

Exploration of Environmental Response Techniques for Land Reclamation in Caofeidian



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Abstract The rational construction and planning of coastal cities has always been an important direction for urban development. The geological environment and sea level changes of the coastline are closely related to the safety of people's property. The interaction of reclamation projects and the changes brought about by ocean hydrodynamic conditions have a significant impact on the coastal zone. The geological environment has had a serious impact. Based on the environmental geological survey and evaluation results of the coastal zone in the Caofeidian New Area in recent years, this paper focuses on the land restoration of coastal cities by analyzing changes in coastlines and lake beaches, changes in tidal currents, coastal erosion and alluvial layers, storm surges and sea level changes. The interaction and impact of reclamation and the geological environment, and corresponding prevention and control suggestions for major issues such as storm surge and sea level rise, and scientific guidance for reasonable planning and disaster warning of coastal cities.

1 Introduction

Caofeidian has become an artificial land connected to land island from the original 4 km² island. An ecological, new and modern industrial park and coastal city have been born on the coast of Bohai. The reclamation area of the Caofeidian industrial area has reached 247 km² (see Fig. 1); The planning area of Caofeidian ecocity is 150 km², population size will reach 1 million people, of which the first phase of the

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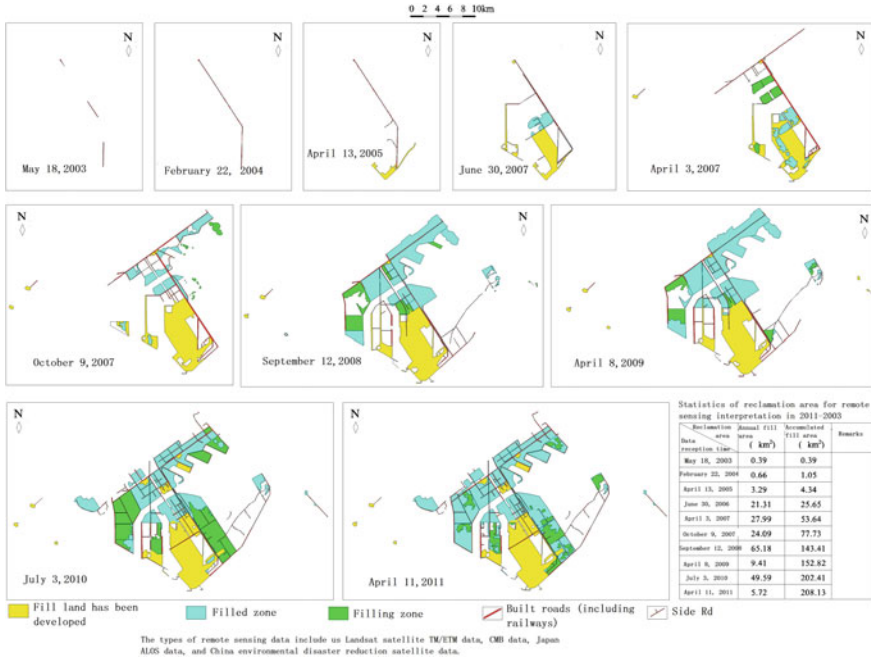


Fig. 1 Remote sensing interpretation map of land reclamation from sea in Caofeidian Industrial Zone

project is a part of the sea reclamation, and gradually to the sea by land construction (see Fig. 2).

2 The Changes and Countermeasures of Land Reclamation Caused the Coastline and Intertidal Zone

Sea reclamation interaction and ocean hydrodynamic conditions changed the composition gradient and the material type, length of coastline and intertidal zone, has a serious impact on the geological environment in the coastal zone. The coast of Caofeidian new area is composed of muddy coast, sandy mud coast, sandy coast, sandy coast and artificial shore dike with different revetment types (see Fig. 3).

