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Shanghai coastal erosion and siltation and its influence on deepwater channel project

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ABSTRACT

The seaward sediments from Yangtze River triggered frequent and variable erosion and siltation of natural coast under conditions of the complex estuary geomorphology and hydrodynamic force, which brought negative influence on great coastal projects and became the main type of ecological disasters in the Shanghai area. This article together with results from monitoring data of sediment transport in the area of Yangtze River estuary analyzed its impact on deepwater channel project in Yangtze River Estuary, providing references for daily maintenance and safety operation of project.

KEYWORDS

Waterway engineering; Deep water channel; Coastal erosion and siltation.

INTRODUCTION

Nearing river and sea, Shanghai has superior geographical position, providing a good basis for development of economy and the reasonable layout of city. Due to the position of the confluence of two golden waterways Shanghai plays a key role in China national economy. With the establishment of economic, financial, trade and ship centers, construction of a wide range of seacoast engineering projects had vital function and made a positive contribution to the formation and development of coastal economic circle.

Influenced by the special geographical site and configuration of delta, the seaward sediments under the condition of the hydrodynamic force interaction of Yangtze River runoffs and sea tidal current, the process of transportation and deposit was complex and changeable, and triggered frequent and variable erosion-deposition of natural coast, which brought negative influence and safety loophole on great coastal projects and became the main type of ecological disasters in the Shanghai area.

This article together with results from monitoring data of sediment transport in the area of Yangtze River estuary analyzed its impact on deepwater channel project in Yangtze River Estuary, providing references for daily maintenance and safety operation of project.

THE FUNDAMENTAL FEATURE OF EROSION-DEPOSITION EVOLUTION IN YANGTZE RIVER ESTUARY

Yangtze River in Shanghai, is about 148 km long with a basin of 2400 km^2. The coastline length was 450 km in Shanghai coastal survey in 1980. Several reclamations in almost 20 years extend the coastline to 500 km now.85 percent of Shanghai coastline is in Yangtze River estuary. The islands accounted for nearly three-quarters of all coastlines.

a) Han Dynasty **(b) Qing Dynasty** **(c) The Contemporary Age**

Figure 1 : The change of Yangtze River estuary

According to record, Yangtze River estuary had undergone a great change for more than 2,000 years. Yangtze River estuary had moved down from Zhenjiang, Yangzhou to Jiangyin as shown in Figure 1(a) and (b). Since the nineteen fifties, Xuliujing manually node had been formed gradually and had became the last node in Yangtze River estuary as shown in Figure (c), and it’s interaction between water and sediment movement of the upstream and downstream gradually had became more subdued. The reach from Jiangyin to Xuliujing was about 90 km long. Due to the control of Jiangyin at the entrance and Xuliujiang at the exit and advantages of gradually forming Jiulonggang and Longzhuayan in the middle reach, the situation of frequent drastic mainstream swing had came to an end and the river channel kept basically stable.

In general, Yangtze River Southport belongs to sedimentation bank slope in the Waigaoqiao in Pudong, while the South Coast of Changxing Island belongs to erosion bank slope; Yangtze River Northport and the North Coast of Changxing Island belong to sedimentation bank slope, while the Yangtze River bank slope of Chongming Island belongs to erosion bank slope. Since the nineteen fifties, continuously construction and consolidation, such as the construction of Haitang T-shaped Dam, keep bank slope generally stable. The alteration of coastal erosion and siltation changes the trunk stream of the Yangtze River and affects deepwater channel, which erodes bank revetment works, affects stability of coast slope, and decreases the effectiveness of waterfront and near shore projects and increases losses on storm and spring tide.

The coastal erosion and siltation of Yangtze River has changed obviously. Under the impact of Coriolis force, rend of the rivers was toward southeast, therefore, the north branch of Yangtze River based on sedimentation and the south branch based on erosion. In general, the north coast bank slope of Yangtze River belongs to sedimentation bank slope and the south coast bank slope of Yangtze River belongs to erosion bank slope, which affects stability of coast slope and threatens near shore projects and influences project lifespan.

