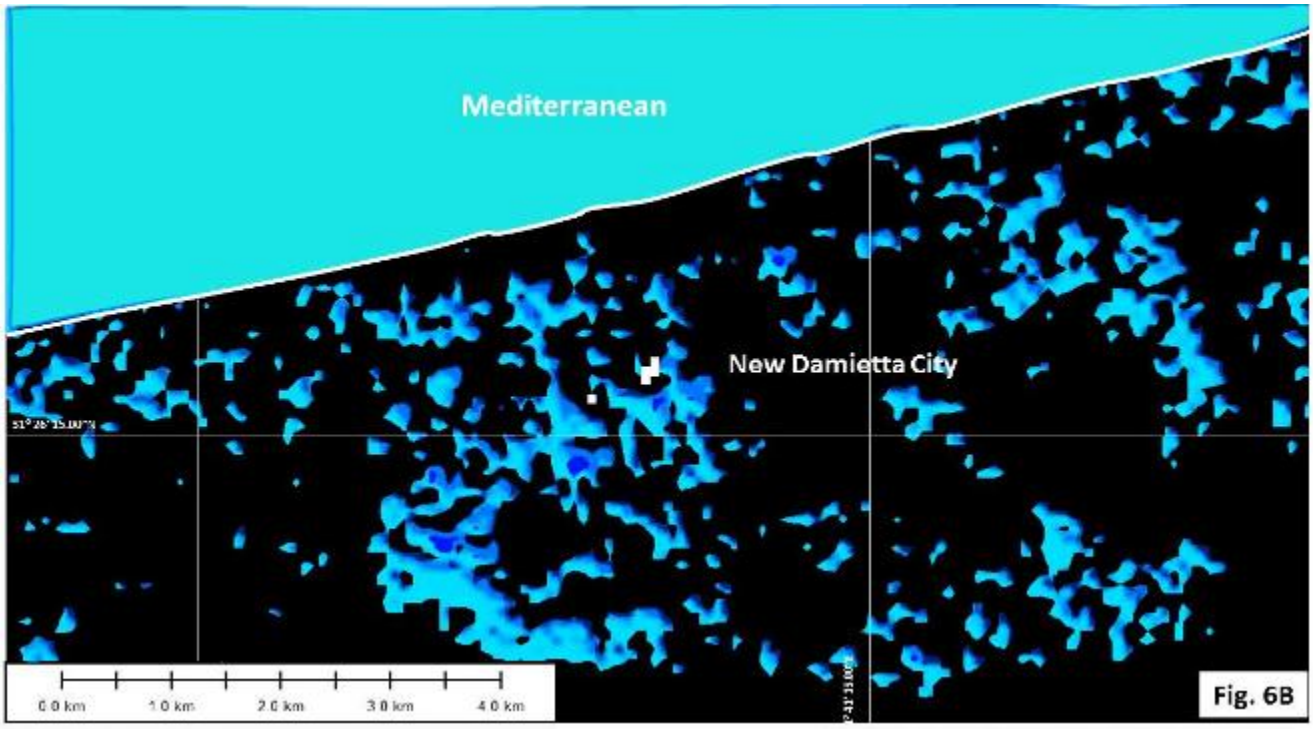
Google Earth program for the same northern part of the delta whose topography is given in figure 5A, showing the effect of sea level rise by a maximum of one meter. The red areas are the low-lying areas threatened by direct incursion by sea water. As for the areas decorated with bubbles and marked with yellow lines, they are the areas that are safe from marine invasion, but they are only likely to be subjected to partial submersion in the event of sea water infiltration into the subsurface sandy soil (depressions near the shoreline) or a rise in the groundwater level as a sequential effect of sea level rise (depressions away from the shore line).

3.1.2. B- The coastal area of the new city of Damietta

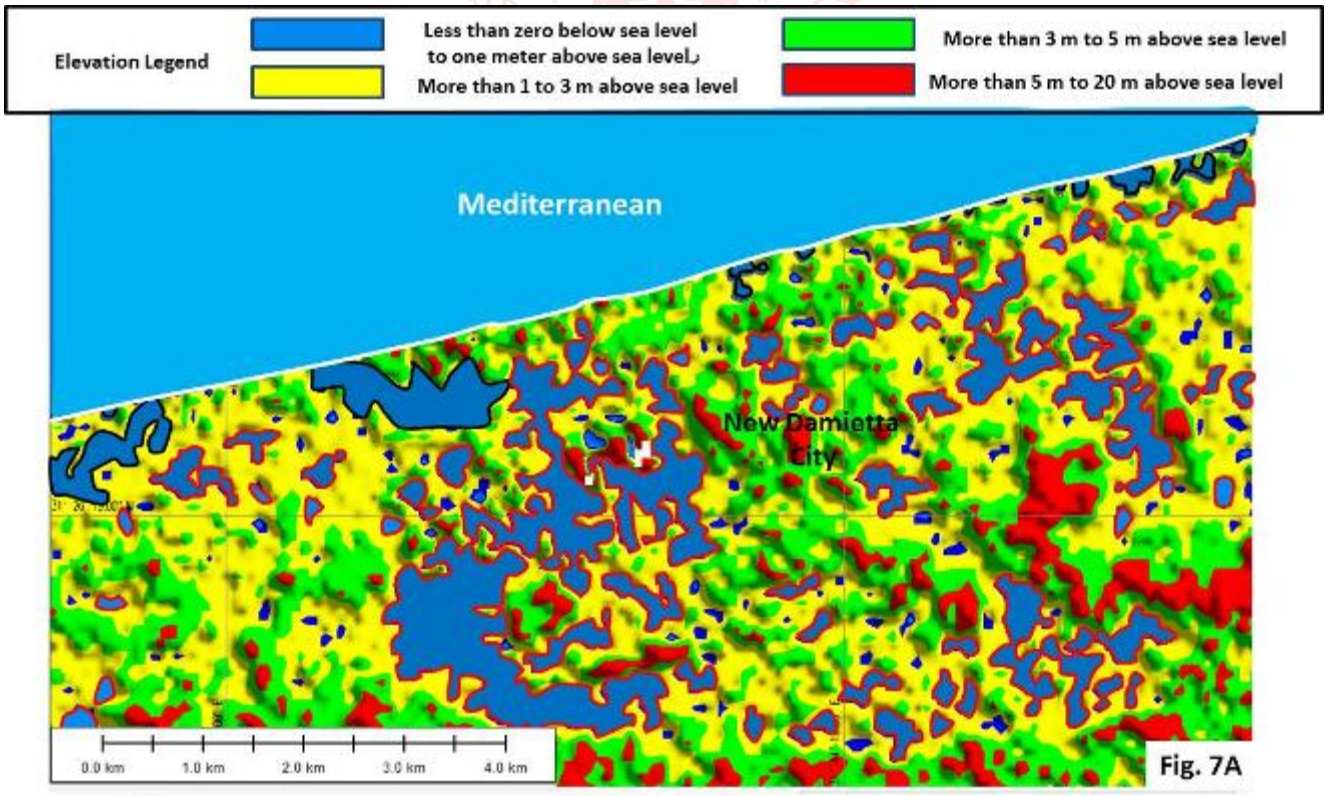
This area, which includes the new city of Damietta, extends from 5.2 to 5.5 km in length and from 4.3 to 5.3 km in width, with a total area of 27 km² (Figs. 6A-6B and 7A-7B). The city is bordered to the north along the coast by a thin chain of sand dunes with a ground level lying between 2.0 and 5.0 meters (with a maximum of 7.0 meters in the western part of the coast) and a width ranging from 550 to 800 meters. These dunes act as a natural wall between the sea in the north and the city in the south. The city is also bordered from the south by the previously mentioned chain of dense, high dunes, which isolate the city from the southern depression of Kafr Al-Wastani. However, the city is permeated and surrounded from the west and north-west by dense interlocking depressions, the level of which ranges between zero and -5 meters below sea level, with an area of about 2.9 km². These depressions are liable to be submerged by the subsurface soil due to their proximity to the shoreline and their sharply low levels.