The coast protection embankment types of Caofeidian eco city are mainly natural earth dams before large-scale construction, including natural earth dams, gravel and natural dams, gravel and geotextiles. There are few surface buildings, mainly aquaculture area, the vegetation is poor, and the sediment types from west to East are mainly argillaceous and Sandy. Basically, there is no protection for any dams. The local part is combined with gravel and geotextile to protect slope (see Fig. 4), the

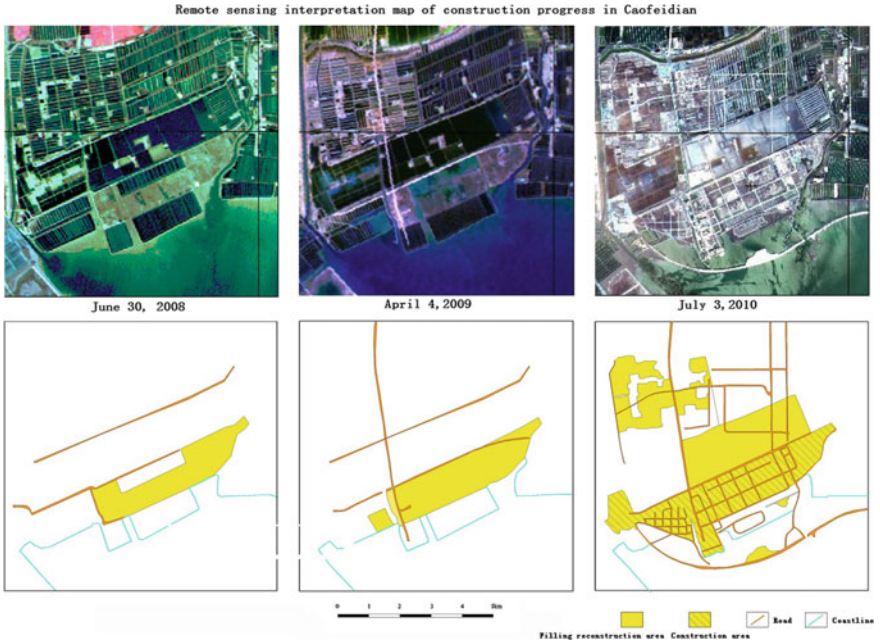


Fig. 2 Remote sensing interpretation map of construction progress in Caofeidian International Eco City

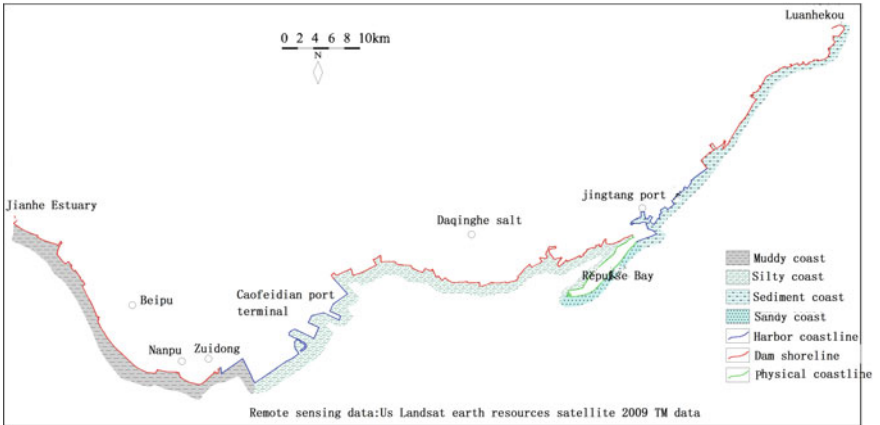


Fig. 3 The coastline type map of Caofeidian in 2009

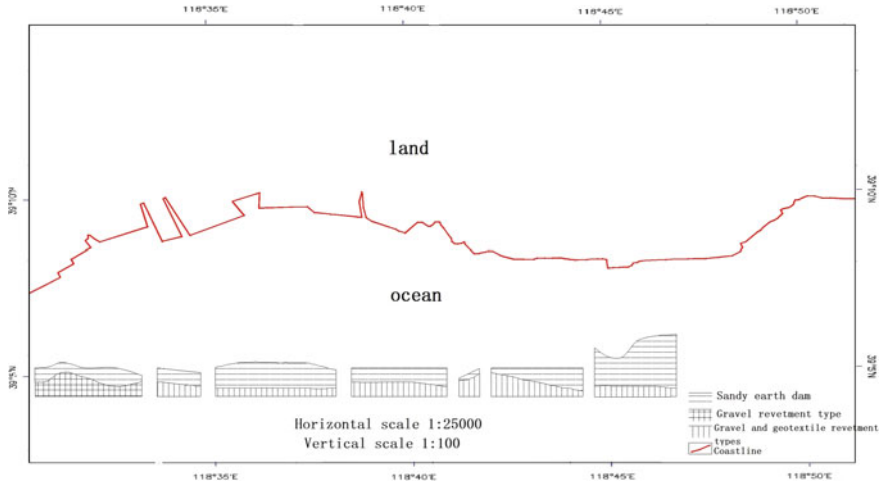


Fig. 4 The Coastal berm type zoning map in Caofeidian International Eco City

average elevation on the top of the coastline is 3.64 m (see Fig. 5), which is very low in resisting the storm hydrodynamic and wave erosion.

