Influence of Water and Sediment Conditions on Flow Path into Sea Movement in the Huanghe Estuary

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Abstract. For researching the laws of flow path into sea movement in siltladen rivers, according to the measured topographic data since 1976 to 2015, it analyses the course of the flow path movement during in Qingshuigou path in Huanghe estuary. The results show that current flow paths deposits and extends controlled by runoffs and ocean hydrodynamics. The old flow paths are eroded and dominated by ocean power. The runoffs and sediment into sea reduce by 42% and 78% after 1996, respectively. As a result, the averaged deposition rate reduces by 81%. The avulsion rate of the flow path into sea is also decreased.

Keywords. Huanghe estuary, flow path into sea, deposition, swing, motion laws.

1. Introduction

Huanghe Estuary is a sandy and weak tide estuary, its sediment is mainly from river. The amount of sediment from river is far larger than other estuaries. In the estuary area, the river evolution is violent, mouth deposition is serious, and coastline adjustment is frequent. In addition, with the situation of water and sediment into sea changing significantly in recent years, the threat of embankment damaged and shore beach erosion is intensified, the ecological environment is degenerated [1]. Therefore, it has important scientific and practical significance to research the evolution laws of flow into sea under the changed conditions of water and sediment into sea.

The flow changed frequently in Huanghe Estuary. The flow has changed tremendously 9 times [2], and diverse little more than 50 times from 1855 to 1976. Since the flow changed into Qingshuigou in 1976, researchers have carried out a lot of studies about the useful life of the flow, the estuary erosion and deposition varieties, the impact of the flow by sediment control and sediment regulation tests, and so on. On the aspect of the estuary erosion and deposition varieties, researchers believe that the deposition level is closely related to the amount of water and sediment into sea. On the whole, there has the law that the new estuary is continuous depositing, and old estuary is continuous eroding. For the phenomenon of erosion and deposition evolution in Huanghe Estuary, researchers have done a lot of studies about the mechanization [3, 4]. On the aspect of coastline variation, the coast evolution is constrained by the water and sediment conditions of Huanghe and ocean dynamics [5]. It is believed that current estuary is mainly affected by the contrast effect of water and sediment conditions from river and sea power [6, 7], and old estuary is mainly affected by sea power.

In this article, according to the variation laws of topography underwater out of estuary since 1976, and the changed conditions of water and sediment into sea in recent years, it researches the movement laws and evolution trends of the traveling and swinging of the flow. It can provide reference for the change law of flow in Huanghe Estuary.

2. Regional Overview

The modern Huanghe Estuary is located on the southwest bank of the Bohai Sea. It is between Bohai...
Bay and Laizhou Bay. And its latitude is between 37 °N and 38 °N. From upstream to downstream, Huanghe Estuary is divided into tail river area, runoff and tidal wave area, runoff and tide area, and coastal area. The downstream boundary of tail river area is the upstream boundary of tidal area (The tidal boundary is generally above the mouth 20 km). The downstream boundary of runoff and tidal wave area is the upstream boundary of stagnation point (It is also known as tidal boundary. It is near the mouth). The downstream boundary of runoff and tide area is the 12 m contour line in the shallow sea. Coastal area is basically out of the sea area which water depth is 12 m based on the Yellow Sea level. It shows in figure 1.

Figure 1. Current flow and shoreline distribution of Huanghe Estuary.

2.1. Runoff Conditions
Lijin hydrological station is the last hydrological station for the Huanghe runoff section. Its amount of water and sediment transport is usually considered to the water and sediment of runoff into sea. Researches show that the fluctuation period of the water and sediment into sea is in 1950~1970, the slow decline period is in 1970~1980, and the accelerate decline period is in 1980~2005. This paper mainly studies the evolution laws of the flow and shoreline of Qingshuigou after 1976. The variation of water and sediment is shown in figure 2.

Annual water supply is $3.39 \times 10^{10}$ m$^3$ in 1976-1985, $1.44 \times 10^{10}$ m$^3$ in 1986-2000, $1.67 \times 10^{10}$ m$^3$ in 2001-2015. Annual sediment supply is $8.3 \times 10^8$ t in 1976-1985, $3.7 \times 10^8$ t in 1986-2000, $1.33 \times 10^8$ t in 2001-2015. It can be seen that the variation trend of water and sediment into sea is consistent before 2000, and the reduction velocity of sediment into sea is greater than that of water into sea after 2000.

Figure 2. Variation laws of water and sediment into sea.
2.2. Marine Dynamic Factors

Yellow River Estuary is a weak tide estuary. The average tidal range is between 0.73~1.77 m. Most storm surges in this region. The waves in Bohai Sea mainly wind waves [8]. After the wave breaks into the shallow sea area, the flow rate is very large, and the coast washes back to form a coastal flow and transports sand. The wave is one of the important factors for sediment transport along the Yellow River Delta [9].

2.3. Data Sources

The data is from Institute of the Yellow River Estuary and Coast Science. The underwater topographic data of the coastal area of Yellow River Delta includes the years of 1982, 2000, 2007 and 2015. The elevation system is 1985 elevation system.

Table 1. Data precision and sources.

| Measure time         | Range                  | Accuracy                      | Source                                      |
|----------------------|------------------------|-------------------------------|---------------------------------------------|
| 1982 August to October | Bohai                  |                               | Institute of the Yellow River Estuary and Coast Science |
| 2000 May to July     | From the mouth of      | The line soacing is 1~2 km,   |                                             |
| 2007 June to August  | Xiaqinghe              | and the sounding point spacing is 0.2~0.5 km |                                             |
| 2015                 |                        |                               |                                             |

3. Study on the Variation Characteristics of Topography in the Yellow River Estuary

It used the five- and ten-meters isobath line to draw the terrain changes of in four periods, for figure 3.

The accumulation and handling of underwater sediment is mainly affected by hydrodynamic conditions. On the combined effect of runoff and ocean dynamic conditions, the flow path mainly deposited and extended outward. On the effect of ocean power, the old rivers are eroded. In the range of the water depth less than five meters, the transportation of the sediment is more frequent and affected by the change of the flow path.

Figure 3. Underwater bathymetric distribution.

4. Changes of Flow Path by the Reduction of Water and Sediment into Sea

The relation of the siltation length of the flow path and the amount of the water and sediment into sea is shown in figure 4. The amount of sediment entering the sea is in good agreement with the trend of the siltation length of the flow path. After 1996, the water into sea reduces by 42%, the sediment into sea reduces by 78%, and the averaged deposition rate reduces by 81%. The deposition rate of the river is significantly reduced by the reduction of the sediment into sea. The branch rate of the flow path into sea is also reduced.
5. Conclusions
According to the measured topographic data since 1976 to 2015, it analyzed the movement laws and the changing trend of the flow path into sea. The current river continually deposits and extends. It is affected by runoff and ocean power. The old rivers are eroded. It is mainly affected by ocean power. After 1996, the water into sea reduces by 42%, the sediment into sea reduces by 78%, and the averaged deposition rate reduces by 81%. The deposition rate of the river is significantly reduced by the reduction of the sediment into sea. The branch rate of the flow path into sea is also reduced.

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