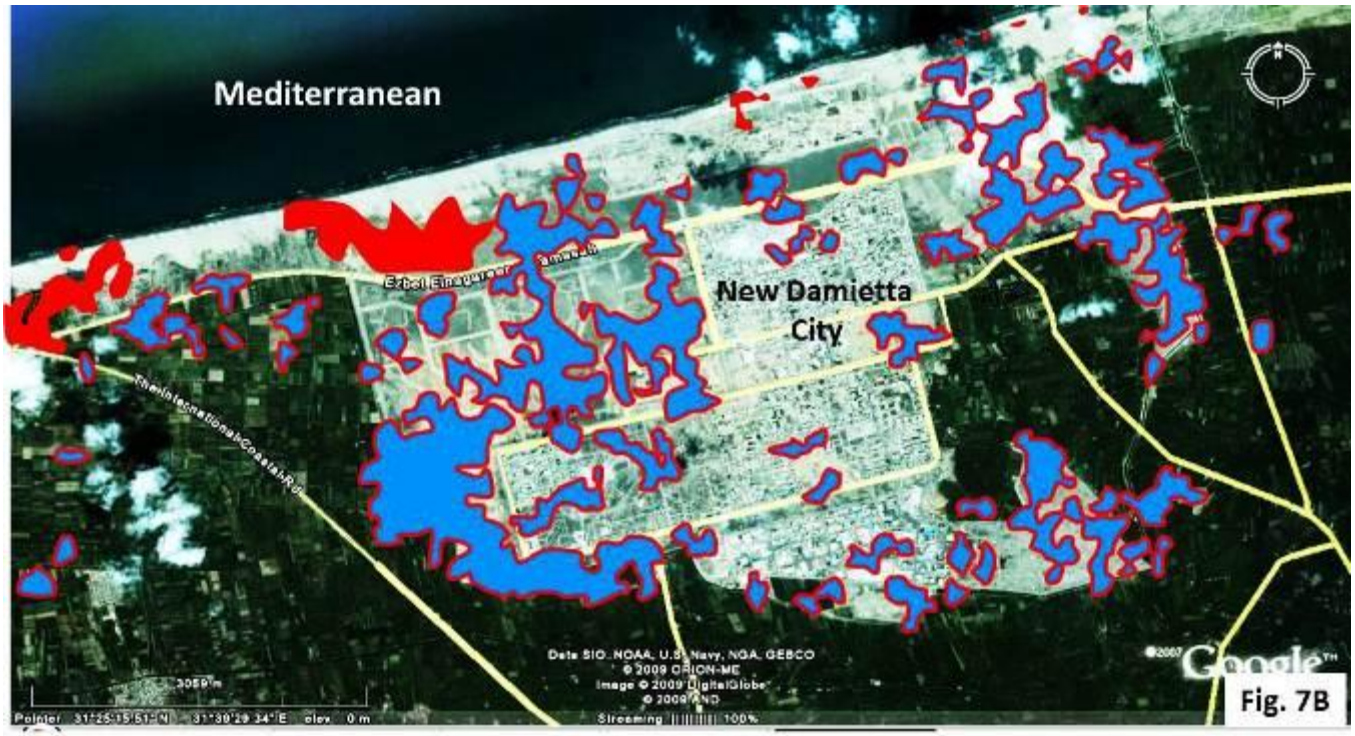
These depressions are mostly not exploited for housing, as shown by satellite images (Fig. 7B), as the city's residences and facilities are located on high levels ranging between 3.0 meters and 5.0 meters above sea level. Therefore, there is nothing currently threatening the city, except that in the event of an increase in sea level by a maximum of one meter, this will expand the area of the depressions to 7.4 km² (27.4% of the area of the region), of which 0.64 km² are beach depressions connected to the sea and threatened by direct invasion northwest of the city, and 6.76 km² of internal depressions threatened with partial flooding due to subsurface water, 5.2 km² of which are concentrated in the west of the city and 1.7 km² are located in the southeast of the city, which will affect the facilities established in the southeast and west of the city. However, this will not cause the city to be invaded or isolated, as it will continue to be connected to the rest of the cities of the Republic, noting that an increase in sea level by two meters will threaten about 13.7 km2, or about 50% of the total area of the area on which the city is built.





Figs. 6A-6B: Fig. 6A: A brief topography of the coastal strip of the new city of Damietta on the coast of the White Sea, as is the current situation. The white line is the current shore line. Black spaces are lands that rise above sea level. The blue areas south of the beach line are depressions below sea level down to -5.0 meters and a maximum of -8.0 meters below sea level, some of which are already submerged and most of them are dry and exploited for residential, industrial or administrative purposes. Fig. 6B: A brief topography of the same coastal strip of the new city of Damietta in the event of a maximum sea level rise of one meter. The white line is the current shore line. Black spaces are lands whose level rises more than a meter above sea level. The blue areas south of the shoreline are lowlands ranging from -5.0 meters (maximum - 8.0 meters) below sea level to one meter above sea level. The vast majority of these depressions are not directly connected to the sea, and therefore they are safe from direct sea invasion. However, their wide spread and transverse extension along the coast, with some of them being very close to the shoreline, prepares them for partial submergence by seawater infiltrating through the subsurface sandy soil or by the action of groundwater if its level rises as a sequential effect of sea level rise due to its sharp drop below sea level.



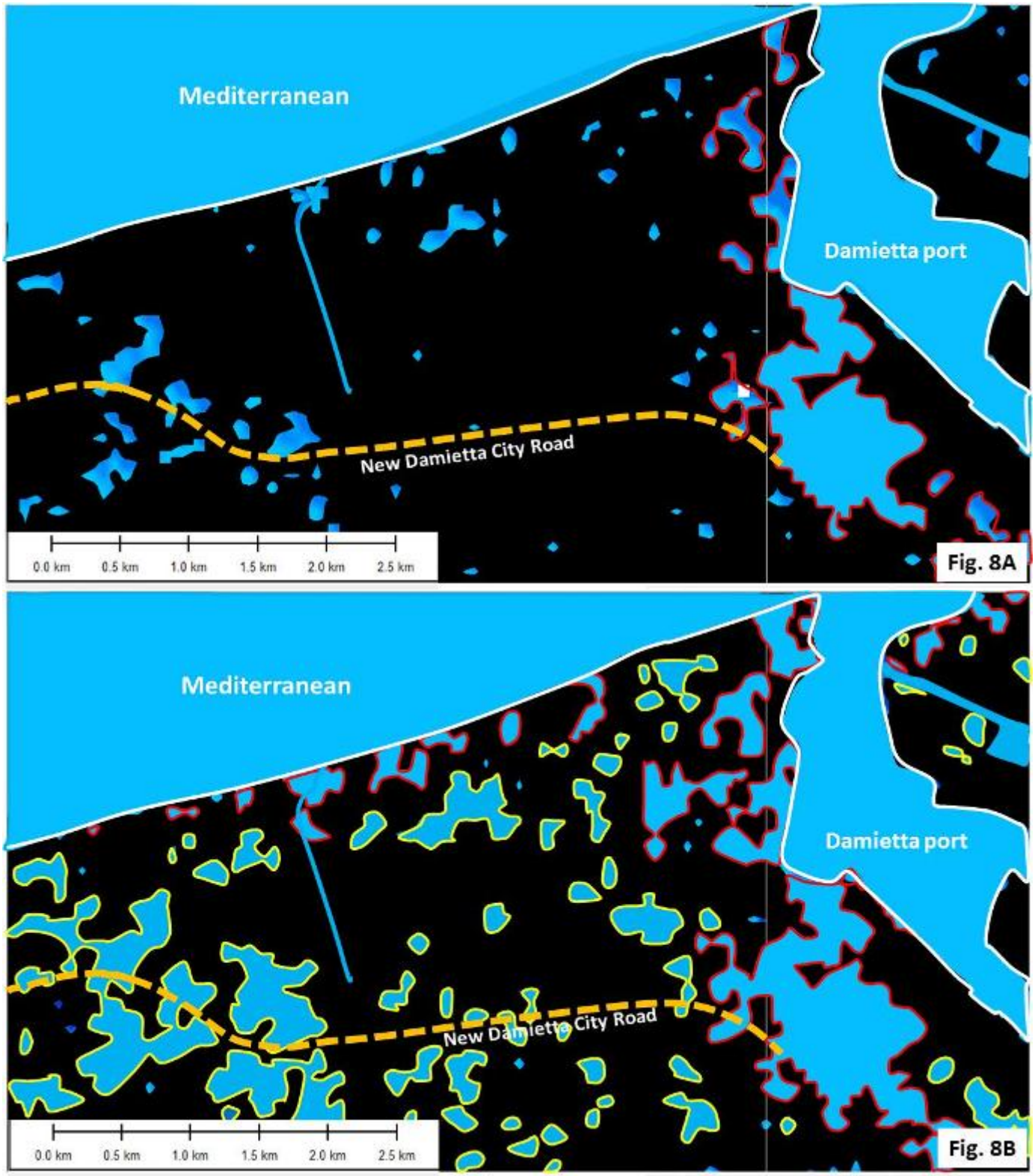


Figs.7A-7B: Fig.7A: A detailed topography of the coastal strip of the new city of Damietta on the Mediterranean coast in the event of a maximum sea level rise of one metre. The white line is the current shore line. The blue beach areas marked with black lines are the low-lying areas threatened by direct encroachment from the sea. The blue areas delimited by red lines south of the shoreline are also depressions ranging from -5.0 meters (maximum - 8.0 meters) below sea level to one meter above sea level, but not directly connected to the sea and isolated from it by intermittent chains of sand dunes of medium height (from 3 meters to 5 meters or more above sea level), and thus are safe from direct sea invasion. However, their wide spread and transverse extension along the coast, with some of them being very close to the shoreline, prepare them for partial submersion by sea water leaking through the subsurface sandy soil. Fig. 7B: A satellite image of the Google Earth program for the same coastal strip whose topography is given in Fig. 7A. The completely red areas are the low-lying coastal areas connected to the sea and threatened by direct incursion from the sea, and they are concentrated in the western part of the coastal strip. The blue areas delimited by red lines south of the shore line are depressions prepared for partial submersion by sea water infiltrating through the subsurface sandy soil due to its bifurcation and proximity to the shore line, or by groundwater in the event of a rise in its level as a sequential effect of sea level rise. Note that the vast majority of the city's residential and administrative facilities are far from the threat,