According to the investigation, in the past thirty years, because of Yantian, aquaculture and continue to expand the scale of Caofeidian coastline is advancing to the sea, shoreline length increased 60 km, the land area increased 304 km², intertidal current width of 2.5–6.6 km, but showed a trend of gradually narrowing the width of the beach face. According to Yang Yanxiong et al. Comparison of Caofeidian reclamation engineering 1983–1996 thirteen years ago, the average bank accumulation rate is 3.2 cm/a, the slope erosion rate under water 7.2 cm/a. According to the 2008–2010 beach erosion dynamic monitoring data show that after the implementation of large-scale Caofeidian sea reclamation project, to the East are to scour from the

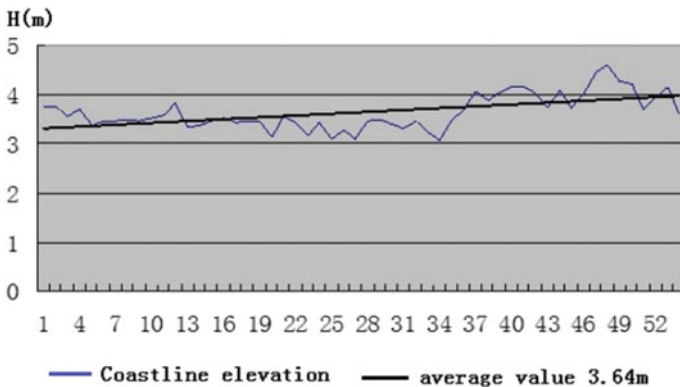


Fig. 5 The coastline top elevation map in Caofeidian International Eco City

intertidal zone, the erosion rate is generally 5–20 cm/a (comprehensive geological survey report of Jingtang Port, Yang Yanxiong et al. (2003)). In this regard, according to Caofeidian marine hydrodynamic conditions and coastal beach erosion, sediment dynamics, scientific layout of land reclamation and coastal engineering, reduce the disturbance to the coast and beach surface, avoid its sharp change.

3 Reclamation of Tidal Current Field and Seabed Caused by Impact on the Changes and Countermeasures

Under the natural condition that the Caofeidian industrial area has not been developed on a large scale, the tide of the Caofeidian sea is a reciprocating flow: In Caofeidian the west to the East, the ebb. Caofeidian to form Cape south into the Gulf of Bohai, the main direction is not the same, but the law is obvious, the mainstream direction basically parallel to the Isobaths, namely Caofeidian the west to west north to East biased towards the south, the ebb tide in the West Austin, Caofeidian slightly southward, ebb tide to the Northeast (see Fig. 6).

According to the studies of Kuang Cuiping et al., Caofeidian industrial zone through Island Road (dam) after the completion of the Caofeidian sea area in deep water area of tidal field did not change significantly, just cut off the channel embankment East and West groove, beach water is divided into two channel embankment East and west part, diffuse Beach flow cannot converge at high tide beach ridge, and converted to current along Breakwater (see Fig. 7).

But the flow field near the reclamation area has changed. The tidal current along the Caofeidian East Sea has been leveed towards the Caofeidian sea head. After the water bypass the Caofeidian head, it is affected by the impact of the pick up flow, and the water flows along the deep trough of the front edge of the Diandian to the northwest. Influence of breakwater, velocity into the excavated area obviously

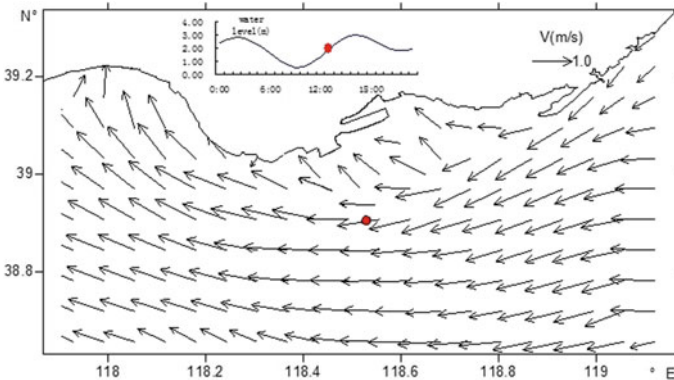


Fig. 6 Rapid flow field map before the construction of the Island Road (embankment) in Caofeidian