Coastal erosion and siltation refers to the recession or extension of coastline because of erosion or sedimentation and phenomenon of seafloor erosion or sedimentation under the impact of oceanic dynamic and movement of sediment. The reasons of coastal erosion and siltation include natural and factitious influences. Coastal erosion and siltation developed at different speeds due to the difference of the main factors. For example, the process of coastal erosion and siltation developed slowly under the condition of regular weather, while the process became sharply and rapidly under the influence of extreme weather like typhoon. For engineering, the speed of coastal erosion and siltation development mainly depends on the impact of engineering on nearby river regime. If the impact on the river regime was sharp, coastal erosion and siltation developed rapidly. On the contrary, if the influence on the river regime was weak, coastal erosion and siltation developed slowly. After the coastal erosion and siltation has developed to a certain degree, it would cause the huge loss of life and property.

Coastal erosion and siltation consists of two aspects, coastal erosion and coastal siltation. Coastal erosion caused massive soil and water loss and serious minification of soil, even the damage of coastal villages and facilities. It also caused submarine landslide and damage of undersea projects, drilling rigs and subsea cables. Sometimes submarine landslide capsized drilling rigs, and underwater petroleum transmission pipeline and cable was warped and cut. The damage caused by coastal erosion was primarily to port and channel. The port and channel erosion caused the problem of ships berthing in port, and even lead to scrapping of port and channel, which incurs a huge loss. The damage of coastal siltation is raising the river level, the failure of the levees and blocking of waterway.

Except in special cases (such as typhoon), coastal erosion and siltation is a gradual process of development. At all times, coast is affected by waves, tides, movements of sediment which caused coastal erosion and siltation alteration sometimes quickly, sometimes slowly, but their cumulative effect usually bring great damages. Although coastal erosion and siltation is a gradual process of development, the damage to project happens instantly. For example, when the coastal erosion developed to a degree, it triggered the collapse and overturn of project.

COASTAL EROSION AND SILTATION HYDRODYNAMIC ANALYSIS

There are three methods to analysis the response relationship between estuary erosion and siltation and runoff, including hydraulic geometry method, mobile bed mathematical model method (through simultaneous equations of flow continuity equation, flow kinematical equation, suspended sediment transport equation and riverbed deformation equation) and multivariate regression analysis method based on observed data.

Hydraulic geometry method established experienced correlation relation between balanced section shape and water and sediment factor. According to the change of water and sediment condition and channel boundary condition, we can predict the impact of human activities such as development of runoff on the change of river erosion and siltation. This method cannot predict the process of dynamic response to human activities but the final stable state.

Mobile bed mathematical model is a dynamic model based on sediment-carrying movement which is a numerical solution of the flow field and sediment field. After verification, we can solve the process of riverbed change according to the change of the flow and sediment elements. But the long-term sediment movement is so complex that it is difficult for dynamic model to ensure the precision of calculation of long watercourse and long-time change in estuaries.

Multivariate regression analysis method established response relation between the change of riverbed erosion and siltation and hydrographic condition with numerical calculations based on observed data of hydrology and geography in estuaries. This simple and reliable method needs a lot of observed hydrology and geography data, which is difficult to achieve in estuaries that are short of data.

Based on the above analysis, we established a mobile-bed numerical simulation model of the mouth of Yangtze River. Because the riverbed width is narrow, one dimensional model can described the law of water movement. Here is the basic equations we used:

The continuity equation of incompressible fluid:

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q_t \quad \textbf{(1)}$$

In this equation: A means the area of the wetted cross-section t means time; Q means quantity of flow; x means river mileage; q_t means unit inflow quantity from river flanking region.

Differential equation of fluid movement:

$$\frac{\partial Q}{\partial t}+2\frac{Q}{A}\frac{\partial Q}{\partial x}+gA\frac{\partial Z}{\partial x}+g\frac{Q|Q|}{C^2AR}-\frac{Q^2}{A^2}\frac{\partial A}{\partial x}=0 \quad \textbf{(2)}$$

In this equation: Z means tide level; C means Chezy coefficient; R means hydraulic radius of riverbed profile.