3.1.3. C - The coastal area between the city of New Damietta and the port of Damietta

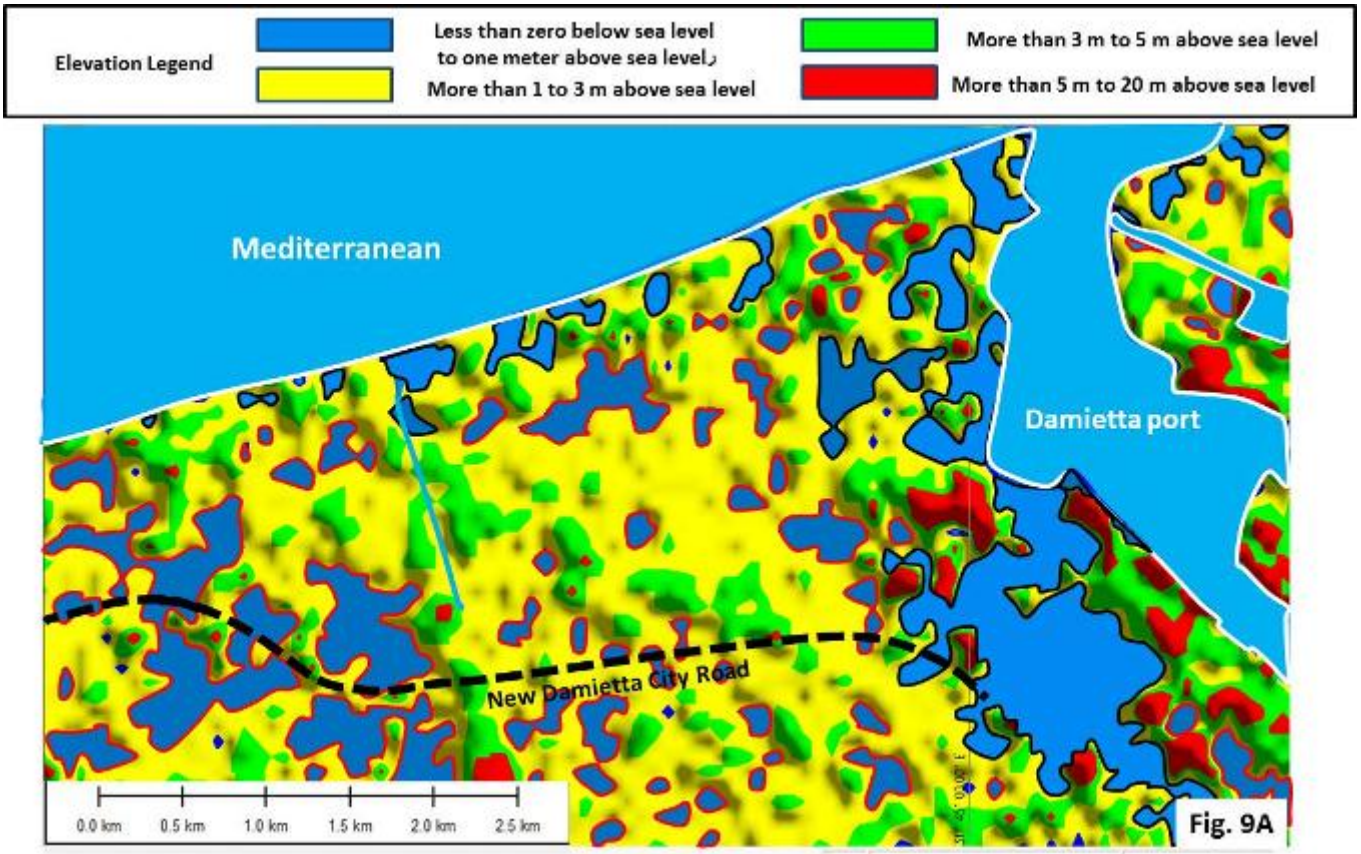
This area extends from 5.6 km to 6.5 km along the shore line, and from 2.8 km to 3.8 km in width, with a total area of about 23.2 km², of which 2.4 km² is below sea level, .3.43 km² rises above sea level by a maximum of one meter above sea level, about 7.0 km² is sand dunes between one and two meters above sea level, and the rest of the area is dunes and sand hills whose level exceeds two meters above sea level (Figs. 8A-8B and 9A-9B)

The most dangerous gaps in this area are concentrated on the western and southwestern sidewalks of the port, where the ground level is lower than sea level up to -7.5 meters northwest of the port and -25.0 meters southwest of the port (Figs. 9B and 10). These depressions are threatened by marine invasion due to their entanglement and direct connection to the port, with an area of 2.67 km², in case the sea level rises by a maximum of one meter. While the rest of the depressions, the level of which does not exceed one meter (3.16 km²), spread throughout the rest of the area away from the beach line and the port, and therefore they are not threatened by invasion, but only by partial immersion, either as a result of sea water infiltration into the subsurface soil (depressions near the beach) or by the action of groundwater (depressions far from the shoreline) if its level rises as a sequential effect of the increase in sea level.



Figs. 8A-8B: Fig.8A: A brief topography of the coastal strip extending between the city of New Damietta in the west and the port of Damietta in the east on the coast of the Mediterranean Sea - as it is the current situation. The continuous white line is the current shoreline. Black spaces are lands that rise above sea level. The blue areas south of the shore line and around the port of Damietta are depressions below sea level down to -2.0 meters (with a maximum of - 7.5 meters northwest of the port and - 25.0 meters southwest of the port), and some of these depressions were cut from the sea and was dried for Damietta port works (blue areas marked with red lines). Fig. 8B : A brief topography of the same coastal strip whose topography is given in Fig. 8A - if the sea level rises by a maximum of one meter. The continuous white line is the current shoreline. Black spaces are lands that rise more than a meter above sea level. The blue areas delimited by red lines are the depressions that are threatened by direct invasion from sea water. They include most of the excised and previously dried areas from the sea on the western side of Damietta port, whose level ranges from -25.0 meters below sea level (southwest of the port) to one meter above sea level. The blue areas marked with yellow lines are the depressions that are threatened with partial

submersion if sea water seeps through the sandy subsurface soil or if the groundwater level rises as a sequential effect of sea level rise. Note the large expansion of the areas of the depressions along the shore line and its extension to the south, compared to what is the current situation in A.



Figs. 9A-9B: Fig.9A: A detailed topography of the coastal strip extending between the city of New Damietta and the port of Damietta on the Mediterranean coast - in case the sea level rises by a maximum of one meter. The continuous white line is the current shoreline. The blue areas marked with black lines south of the shoreline and west of Damietta port are the low areas threatened by direct invasion from the sea due to their direct contact with the sea. They include the areas previously cut and dried from the sea on the western side of Damietta port. The blue areas delimited by red lines are the low-lying areas threatened with partial submersion in the event of seawater infiltration into the subsurface sandy soil due to their intertwining and close proximity to the shoreline. Fig.9B : Google Earth satellite image of the same coastal strip whose topography is given in Fig. 9A - showing on it the effect of sea level rise by a

maximum of one meter. The completely red areas are the areas threatened by direct intrusion by sea water, while the empty areas marked with red lines are the most important areas threatened by partial submersion in the event of sea water leakage into the subsurface sandy soil, or the rise in the groundwater level. Note that the threat of invasion extends to the facilities built on the western side of the port of Damietta (see the next enlarged image of the port).

Fig. 10: An enlarged satellite image of the Google Earth program for the port of Damietta on the Mediterranean coast - showing the effect of sea level rise by a maximum of one meter on the facilities built around the port. The completely red areas are the areas threatened by direct intrusion by sea water, while the empty areas marked with red lines are the most important areas threatened by partial immersion in the event of sea water leakage into the subsurface sandy soil.

3.1.4. D- The coastal area directly east of Damietta port, extending south to the River Nile, Damietta branch

This area extends from 2 km to 3 km along the shoreline, with a depth of 4.7 km inland, and a total area of 11.8 km², including the eastern and northeastern berths of Damietta port (Figs. 10 and 11A-11B). The level of this region is high by 87% of its total area by more than a meter above sea level. Intermediate depressions, the level of which does not exceed one meter above sea level, constitute 13% of this area, and they are dispersed among the high sandy hills, and are subject to flooding by subsurface infiltration, but they are not threatened by direct sea invasion - with the exception of some small depressions that do not affect along the shore line and near from the Nile River.