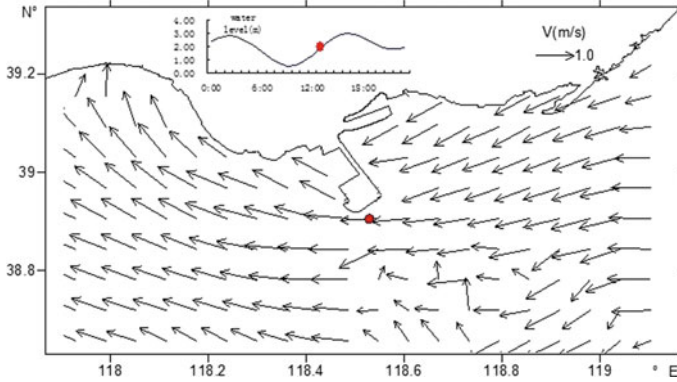


Fig. 7 Rapid flow field map after the construction of the Island Road (embankment) in Caofeidian

slowed down, a large amount of water around the east engineering reclamation area into shoal until through Island Road (dam); the ebb, West shallow water flows to the excavated harbor basin, most still from the west is not included in the reclamation areas deep trough along the deep channel from the west to the northwest, flowing into the heavy head, the head heavy deflecting effect to the northeast to flow. Thus, the rise and fall trend is significantly affected by the deflecting effect has heavy head reclamation headland, so both sides of velocity significantly affected (see Fig. 8). Yin Yanhong [1] suggested that through Island Highway through the shoal tidal channel and the main trend of marine protection system. The reclamation of soil in the reclamation area should not be carried out near the barrier island of Caofeidian and its deep trough in the front, protecting the bottom of these key parts from damage and maintaining the function of the port.

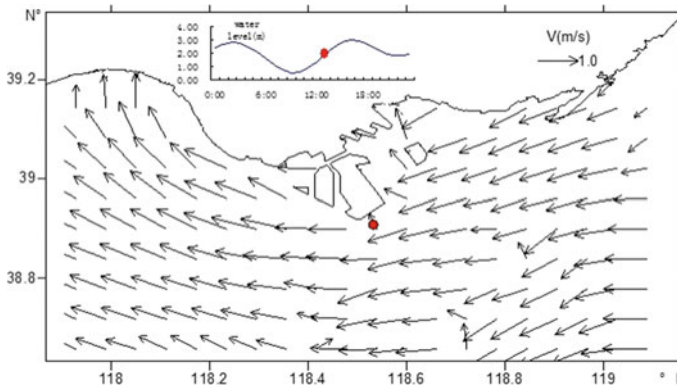


Fig. 8 Rapid flow field map of the current condition of the enclosed Engineering in Caofeidian

Caofeidian port site is the only one in Bohai does not require excavation of waterways and basins can build 300 thousand ton berths large natural harbour, with excellent depth, large and stable, berth trough to anchor well in the Gulf of Bohai incomparable natural advantages. Due to land reclamation in Caofeidian Industrial Zone and Island Road (DI) construction, exacerbated by the heavy head Cape effect, caused by tidal flow field changes Heavy head deep groove bypass ahead of time about 20 min, the average velocity of flood and ebb tide increased, an increase of 1.8–31.4%, the increase of 4.5–30.2%, resulting in 0.1–0.5 m ranging from scouring Caofeidian front range of 3, 5 km and slight erosion until The west side of the plateau has a maximum erosion of more than 0.5 m. There is about 0.2 m deposition in the 3 km area of the western front of the Caofeidian project, while 5–6 km is slightly eroded outside, and the local scour is relatively large. The maximum siltation of about 0.3 m near the port gate of a port has a maximum of about 0.7 m deposition near the gate of the two ports. By the wave action, Western and Eastern Beach Caofeidian respectively Shatuo is greater than that of 1.2 and 1.4 m in Western beach erosion; erosion results in front of deep groove 0.1–0.4 m ranging from deposition, while the eastern Shatuo led to the erosion of laolonggou deep trough 0.12–0.53 m deposition (see Fig. 9).