Suspended sediment transport equation

$$\frac{\partial AS}{\partial t}+\frac{\partial QS}{\partial x}=-\omega B\left(T_1S-T_2S_*\right) \quad \textbf{(3)}$$

In this equation: ω means sediment deposition velocity; S means the average content of cross-section sediment concentration; S_* means cross-section sediment-carrying capacity; T_1 means the ratio of base sediment content to average sediment content along vertical direction ; T_2 means the ratio of base sediment content to sediment-carrying capacity ; B means channel width.

Riverbed deformation equation:

$$\gamma_s\frac{\partial Z_0}{\partial t}=\omega\left(T_1S-T_2S_*\right) \quad \textbf{(4)}$$

In this equation, γ_s means dry unit weight of riverbed sediment.

The calculation formula of sediment-carrying capacity:

$$S_*=f\left(u,h,\omega\right) \quad \textbf{(5)}$$

In this equation, u means flow velocity; h means river depth. Other symbols meaning are same as mentioned before

Solving the equation of water and sediment control can be divided into three steps. The first step is fluid calculation, and next step is suspended sediment transport calculation (using method of fractional steps to calculate the distribution of sediment content of suspended load). The last step is longitudinal deformation of riverbed calculation, and we can get the riverbed level altitude at the end of this stage.

YANGTZE RIVER ESTUARY DEEPWATER CHANNEL AND ITS IMPACT OF EROSION AND SILTATION

The project profile of deepwater channel project

The Yangtze River estuary Deepwater Channel Project is located North Passage of the Southport. Using a scheme of combining of renovating and dredging to construct diversion port project, the double-dyke project and T-shaped Dam project with measure of dredging, which excavates, forms and maintains Deepwater Channel as shown in Figure 2. Construction of the first stage of Yangtze Estuary Deepwater Channel Regulation Project began on January 27, 1998, and the whole line has achieved the objective depth which was 8.5m in late March, 2000. The second stage of project began in late April, 2002. Deepwater Channel of 9m has opened up on May 10, 2004. The governance goal of the second stage of project that the whole line has achieved 10m deep was achieved in March, 2005. The third stage of project was centered at dredging and achieved 12.5m deep, which completed by the end of 2010.

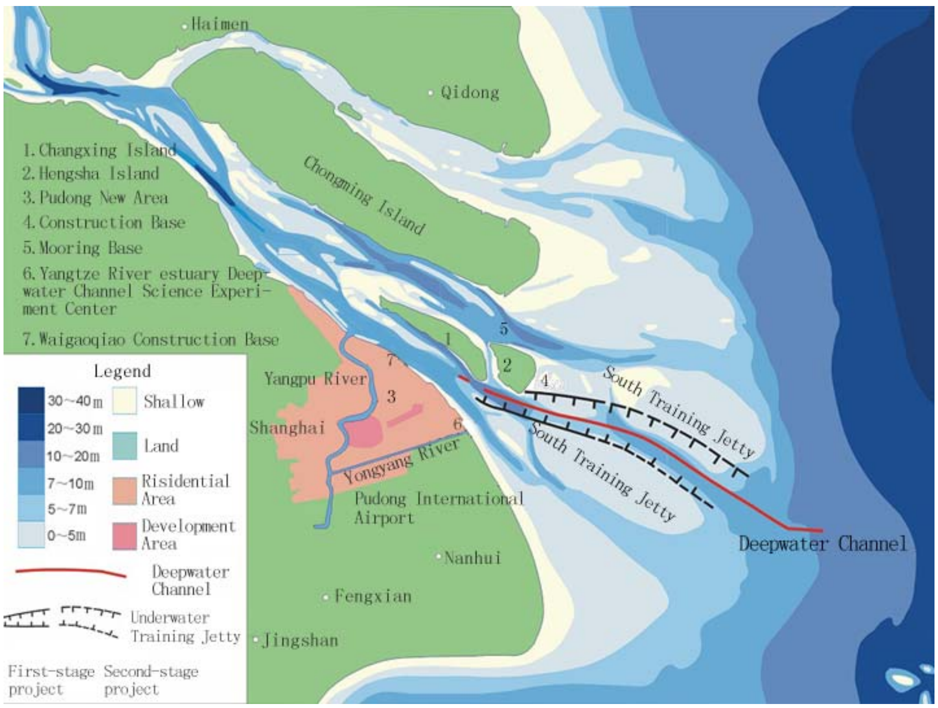

Figure 2 : The Yangtze River estuary underwater topography and Deepwater Channel Project