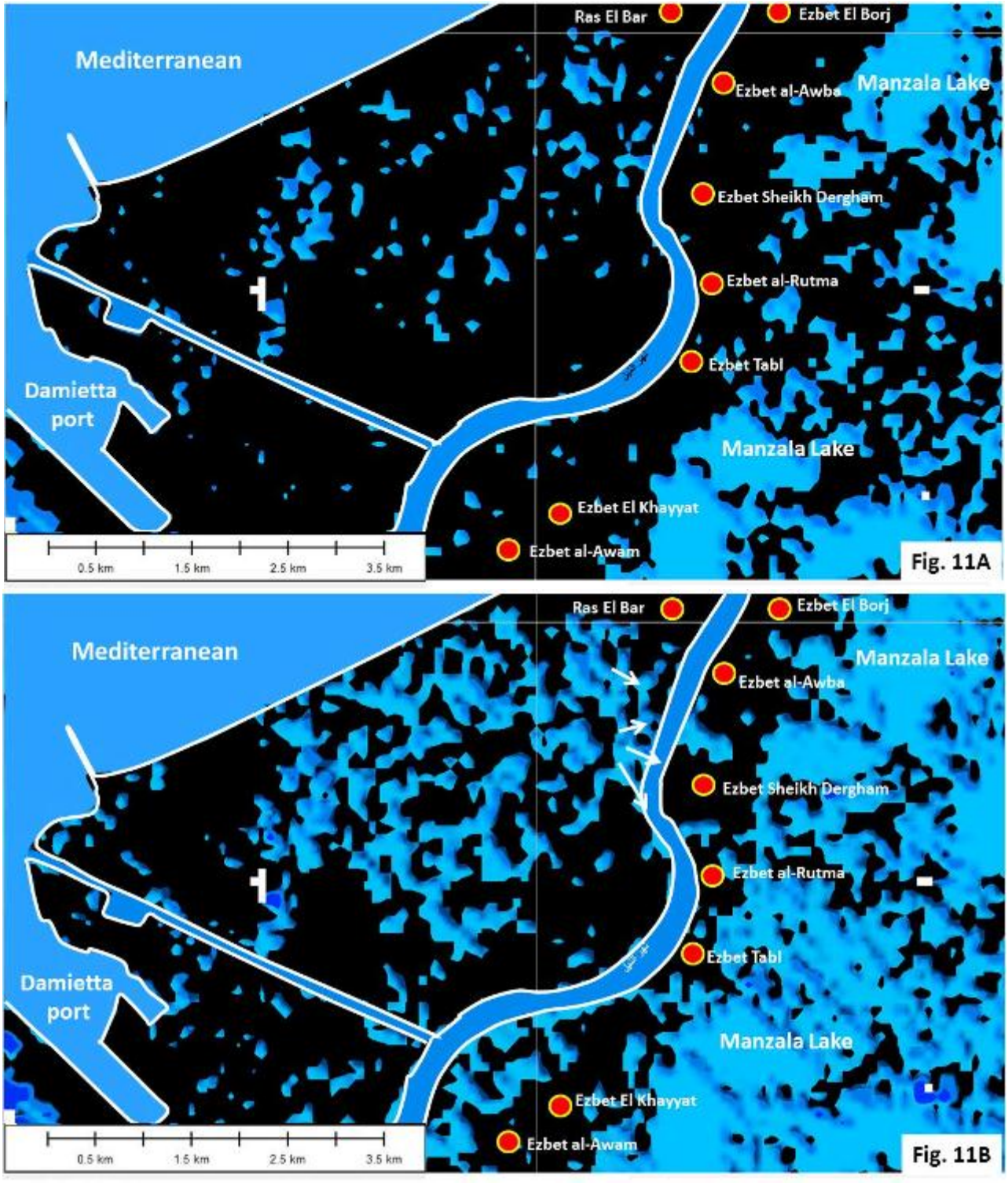
3.1.5. E- The coastal area directly southwest of Ras El-Bar, which is completely enclosed between the sea to the north and the River Nile, Damietta branch to the south

This area extends from 3.0 km to 4.5 km along the shoreline, with a depth of 2.6 to 4 km inland, and a total area of 13.9 km². This area is the most threatened site on the coastal strip extending between Gamasa and Ras El Bar (Figs.11A-11B and 12A-12B). Its level does not exceed 1.5 meters above sea level in about 70% of its total area. It is bordered to the south along the Nile River, and to the northeast along the coast by short chains of sand dunes with levels ranging from 3.0 meters to 5.0 meters above sea level. The gaps below the sea level occupy about 12% of the area of the region, and these gaps will expand and intertwine to form about 41% of the total area of the region if the sea level rises by a maximum of one meter. The area is connected to both the sea in the north and the Nile River in the south, and then it is threatened by direct invasion from the sea, in addition to what threatens it from being submerged by groundwater due to its close proximity to the Nile River.

Due to the intertwining of the depressions and their branching, the majority of the high areas that permeate them will be completely isolated, which makes it difficult for the continuation of industrial and residential activity in the region (Figs. 12A-12B). Thus, the region is considered by 76% of its area as one of the most affected areas in

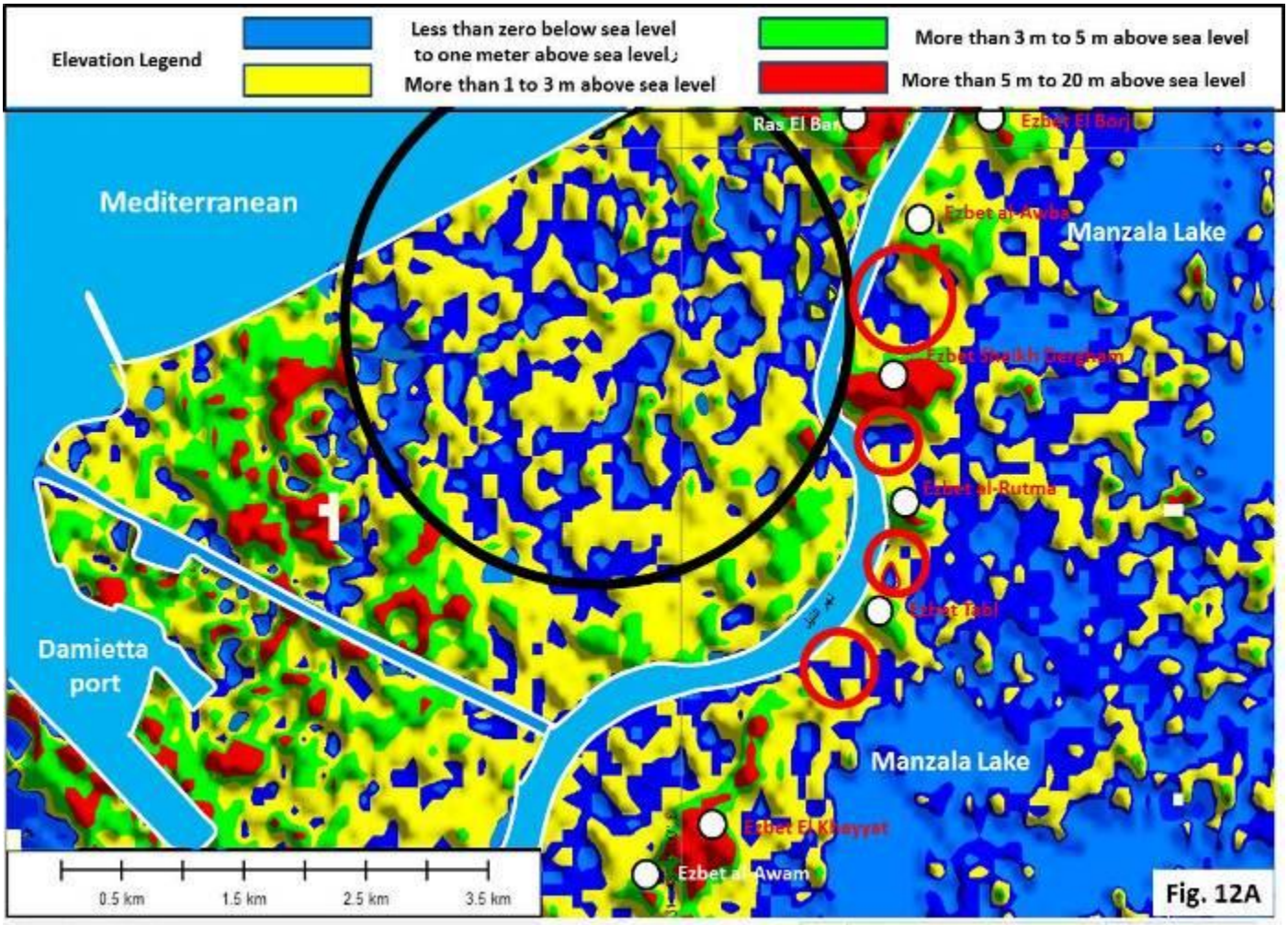
the event of an increase in sea level. Note that the damage will be complete and inclusive of the entire area if the sea level rises by 1.5 meters.