Impact of the construction of Caofeidian port engineering of sea wave field is very obvious, after the completion of the project, harbor pool, tidal channel in the wave field changed significantly, the wave height and period significantly reduced, controlled by the incident wave to change to engineering and trend, and for the wave characteristics of sea engineering outside the area has little influence on [2].

According to the dynamic monitoring of 2008–2010 four profiles, Caofeidian West to a lesser extent; continuous siltation, heavy head east main scour, near laolonggou sea monitoring points to micro in main.

According to the Caofeidian deep trough to the north and South ADCP walking and sailing velocity measurement, vertical upward velocity decreases with the

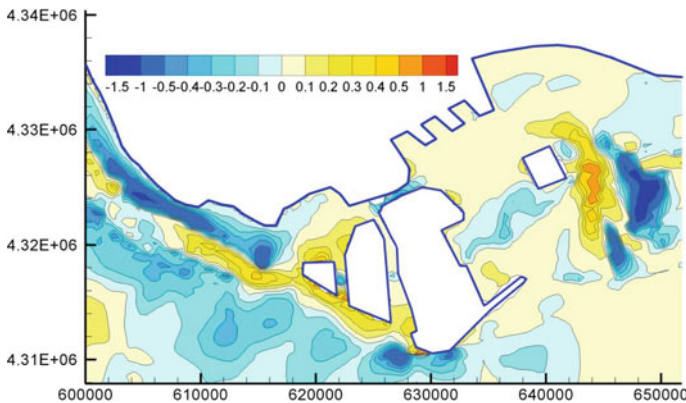


Fig. 9 The seabed scour and deposition intensity distribution map of existing engineering conditions in the coastal area of Caofeidian. (*Note the positive is silt, the negative is the scour, unit: m)

increase of water depth, the strongest Caofeidian deep groove flow profile, on the one hand it is the main power to maintain the Caofeidian deep groove, on the other hand, is also one of the factors causing the Caofeidian Industrial Zone water slope instability. According to the data analysis, the existing engineering construction although the cause of marine hydrodynamic conditions changed, Caofeidian slightly erosion, but the slope under heavy water remained relatively stable, yet obvious erosion.

Compared with the survey data before 1996, the surface sediments of the seabed are in a certain degree of coarsening. From 2008 to 2010, affected by the reclamation and marine hydrodynamic conditions, suspended sediment content in Caofeidian sea area has been reduced year by year, which in 2009 decreased by 15% compared with 2008, 2010 is about 39% less than in 2008.

The change of tidal current caused Caofeidian coastal erosion and port and waterway rush to destroy coastal protection works and other coastal facilities such as seawall. The loss of coastal land not only threatened the safety of Caofeidian industrial area and International Eco-City, but also increased the deposition of ports and waterways. Superimposed with other disasters such as storm surge and land subsidence, the disaster aggravated further, and reduced the stability of coastal engineering foundation, which seriously affected the safety of the geological environment and the sustainable development of economy and society in coastal cities [3, 4]. The change of scouring and silting of port and waterway in the area has led to deep groove topography changes and underwater slope stability, which is a significant geological environmental problem in the development of Caofeidian new area. With the continuous development of Caofeidian port construction, further progress of effects of reclamation and port engineering construction of marine power, suspended sediment distribution and seabed evolution will. Therefore, should strengthen the Caofeidian marine hydrodynamic environment, Caofeidian deep trough siltation (especially tidal river open, the tidal current field can restore to the original state, heavy head deep channel trend will continue to increase), underwater slope stability monitoring and research, closely tracking the interaction and land reclamation effect of engineering and layout and flow field, it will affect the safety of port engineering, to further optimize the land reclamation to provide the scientific basis for the safe operation of the project scale and layout as well as the Caofeidian Industrial zone.