The reflection of erosion and siltation influence

After the construction of the second stage of Deepwater Channel Project, the depth of deepwater channel has became deeper in most regions of North Passage, but strong siltation region has appeared at the turning in the middle of channel as shown in Figure 3. The appearance of strong siltation region leaded to the increase of North Passage silting amount from original twenty million m^3/year to thirty million m3/year, and the share of silting amount to the total increased from 30% in 2001 and 2002 to more than 70% in 2008, which caused huge costs of dredging.

The analysis of erosion and siltation factor

The mainly factor of the siltation centralized distribution are the water containing high-density sediment near the bottom and net sand transportation pointed to the channel. After the analysis of strong siltation at the back of turning part of the second stage of project, the mainly factors are as follow. (1) Due to the lack of protection of upstream of Ruifeng spits, after the construction of the second stage of project Ruifeng spits sediment erosion downstream deposited at turning part of channel; (2) Because of the impact of Deepwater Channel South Training Jetty, the beach face sediment at downstream

Jiuduansha entered the corner and deposited driven by tidal flood current. The sediment from upstream and downstream became the abundant source of channel turning part. (3) Due to the poor dynamic condition at turning part, there is an obvious mismatch in the flux and reflux fluid passage, which led to the development of subcritical flow area and was conducive to sediment siltation.

Figure 3 : The erosion and siltation change of North Passage during 1998.8-2005.11

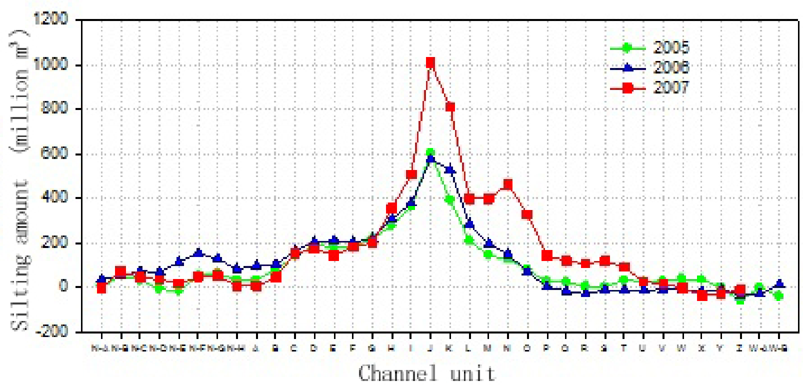

Figure 4 : North Passage annual silting strength scatter gram (2005-2007)

Due to the complex hydrological environment of the Yangtze river estuary, various conditions were changed significantly after the construction of project. The lack of clear understanding about above problems before the construction of project led to the partly siltation after the second stage of project.

COASTAL EROSION AND SILTATION COMPREHENSIVE PREVENTION MEASURES

The forming reasons of coastal erosion and siltation were complex and its influence factors were such a lot. The direct reason of coastal erosion and siltation was the changes of sediment condition and coastal dynamic, while the basic reason was natural changes and human impact. Among them, the natural changes included the change of river courses, precipitation decline, rising sea levels, storm surges erosion and topographical variation and so on. While the human impact included coastal dredging, the decreases of transporting sediment load and the change of river regime caused by coastal project and so on.

To solve the above problem of deposition, it is recommended that the Yangtze estuary Deepwater Channel Project take the following measures.

Stabilize the active sediment and reduce the sediment from upstream. Building sediment barrier dyke inside South Training Jetty intercept the Jiuduansha sediment over the dyke.

The project planning design need to study the river regime change sufficiently and analyze the maximum margin of erosion and siltation and its occurrence area before and after the construction of project. Optimal project planning based on this could reduce range of erosion and siltation or proactively protect the impact of erosion and siltation.