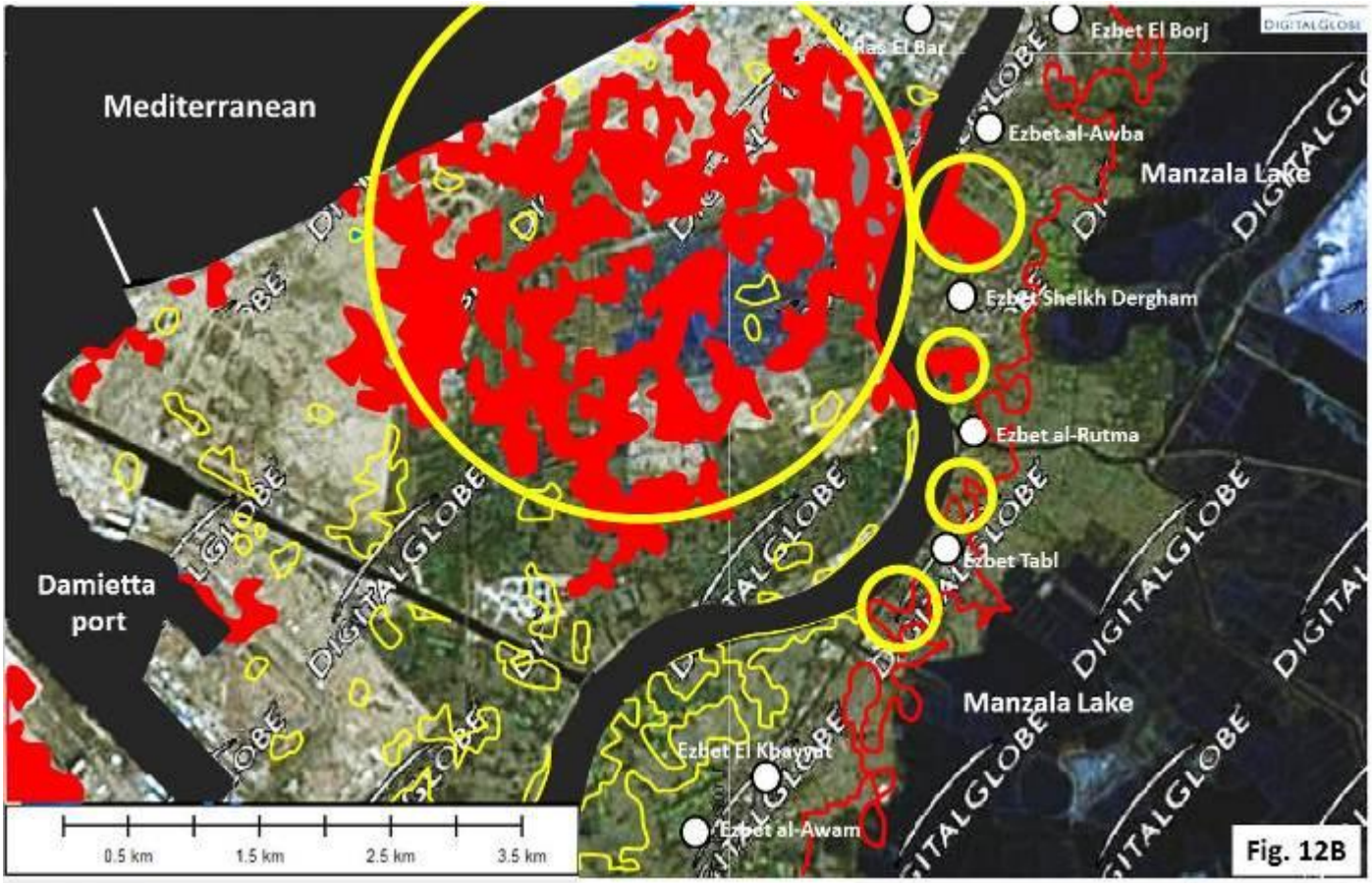
One of the dangers of the sea water invading this area is threatening the course of the Nile (Damietta Branch) north of Damietta City. The eastern bridge of the Nile extending from Ezbet Al-Burg in the north to Damietta in the south, its level usually does not exceed 2.0 meters above sea level and is interspersed with low gaps of less than a meter above sea level. Hence, a rise in the level of the surface of Lake Manzala by up to a meter will result in the emergence of four low gaps that permeate the eastern bank of the river between Ezbet Al-Awba and Ezbet Al-Sheikh Dargham, and between Ezbet Al-Sheikh Dergham and Ezbet Al-Ratmah, and between Ezbet Al-Ratmah and Ezbet Tabbal, and between Ezbet Tabbal and Ezbet Al-Khayat from the diameters range from 400 to 600 meters, will act as water passages between Lake Manzala and the Nile River. In the event that this level rises by an amount ranging from 1.25 meters to 1.5 meters, the connection between the Nile River and Lake Manzala will be comprehensive.



Figs. 11A-11B: Fig.11A: A brief topography of the coastal strip extending between the port of Damietta in the west and Ras El Bar in the east on the Mediterranean coast - as it is the current situation. The

continuous white line is the current shoreline of the sea, the Nile River, the port of Damietta, and the industrial canal between the river and the sea. The black areas are lands whose level rises above sea level, while the blue areas south of the shoreline are depressions whose level is less than zero (down to -2.0 meters and a maximum of -10.0 meters north-east of Damietta Port) below sea level. Among these depressions what is immersed (Lake Manzala, east of the Nile River, Damietta branch) and the rest is dry or dried (near Damietta port and south of Ras El Bar). The white polygons are regions not observed by satellite elevation. Fig.11B: A brief topography of the coastal strip extending between the port of Damietta in the west and Ras El Bar in the east on the Mediterranean coast - if the sea level rises by a maximum of one meter. The continuous white line is the current shoreline of the sea, the Nile River, the port of Damietta, and the industrial canal between the river and the sea. Black spaces are lands that rise more than a meter above sea level. The blue areas south of the shoreline are depressions ranging from -2.0 meters (and a maximum of -10.0 meters northeast of Damietta port) below sea level to one meter above sea level. Note the vast expansion in the areas of depressions south and southwest of Ras El Bar, and between Lake Manzala and the Nile River, compared to what is the current situation in A.





Figs.12A-12B: Fig.12A: A detailed topography of the coastal strip extending between the port of Damietta in the west and Ras El Bar in the east along the Mediterranean coast - in the event of a maximum sea level rise of one meter. The white line is the current shoreline of the sea, the Nile River and the port of Damietta. The blue areas within the black circle south of the shoreline are the low areas threatened by direct invasion from the sea due to their direct contact with the sea. Note the impact of this invasion on the Nile River in front of Ezbet Sheikh Dergham. The red circles represent the locations of the low gaps on the eastern bank of the Nile River, the Damietta branch, which in turn can turn into waterways between Lake Manzala, if it is invaded from the sea, and the Nile River from the east. The blue areas outside the scope of the circles are also low-lying areas, but not directly connected to the sea or the lake, and are subject to partial submersion by subsurface waters - but their effect is very limited in this coastal strip. Fig. 12B - A satellite image of the Digital Globe program of the coastal strip extending between the port of Damietta in the west and Ras El Bar in the east whose topography is given in Fig. 12A - showing on it the effect of sea level rise by a maximum of one meter. The red areas south of the shoreline are the lands threatened by direct invasion from sea water due to its direct contact with the sea, while the areas marked with yellow lines are also low lands, but not directly connected to the sea or Lake Manzala, and are subject to partial submergence if the subsurface water level rises. The red line east of the Nile River (Damietta branch) is the new shoreline of Lake Manzala, as the surface level of the lake rises after it is engulfed by the sea. Note the approach of this line to the borders of the Nile River and its fusion with it in some locations; in addition to the threat arising from the sea's invasion of the Nile River in front of the Sheikh Dergham estate (yellow circles indicate the most dangerous sites of invasion or fusion).

3.1.6. F- The city of Ras al-Bar

The town of Ras el-Bar itself and Ezbet al-Burj opposite it are located on elevations between 3.0 and 8.0 meters above sea level, and are therefore safe from the dangers of rising sea levels - except for the remaining part of the tongue of Ras al-Bar, which is subjected to permanent erosion (Fig. 13). As for the beaches of Ras El Bar along the coast of the Mediterranean, there is no longer anything that can threaten them. The natural beaches of this summer resort were drowned long ago as a result of sea erosion, and the ground level of the city has now risen directly above the beach line by 4.0 meters to 8.0 meters along the coast of the city, and thus there is no longer anything to threaten the city or its beaches - except for three small, unaffected sites in the far western part of the city's beach. . However, the city will suffer from a water blockade from all directions if the sea level rises by up to a meter.