4 Effects and Countermeasures of Storm Surge and Sea Level Rise on the Geological Environment of Coastal Zone

The region is flat, especially Beipu, Daqing River salt field, Luanhe estuary, coastal salt shoals, Qilihai fishing port, because there is no seawall to prevent or levee elevation is low, is the key areas vulnerable to storm surge disaster damage. As part of the flood diversion areas of Luan River, no standard seawall to prevent, by the influence of economic development, the mouth also has large tracts of farmland and ponds,

vulnerable to storm surge; Seven the Caspian Sea fishing port, in 2003 during the "1011" storm surge, Sheung Shui pier near the houses flooded water about 1 m; The two part of the Luanhe River Estuary, because there is no effective construction of the seawall is the main region of the current storm surge inundation. There have been many storm tide disasters in the history area which have a great influence on the geological environment of the coastal zone. According to historical records, in 1895 and 1900, there were two strong storm surges attacking Caofeidian. The temples and shops on the island were all washed into the sea, and the migration of the islanders gradually cooled down. According to statistics from the past twenty years, 0.9 waves of wave height greater than or equal to 6 m occur every year in Bohai, including 9 waves of cold waves, 12 cyclones and 2 waves of typhoons [5].

The average elevation of Caofeidian coastline is about 4 m, the lowest elevation is located in the coastal shoreline of Beipu Jianchang, Daqing River, the average height less than 3 m, which is lower than the local coastal storm surge warning level value 3.8 m and value 3.65 m the highest tide level (see Fig. 10). Due to the influence of ground subsidence and other factors, the elevation of the coastline in 2009 is lower than that of the 2008 shoreline elevation, but the decline of most of the banks is smaller. The coastline elevation of the Caofeidian industrial area is about 3.5 m, and the average height of the breakwater is about 4.75 m. Most of the coastline heights are lower than the local storm surge warning level. However, the height of the breakwater dike is mostly higher than the highest tide level and the Centennial tide value is 4.48 m.

According to this study of Yu Daoyong, Zhang Yecheng, and others, in the past 1980–2008 years, the coastal sea level of Caofeidian has fluctuated upward trend, which has increased by 118 mm on average for 28 years, and the annual rate of long-term change is 4.1 mm/a (see Fig. 14). In order to predict the future trend of sea level change, the regression equations (Table 1 and Figs. 11, 12, 13) are established by using the measured data of Caofeidian in the past two years and the synchronous

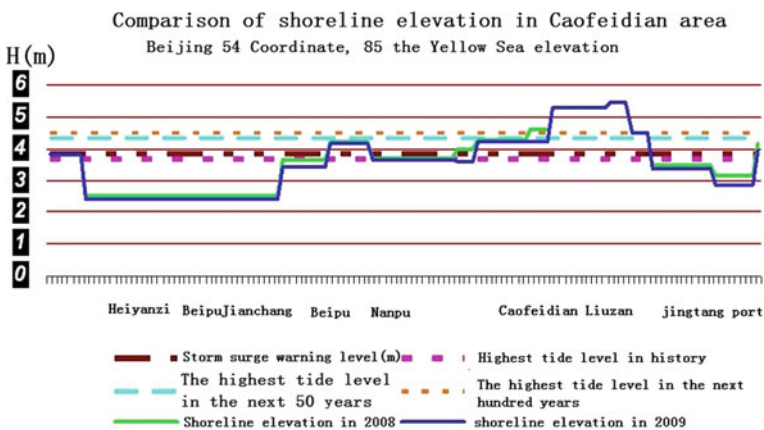


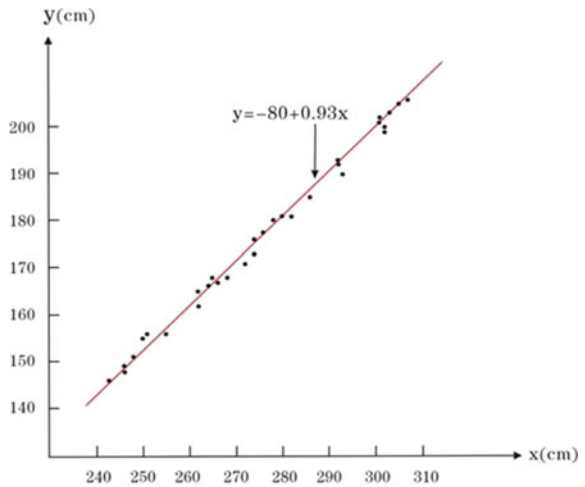
Fig. 10 The elevation curve variation chart of Coastline in Caofeidian

Table 1 Correlation coefficient of regression equation

Number of samples	Category	Correlation coefficient	Significant level	
			0.05	0.01
33	Monthly mean sea level between Caofeidian and Tanggu $\Upsilon 1$	0.997	0.344	0.443
33	Monthly average maximum sea level between Caofeidian and Tanggu $\Upsilon 2$	0.954	0.344	0.443
33	Monthly mean sea level between Caofeidian and Qinhuangdao $\Upsilon 3$	0.993	0.344	0.443
33	Monthly average maximum sea level from Caofeidian to Qinhuangdao $\Upsilon 4$	0.464	0.344	0.443