During the construction of project, the topographical field observation should be enhanced. Arranging a net of hydrological observation stations and having a long-term observation are well used to find disaster and hidden peril as early as possible, which could guide the construction and management and take the relevant measures.

To solve the problem of erosion, the coastal protection project should be built, such as dike near the coast, stone bank revetment, planting vegetation and protection forest. Building levee revetment could protect eroded shore, and the T-shaped Dam built at the shore formed indented new shore, which protected original shore.

To solve the problem of deposit, extending the T-shaped Dam could narrow the flow, decrease subcritical flow area and deposit. Building Siltation Reduction Project could change the structure of flow and sediment or dredging could control deposit.

CONCLUSION

(1)The long-term detailed investigation of basic data about the Yangtze river estuary geological condition, the change of channel water volume and the river sediment concentration and so on is precondition for analysis on the rule of coastal erosion and siltation, so we need long-term observation now and later.

(2) After the construction of the second stage of project, the channel depth has became deeper in most regions of North Passage, but strong siltation region has appeared at the turning in the middle of channel.

(3) Taking effective measures such as intercepting upstream sediment, optimizing dredging engineering and extending T-shaped Dam could adjust flow field further and reach new balanced cross section.

REFERENCES

[1] Wu Hualin, Zhang Junyong; Regulation parameters and regulation schemes for the Yangtze River estuary waterway regulation project [J]. Port & Waterway Engineering, **11**, 1-6 **(2013)**.

[2] Liu Junyan, Xia Fang; Statistical analysis of benefit from regulation engineering in the Yangtze estuary deepwater channel[J]. Port & Waterway Engineering, **11**, 29-32 **(2013)**.

[3] LI Bing; Underwater Topography Evolution and its Driving Mechanisms Over the Past Nearly 30 Years in Shanghai Offshore Area[J]. Shanghai Geology, **31(3)**, 29-34 **(2010)**.

[4] Liu Xi, Yang Lijun, Xu Junjie; The Evolution of the North Branch of Yangtze River Estuary Characterizedby Being Narrower and Shallower [J]. Shanghai Geology, **31(3)**, 35-40 **(2010)**.

[5] Hu Jin, Chen Shenliang, Hu Xiaolei; Evolution of the Northern Jiangsu Coast Under the Impact of Climate Change [J]. Shanghai Land and Resources, **34(2)**, 41-49 **(2013)**.

[6] Ren Ren-Xi-Zi, Chen Shen-Liang; Sediment Dynamics in the Littoral Zone of the Yellow River Delta [J]. Shanghai Land and Resources, **33(2)**, 62-68 **(2012)**.

[7] Zhao Baochegn; Bedforms on Northern Hangzhou Bay Subaqueous Slope: Its Implication to Seafloor Erosion [J]. Shanghai Land and Resources, **32(3)**, 27-34 **(2011)**.

[8] Wang Dongmei, Cheng Heqin, Zhang Xianlin; Impact of Multifactors and Prediction Technique of Relative Sea Level in Shanghai [J]. Shanghai Land and Resources, **32(3)** 35-40 **(2011)**.

[9] Liu Yongwen, Yang Shilun, Luo Xiangxin; Study on Techniques of Monitoring and Predicting Change of East Antarctic Ice Sheet / Ice Shelf [J]. Shanghai Land and Resources, **32(3)**, 23-26, 45, 52 **(2011)**.

[10] Zhang Qing; Sea Level Change on the Southern Yangtze Delta Plain, China: Since 15 ka BP Reconstructed from Salt Marsh Peat [J]. Shanghai Land and Resources, **34(1)**, 37-41 **(2013)**.

[11] Gong Shi-liang, Li Cai; Environmental Geological Problems and the Prevention for Shanghai Chongming Thoroughfare Engineering Across the Changjiang River[J]. Port & Waterway Engineering, **6**, 1-5 **(2007)**.

[12] Li Bing, He Zhongfa; Ideas of construction and management of coastal geo-environmental monitoring system: case of Shanghai [J]. Shanghai Geology, **31(1)**, 6-10, 20 **(2010)**.