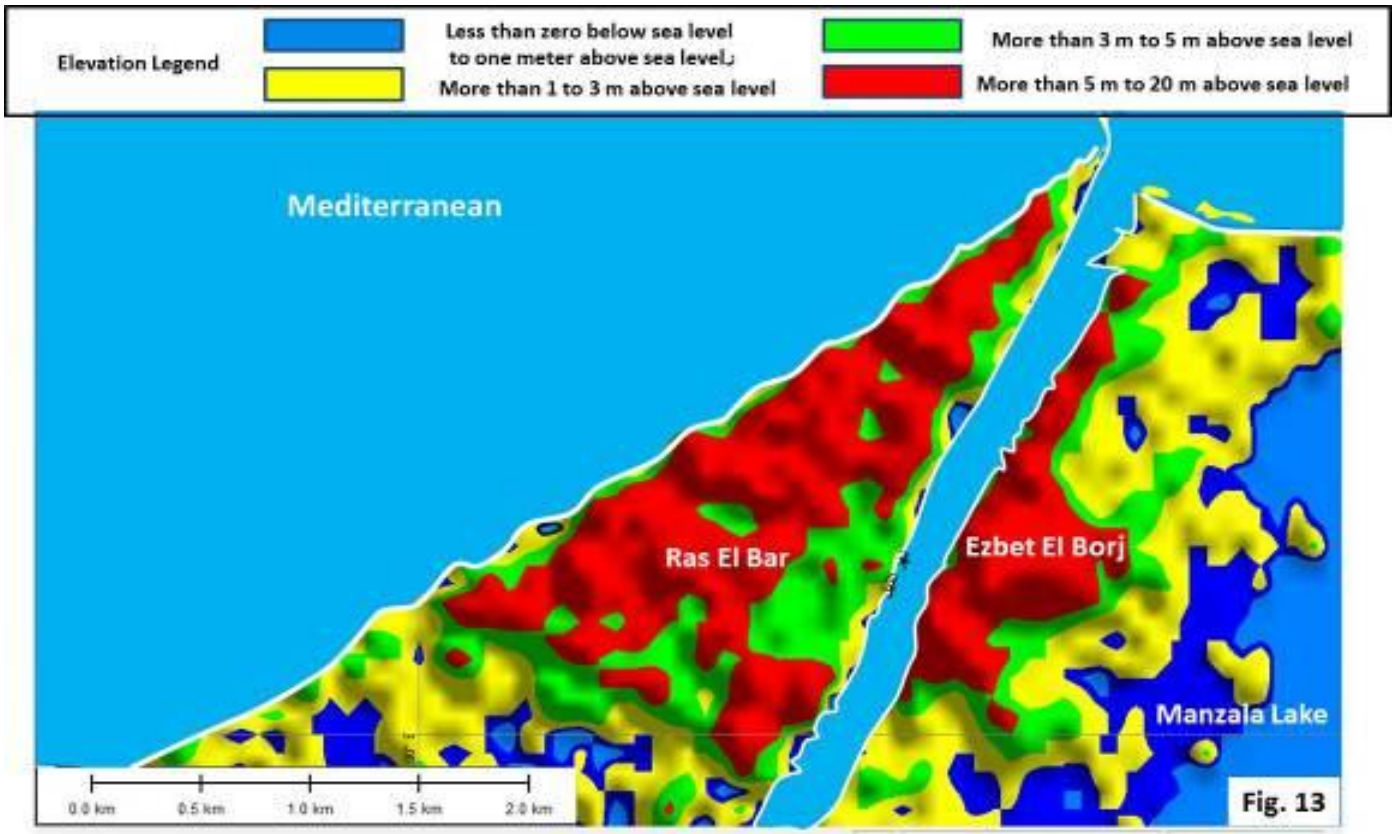


Fig. 13: A detailed topography of the coastal strip of the city of Ras El Bar and Ezbet El-Burj - in the event of a sea level rise of a maximum of one meter. The white line is the current and new beach line. Note that the effect is non-existent along the shore line due to the natural and human processes that led to the erosion and dredging of the ancient beaches. The ground level rises directly above the beach line by a distance ranging from 4 meters to 8 meters, and therefore there is nothing that threatens the current beach - with the exception of three small, unaffected sites in the far western part of Ras El Bar beach. Note also that the depressions located southwest of Ras El-Bar are more widespread and extended (the blue areas south of the beach line), while the city of Ras El-Bar is devoid of depressions. Likewise, the depressions are expanding north and east of Ezbet Al-Burj village (the dark blue areas), as they threaten some industrial and agricultural activities established between the lake and the village - but these depressions do not affect the village of Ezbet Al-Burj, as the village is built on heights of up to 10 meters above sea level.

4. Conventional defense policies to be applied

The construction of defenses must be within the framework of a comprehensive national plan to protect the northern coast of the Delta. In this regard, Ouda (2022c) specified the locations of the coastal gaps that are required to be protected, and proposed lines of defense for the northern coasts of the Delta, and divided the lines of defense into a first line of defense and a second line of defense. Defense here is not meant to protect the beaches only from the impact of rising sea waves, as is the case in Alexandria Governorate. Rather, it is intended to protect all the low coastal plains, including villages, cities, and agricultural lands along the northern arc of the delta. Hence, the matter is no longer limited to the construction of a few breakwaters or wave walls 1, but goes beyond it to the following:

First: Establishing submersible armored cement walls capable of repelling any marine invasion or leakage into the land in the locations where low coastal gaps are spread. These walls are erected along the shorelines facing the sea in the coastal sites that are not separated from the sea by strong sand belts and in the low-lying sites that can be invaded, which results in the flooding of vast areas of the lands located south of it. Armored walls mean concrete walls made of sand and chemically treated cement to achieve the highest level of hardness and cohesion, and to ensure complete adhesion of sand grains used in concrete facing the sea, provided that these walls are submerged below sea level at a depth ranging from 3.0 meters to 5.0 meters through soil injection operations to prevent surface leakage, and to rise above sea level by no less than 2 meters - that is, a total height ranging from 5.0 meters to 7.0 meters. As for the thickness of these walls in each location, it is left to the specialized engineers in proportion to the length of the breach and its extension along the shore line, and in a way that is able to resist the pressure of the excess sea water.

In this regard, we recommend the construction of reinforced concrete walls in the following locations along the coast extending from Gamasa in the west to Ras El Bar in the east:

- An immersed armored concrete wall in front of the beach line directly facing the Mediterranean Sea along the northern coast of the Delta, which extends 3.0 km east of the Bahr Bassandila drain directly (east of the Gamasa summer resort and north of Al-Rikabiya), with a depth below sea level of not less than 3.0 meters and a height above sea level not less than 2.0 meters (with a total height of 5.0 meters) (Fig. 14).
- Two armored concrete walls in front of the beach line directly facing the Mediterranean Sea on the coast of New Damietta City, one of which is northwest of the city with a length of 500 meters, and the other northwest of the city with a length of 750 meters, provided that the walls sink to a depth of not less than 5 meters below sea level and a height above sea level of not less than 2.0 meters (Fig. 15).
- An immersed armored concrete wall directly in front of the beach line facing the Mediterranean Sea along the northwestern quay of Damietta Port in the northern part of the Delta, with a length of 3.2 km, a depth below sea level not less than 5 meters, and a height above sea level not less than 2.0 meters (with a total height of 7 meters) (Fig. 16).
- An immersed armored concrete wall in front of the beach line directly facing the Mediterranean Sea, along the coast extending 2.75 km west of Ras El Bar (between Ras El Bar in the east and the port of Damietta in the west), with a depth below sea level of not less than 5 meters, and a height above sea level of not less than 2.0 meters (with a total height of 7 meters) (Fig. 17).

Second: The previous procedure is considered as a first line of defense, and a second line of defense is attached to it through the construction of cement ground bridges south of the beach line, with a height of no less than 2.0 meters above sea level, and with flat surfaces and sloping sides north and south extending along the coast, or by exploiting already existing roads after raising its level to 2.0 meters above sea level, to take the place of these bridges as follows:

- Exploiting the international coastal road extending east of the Bahr Bassandila drain directly (south of the eastern village of Gamasa) with a length of 3.7 km along the northern coast extending between the Gamasa resort in the west and New Damietta city in the east (Fig. 14), as well as the New Damietta city road with a length of 8 km north of the city (Fig. 15). This is provided that the level of these roads is raised by not less than 2.0 meters above sea level. The raising of these roads in the specified places is intended to reinforce the lines of defense of the southern depressions in Dakahlia Governorate (the depressions of Kafr al-Wastani and the depressions of the new city of Damietta).
- Strengthening and raising the levels of the eastern and western bridges of the Nile River, Damietta branch, between Ezbet Tabl in the south and Ezbet El Borj in the north, to a height of 2.0 meters above sea level (Fig. 17). As for the western bridge, the path required to be raised is located in front of Ezbet Sheikh Dergham, with a length of 1.06 km. This is with the knowledge that the topography of the bridge along this path often ranges between zero and 0.5 meters above sea level, and then the height of the bridge will range on average from 1.5 to 2.0 meters long, about 900 meters long. The danger of this low path lies in its being a source of threat to the Nile River from the west in the event that the waters of the Mediterranean Sea invade the low plains located south of Ras El Bar Nile, or if the water seeps into these plains through the subsurface sandy soil.

The eastern bridge needs to be strengthened and its level should be raised between Ezbet Tabl and Ezbet Al-Ratma. between Ezbet al-Ratma and Ezbet al-Sheikh Dergham, and between Ezbet al-Sheikh Dergham and Ezbet al-Awba, south of Ezbet al-Burj, with a total length of about 1000 meters, and a height of 2.0 meters above sea level, in order to prevent the invasion of Lake Manzala into the Nile River through the gaps that permeate the eastern bridge.

Third: Filling and raising the level of the depressions that permeate the New Damietta city and surround it from the west and north-west, and whose level ranges between zero and -5 meters below sea level, with a total area of about 2.9 km², with the prohibition of building residential constructions on them. These depressions are liable to be submerged by superficial soils due to their proximity to the shoreline and their sharply low level. They are mostly not exploited for housing, as shown by satellite images where the city's residences and facilities are located on high levels ranging between 3.0 meters and 5.0 meters. There is nothing currently threatening the city - except that in the case of an increase in sea level by a maximum of one meter, this will expand the area of the depressions to 7.4 km², or 27.4% of the area of the area on which the city is built.