$\Upsilon 1$ – $\Upsilon 4$ are significantly correlated, but $\Upsilon 4$ is not good

Fig. 11 Regression line of monthly average sea level between Caofeidian and Tanggu



data of nearby Tanggu and Qinhuangdao stations. The historical sea level sequence data of Caofeidian is calculated by using the established regression equations and the historical measured sea level sequence data of Tanggu and Qinhuangdao stations. Then, the calculated Caofeidian sea level data series are used to analyze its long-term change trend, amplitude, annual rate and multi-year high sea level, and predict the future change. It is expected that the sea level of Caofeidian will rise by 157–187 mm in the next 30 years than in 2010.

Fig. 12 Regression line of monthly average maximum sea level between Caofeidian and Tangu

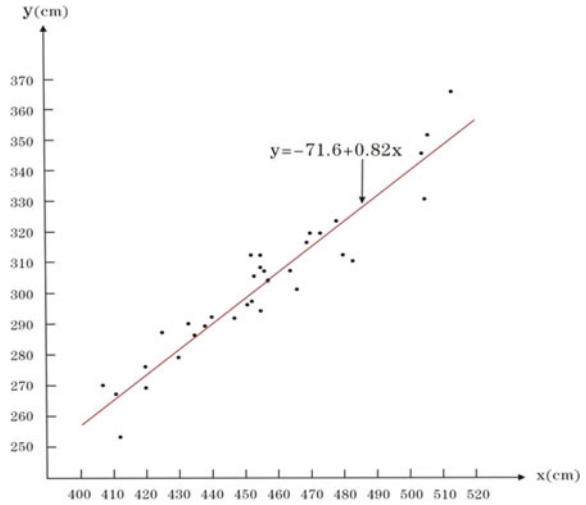
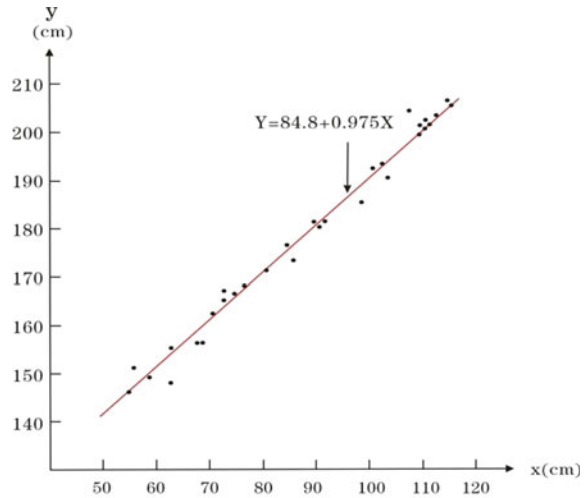


Fig. 13 Regression line of monthly mean sea level from Caofeidian to Qinhuangdao



Monthly mean sea level between Caofeidian and Tangu:	$y = -80 + 0.93x$	(1)
Monthly average maximum sea level between Caofeidian and Tangu:	$y = -71.6 + 0.82x$	(2)

(continued)

(continued)

Monthly mean sea level between Caofeidian and Qinhuangdao:	$y = 84.8 + 0.975x$	(3)
Monthly average maximum sea level from Caofeidian to Qinhuangdao:	$y = 134 + 0.1457x_1 + 0.0367x_2$	(4)

Thus, the ability to resist storm surge in some sections of the Caofeidian new area is relatively weak in the context of the continuous rising sea level. Caofeidian Tong Dao Road (dike), Shougang Group, petrochemical platform, oil and Ore Wharf and other important projects are the main facilities for the storm surge. From the Nanpu Economic Development Zone, Nanpu oil field, Caofeidian Industrial Zone, Caofeidian International Eco-City, to shijiutuo Island Tourism Zone, development zone, seven Caspian Sea tourist area and natural protection zones are needed Focus on prevention and protection. Therefore, when designing the coastal dyke, we should consider not only the beach type and the coastline change characteristics, but also the bank's functions, strength and top elevation to prevent extreme marine disasters, and optimize the layout and engineering design of the embankment. We should fully consider the ground elevation loss problem caused by ground subsidence, sea-level rise and other factors, when design the moisture-proof crest elevation (Fig. 14).