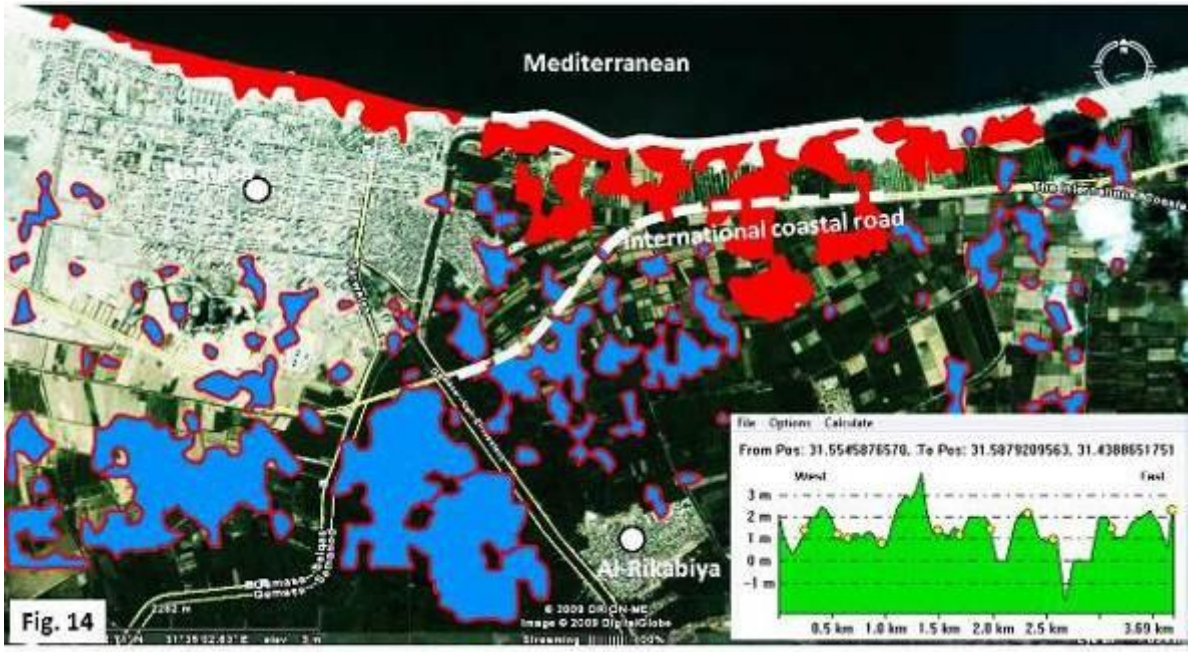


Fig. 14: A satellite image of the Google Earth program for the coastal strip extending between the resort of Gamasa in the west and the new city of Damietta in the east on the Mediterranean coast - showing on it the effect of sea level rise by a maximum of one meter, and the proposed lines of defense, including the following: The first line of defense(Continuous white beach line) is represented by a submerged armored concrete wall in front of the beach line directly facing the sea with a length of about 3.0 km, a depth of 3.0 meters below sea level, and a height of 2.0 meters above sea level (with a total height of 5.0 meter). The second line of defense (the white dashed line) is represented by the international coastal road that extends east of Bahr Bassandila drain, with a length of 3.7 km, after raising its level to 2.0 meters above sea level, noting that the road level along the proposed path often ranges from zero to 2, 0 meters above sea level, and then it is necessary to raise the road level by an average of one meter with a length of about 3.0 km. Note that the entire Gamasa beach is threatened by a direct invasion from the sea, and there is no way to defend it except by raising its level by more than a meter by throwing sand on it. As for the city itself, it is safe from any threat due to a rise in its level above sea level by more than 3.0 meters.

Fourth: Raising the level of the northern Gamasa resort beach and the western Ras El-Bar beach level by throwing sand on the low parts facing the sea to raise it to a height of 1.5-2.0 meters above sea level

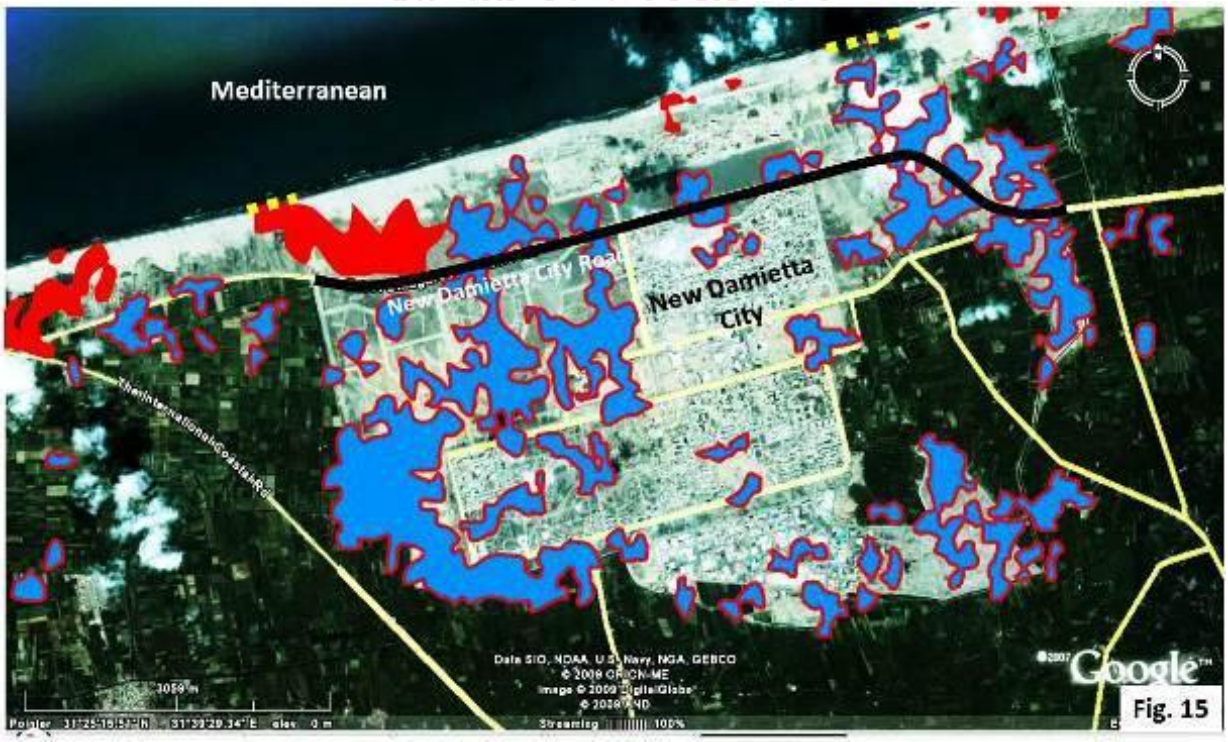


Fig.15: A satellite image of the Google Earth program for the coastal strip of the new city of Damietta on the Mediterranean coast in case the sea level rises by a maximum of one meter - indicating on it the

proposed lines of defense. The yellow dashed lines are the first line of defense, represented by 2 armored concrete walls submerged directly in front of the beach line facing the sea, one of which is northwest of the city with a length of 500 meters, and the other north-east of the city with a length of 750 meters, provided that the walls sink to a depth of not less than 5 meters below the sea level, and a height above sea level of not less than 2.0 meters. The second line of defense (the continuous black line) is the New Damietta city road that extends 8 km north of the city after being raised by no less than 2 meters above sea level. Note that the means of defense here include raising the beaches in front of the low coastal sites using sand, as well as raising the level of the southern depressions with backfilling and drying the wet ones using sand mixed with cement, with no building on top of them except after taking all measures that guarantee the safety of future facilities. . Note also that the vast majority of the city's residential and administrative facilities are far from the threat, as they were built on high lands ranging between 2 and 8 meters above sea level.

Fifth: All these coastal defenses are indispensable for plans for draining water and draining it away from the sea. Sea water, when its level increases, can permeate the sandy, superficially abrasive soil along the delta coast, submerging some depressions, or mix with groundwater, increasing its level, which may cause partial submersion of the low-lying areas located south of the sandy belt surrounding the coast of the delta. In addition, the increase in sea level will increase the height of waves in the winter season and their ability to cross some natural or artificial barriers along the shore line. Therefore, it must be planned to construct a network of pipes or channels to drain the sea water that will penetrate the coastal defenses along the coast and drain it in low desert areas far from the seashore. The sea is not suitable as a drain for sea water.

Fig. 16: A satellite image of the Google Earth program for the coastal strip extending between the city of New Damietta in the west and the port of Damietta in the east on the Mediterranean coast - showing on it the effect of sea level rise by a maximum of one meter and the proposed lines of defense for the port. The continuous white line is the first line of defense proposed to repel the sea's invasion of the western docks of the port. It is represented by a submerged armored concrete wall in front of the shoreline directly facing the sea, with a length of about 3.2 km, a depth of 5.0 meters below sea level, and a height of 2.0 meters above sea level (with a total height of 7.0 meters). Note that this wall will not prevent the sea water from leaking into the southwestern part of the port through the subsurface sandy soil due to the great depth of the depressions in this part, which reaches -25.0 meters below sea level, and then all precautions must be taken before completing any constructions southwest of the port.

5. Conclusions

The coastal strip, which extends between Gamasa in the west and Ras El Bar in the east, has a length of about 27.5 km and a width ranging from 3 km to 4.8 km, is subject to the threat of partial invasion by sea water, or

partial submersion of subsurface water in the event of a rise in sea level by one meter, as about 25% of the total of the area of this strip does not exceed one meter above sea level. This strip is characterized by a wide human, demographic, tourist and industrial activity, as the New Damietta City, the Damietta Port and the city of Ras El-Bar are located on it. In view of its tourism importance and its different topography, in this research we explain the different coastal areas of this strip to know which are more threatened than others and the nature of the threat as a result of the increase in sea level as a direct impact of the climate changes that the world is witnessing during this century. as follows:

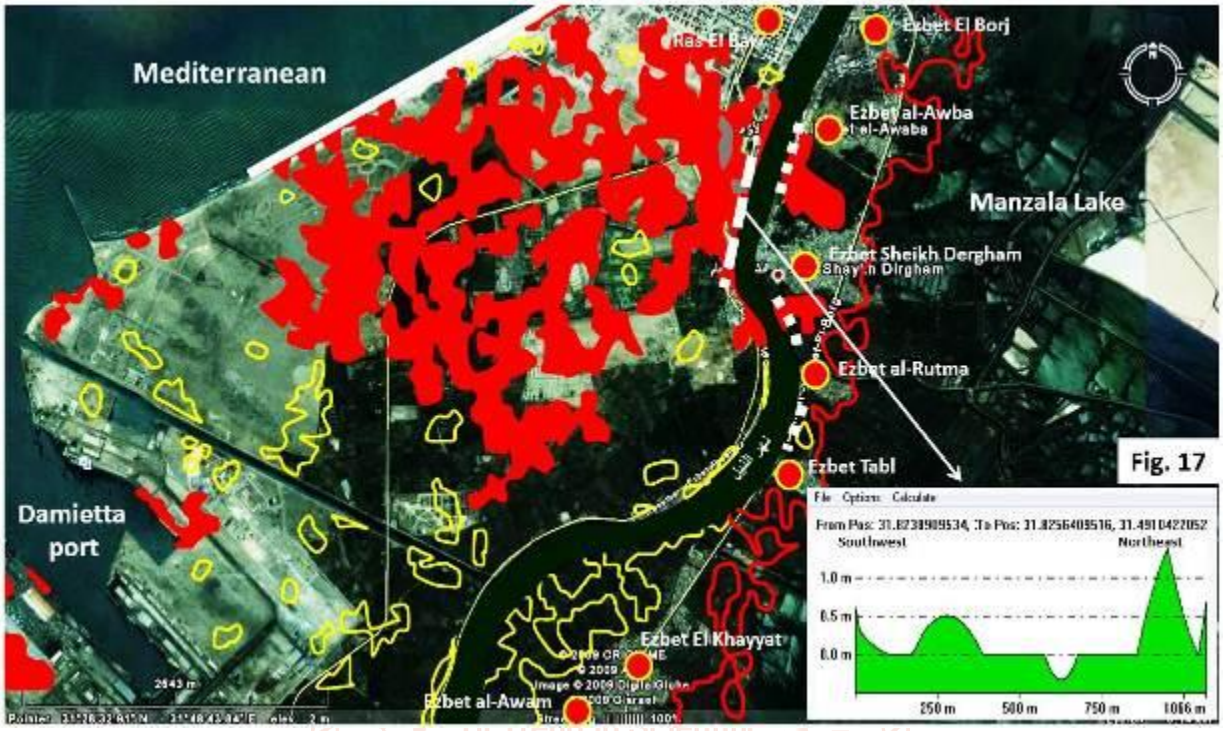


Fig. 17: A satellite image of the Google Earth program for the coastal strip extending between the port of Damietta in the west and Ras El Bar in the east on the Mediterranean coast - showing the impact of sea level rise by a maximum of one meter, and the proposed defense lines. The continuous white beach line is represented by a submerged armored concrete wall in front of the beach line directly facing the sea, 2.75 km long, 5.0 meters deep below sea level, and 2.0 meters high above sea level (total height 7.0 meters). The white dashed line on the western bridge of the Nile River is the path required to ascend the western bridge of the Nile River in front of Ezbet Sheikh Dergham to a height of 2.0 meters above sea level, and a length of 1.06 km (see the topography of the bridge during this path in the attached diagram). The small white dashed lines on the eastern bridge of the Nile are the paths required to raise the eastern bridge of the river, with a total length of approximately 1000 meters and a height of 2.0 meters above sea level, in order to prevent Lake Manzala from encroaching into the Nile through the gaps that permeate the eastern bridge, which will be effective if the lake surface level rises from 1.25 to 1.5 meters.

A. The coastal area extending between the resort of Gamasa to the west and the new city of Damietta to the east

The depressions threatened by marine invasion in the event of an increase in the global sea level in this region are concentrated in the area located directly east of the mouth of Bahr Basindila, and extending between the shore line in the north and Al-Rikabiya in the south, with a length of approximately 3 km and an area of 7 km². It is an area partially exploited as salines, and 33% of its total area (2.32 km²) is subject to direct invasion if the sea level rises by one meter. It represents a potential danger to the agricultural depression located south of the sand belt (Kafr al-Wastani depression) in case the sea level rises between 1.25 and 1.5 meters

B. The coastal area of the new city of Damietta

The city's residences and facilities are located on elevated levels ranging from 3.0 meters to 5.0 meters. There is nothing currently threatening the city, but it permeates the city and surrounds it from the west and north-west with dense and intertwined depressions ranging between zero and -5 meters below sea level, with an area of about 2.9 km². These depressions are liable to be submerged by the subsurface soil due to their proximity to the shoreline and their sharply low levels. In the event of an increase in the sea level by a maximum of one meter, this will expand the area of the depressions to 7.4 km², of which 0.64 km² are beach depressions connected to the sea and threatened with direct invasion northwest of the city, and 6.76 km² internal depressions threatened with partial

inundation due to subsurface water.

C. The coastal area between the city of New Damietta and the port of Damietta

The most dangerous gaps in this area are concentrated on the western and southwestern sidewalks of the port, where the ground level is lower than sea level down to -7.5 meters northwest of the port and -25.0 meters southwest of the port. These depressions are threatened by marine invasion due to their entanglement and direct connection to the port with an area of 2.67 km² in case the sea level rises by a maximum of one meter.

D. The coastal area directly east of Damietta port, extending south to the River Nile, Damietta branch

Intermediate depressions whose level does not exceed one meter above sea level in this region constitute 13% of its area (11.8 km2). They are dispersed among the high sandy hills, and are subject to partial immersion as a result of sea water infiltration into the subsurface soil (depressions near the shore line) or by the action of groundwater (depressions far from the shore line) if its level rises as a sequential effect of the increase in sea level, but the area is not threatened by the direct invasion of the sea.

E. The coastal area directly southwest of Ras El-Bar, which is completely enclosed between the sea to the north and the River Nile, Damietta branch to the south

This area is the most threatened site on the coastal strip between Gamasa and Ras El Bar. It is bordered to the south along the Nile River, and to the northeast along the coast by short chains of sand dunes whose levels are ranging from 3.0 meters to 5.0 meters above sea level. The gaps below the sea level occupy about 12% of the area of the region, and these gaps will expand and intertwine to form about 41% of the total area of the region if the sea level rises by a maximum of one meter. These gaps are connected to both the sea in the north and the Nile River in the south, and then they are threatened by direct invasion from the sea, in addition to inundation by groundwater due to their close proximity to the Nile River. Due to the intertwining of the depressions and their branching, the majority of the elevated areas that permeate this region will be completely isolated, which will make it difficult for the continuation of industrial and residential activity in the region.

F. The city of Ras al-Bar

The city of Ras al-Bar itself is built on heights ranging between 3.0 and 8.0 meters above sea level and has artificial beaches due to the complete erosion of its natural beaches. Hence, it is safe from the dangers of sea level rise, but it will suffer from a water blockade from all directions if the sea level rises by up to a meter.

It is possible to avoid the damages arising from the rise in the global sea level through the construction of submersible armored concrete walls that are capable of repelling any marine invasion or leakage into the land in the locations where low coastal gaps are spread. These walls are erected along the shorelines facing the sea in low coastal locations that can be invaded, provided that these walls are submerged below sea level at a depth ranging from 3.0 meters to 5.0 meters through soil injection operations to prevent subsurface leakage, and that these walls rise above sea level by no less than two meters. These walls are being built along the northern coast of the Delta, which extends for a length of 3.0 km, directly east of the Bahr Bassandila drain (east of the resort of Gamasa and north of Al-Rikabiya), as well as along the northwestern quay of Damietta port in the northern part of the delta, with a length of 3.2 km, and along the coast extending 2.75 km west of Ras El Bar directly in the northern part of the Delta (between Ras El Bar in the east and the port of Damietta in the west). Two armored concrete walls in front of the beach line directly facing the coast of New Damietta City, are also proposed ,one of which is northwest of the city with a length of 500 meters, and the other northwest of the city with a length of 750 meters.

These walls serve as a first line of defense attached to other defense lines, such as exploiting the international coastal road that extends directly east of the Bahr Bassandila drain (south of the eastern village of Gamasa) with a length of 3.7 km along the northern coast that extends between the resort of Gamasa in the west and the new city of Damietta in the east, after raising its level to 2 meters above current sea level. As well as strengthening and raising the levels of the eastern and western bridges of the Nile River, Damietta branch, to a height of 2.0 meters above sea level; as for the eastern bridge, it needs consolidation and raising the level between Ezbet Tabl and Ezbet Al-Ratma, between Ezbet al-Ratma and Ezbet al-Sheikh Dergham, and between Ezbet al-Sheikh Dergham and Ezbet al-Awba, south of Ezbet al-Burj, with a total length of about 1000 meters. As for the western bridge, the path required to be raised is located in front of the Sheikh Dergham estate, with a length of 1.06 km.

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