According to the factors such as ground elevation, 100 years' tide level, land subsidence rate and sea level rising rate, it is suggested that the top elevation design of the embankment of Caofeidian new area should be 6.79 m at one hundred years (the national 85 elevations). In order to avoid and mitigate the losses caused by storm surge disasters and safeguard the safety of people's lives and property, there are three ways to evacuate the storm surge: In the first case, a proposal for evacuation and transfer of high safety level for ground elevation control is proposed; The second is the suggestion of evacuation and transfer in the risk level area of the temperate storm flood; The third case is for the evacuation and transfer of typhoon storm flood risk level area, as shown in Fig. 15.

5 Conclusion

This paper analyzes the mutual influence of Caofeidian reclamation and coastal geological environment from the change of the coast and beach, tidal current field and seabed erosion, storm surges and rising sea levels. The reclamation of the new city has caused the change of sedimentary environment and hydrodynamic conditions of the ocean, changing the coast, beach, seabed erosion and siltation status. Storm surge and sea-level rise have intensified the impact on the geological environment of the coastal zone, which is a major issue to be paid attention to in the construction of the new area of Caofeidian. Suggestion:

- (1) To study the degree of land reclamation and interaction influence engineering and flow field development, strengthen erosion dynamic monitoring of heavy

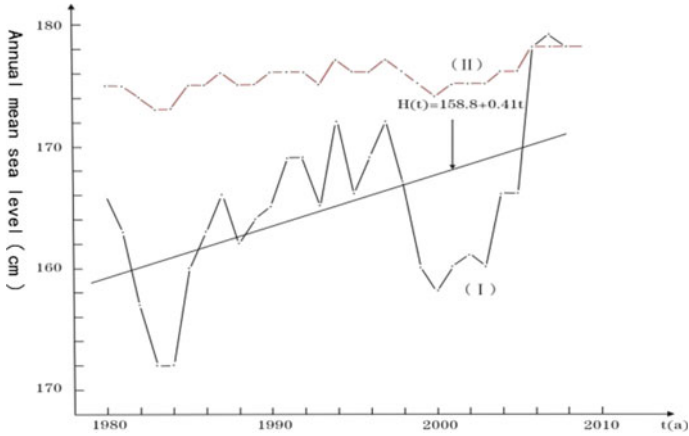


Fig. 14 The annual mean sea level change Diagram of tide gauge station in Caofeidian

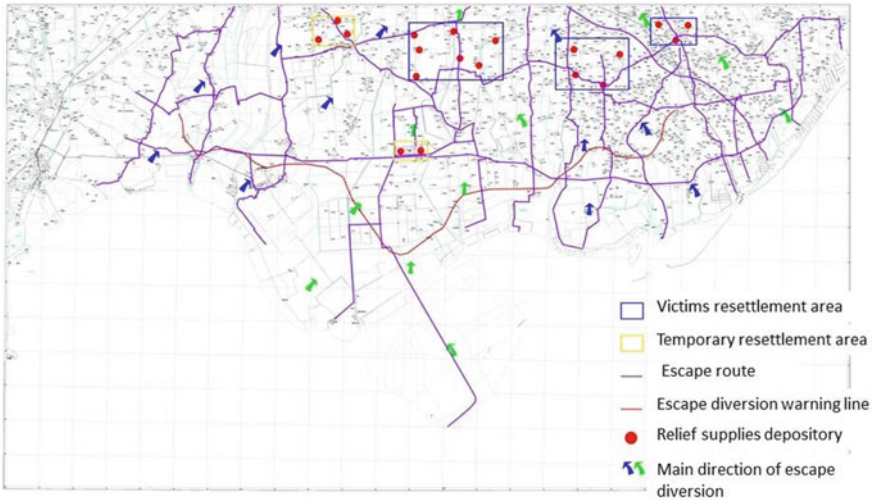


Fig. 15 The evacuation transfer sketch map of suffered storm surge disaster in Caofeidian

- head submarine deep groove in Caofeidian sea area, to provide a scientific basis for further optimize the land reclamation engineering scale and layout.
- (2) We should strengthen the dynamic monitoring and research of the underwater slope stability in key coastal areas such as the Caofeidian industrial area and International Eco city by using a variety of technical means and methods.

Fund Project

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