Sand Bar Evolution Process Numerical Simulation Analyze Based on two Dimensional Numerical Model

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Abstract. The sand bar lies near the entrance to the sea, which is not only detrimental to the flood discharge and sediment discharge of the river, but also an important factor causing the swing the flow path to the sea. With the formation and development of the sand bar, the form of the sand bar is constantly changing, the river is expected to extend continuously, and the water level and velocity of the estuary river change within a certain range, thus affecting the estuary flood control and river management measures. It is of great significance to study the development process of sand bar and its form for flood control of estuarine rivers and to put forward reasonable control measures of the sand bar. The sediment inflow into the sea is calculated by using the validated two-dimensional numerical model of estuarine and rivers. In this paper, the variation and development process of the sediment form with time and space are analyzed from the following aspects: the process of sediment deposition thickness into the sea, the distribution chart of sediment deposition thickness along the direction of water flow into the sea, the process chart of seabed deposition height, the variation of intraday flow velocity along the sea and the analysis of the temporal and spatial variation of sediment concentration, etc. The calculated and analyzed results are consistent with the measured data.

1. Introduction
The Yellow River estuary is an accumulation estuary with weak tide, much sand and frequent swing. The water and sediment of the Yellow River flow into the Bohai, the energy of the water flow into the sea is sharply reduced due to the influence of tidal crest support and current diffusion. Meanwhile, due to the mixing of brine and fresh water and flocculation of sediment, the sediment accumulation body is formed, namely the sand bar. The sand bar lies near the entrance to the sea, which is not only detrimental to the flood discharge and sediment discharge of the river, but also an important factor causing the swing the flow path to the sea. With the formation and development of the sand bar, the form of the sand bar is constantly changing, the river is expected to extend continuously, and the water level and velocity of the estuary river change within a certain range, thus affecting the estuary flood control and river management measures. It is of great significance to study the development process of sand bar and its form for flood control of estuarine rivers and to put forward reasonable control measures of the sand bar.
In the study of the formation and development of sand bar, many people use less measured data to analyze and discuss. Based on the measured hydrological and sediment data in the Yellow River estuary, Li Zengang\cite{1,2} analyzed the causes of the formation of the barrier sand and clarified the deposition process of the sediment near the stagnation point. According to the hydrological and sediment simultaneous observation data, the dynamic conditions and process of the formation of the barrier sand in the Yellow River estuary are analyzed, and the dynamic mechanism of sediment deposition at the bidirectional dynamic equilibrium position - the point of traceback on the high tide is demonstrated in detail. At the same time, the change of scouring and silting at the mouth of the river is explained. From the point of view of dynamic balance between river and sea, the characteristics of the sediment deposition near the stagnant point, the position change of the stagnant point, the development and evolution of the sand bar are illustrated. Ji Zuwen and Hu Chunhong\cite{3} summarized the law of tidal change prevention by these hydrodynamic factors on the basis of analyzing the velocity, sediment concentration and sediment particle size in the Banmensha area of the Yellow River estuary. Combined with the variation characteristics of the arrears in estuarine area, the relationship between the hydrodynamic characteristics and the evolution model of the arrears in estuarine area is preliminarily discussed. Based on the measured data of the barrier sand at the Yellow River estuary in 1984, 1987 and 1989, Chen Zhangrong \cite{4}, on the basis of clarifying the morphological characteristics of the barrier sand at the Yellow River estuary, calculated the amount of scour and deposition by using the measured water depth data, and analyzed the formation, evolution and evolution mechanism of the sand bar. Cui Jinrui and Xia Dongxing \cite{5} discussed the formation mechanism and evolution law of the sand bar in the Yellow River estuary on the basis of studying the dynamic process and sediment movement characteristics of the Yellow River estuary. Liu Fengyue\cite{6} revealed the geomorphological characteristics and formation mechanism of the sand bar through the longitudinal section of the estuary of the Yellow River. Due to the lack of measured data, the above research on the evolution of the sand bar is not comprehensive enough in the analysis of spatial and temporal distribution. In this paper, the sediment deposition and diffusion into the sea are calculated through two-dimensional numerical simulation of estuarine and river Marine sediment, and the change and development process of the barrier sand form are analyzed, so as to provide a reference for estuarine sand bar treatment.

2. Numerical simulation basic theory methodology

2.1. The governing equations and deterministic conditions (Li Dongfeng, 2004, Zhang Shiqi, 1990)

It is viable to use depth-averaged planar 2-D shallow water equations as the governing equations for tidal computation. They are as follows:

The equations of continuity:

\[
\frac{\partial Z}{\partial t} + \frac{\partial (HU)}{\partial x} + \frac{\partial (HV)}{\partial y} = 0
\]

(1)

The equations of motion:

\[
\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} + g \frac{\partial Z}{\partial x} + \frac{g n^2 U \sqrt{U^2 + V^2}}{H^{\frac{3}{2}}} - fV - \nu \left( \frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2} \right) = 0
\]

(2)

\[
\frac{\partial V}{\partial t} + U \frac{\partial V}{\partial x} + V \frac{\partial V}{\partial y} + g \frac{\partial Z}{\partial y} + \frac{g n^2 V \sqrt{U^2 + V^2}}{H^{\frac{3}{2}}} + fU - \nu \left( \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} \right) = 0
\]

(3)

where \( \mu, \nu \) is x, y direction components of depth averaged velocity; \( z, h \) is water level (or tidal level) and depth; \( g \) is acceleration due to gravity; \( \nu \) is turbulent viscosity coefficient; \( C \) is Checy’s coefficient, \( C \) is calculated by Checy’s formulation.


\[ C = \frac{1}{n} R^{\frac{1}{n}} \]

\( n \) is Manning roughness coefficient; \( f \) is Coriolis force coefficient; \( f = 2\sigma \sin \phi \); \( \sigma \) is rotation angular velocity of earth; \( \phi \) is the latitude of computed reach.

2.2. Boundary conditions

The deterministic conditions involve boundary conditions and initial conditions. Boundary conditions include opening boundary and closing boundary. The former is inlet and outlet water boundary, and is governed by field tidal process for model. The latter is land boundary and the normal velocity is treated as zero for model.

The outlet and open boundary condition: the tidal spring and ebb are control by the tidal level. It is calculated by the formulation:

\[ Z(x, y, z) \bigg|_{\Gamma_1} = Z^*(x, y, t) = A_0 + \sum f^t H \cos(qt + G(v_0 + \mu) - g) \]

in which \( \Gamma_1 \) expresses open boundary; subscript * expresses a given value (the measured value or analyzed value).

At the entrance, flow discharge is given, such as \( Q(x, y, t) = Q_0(x, y, t) \), \( Q_0(x, y, t) \) is the discharge process.

For the closed and rigid boundary the velocity is zero, ie: \( \mu_n \big|_{\Gamma_2} = \nu_n \big|_{\Gamma_2} = 0 \) in which; \( \Gamma_2 \) expresses closed boundary; \( n \) expresses normal unit vector.

2.3. Model validation

The boundary conditions and validation of the model can be found in [7]-[8].

3. Sand bar evolution and analysis

Sediment diffusion and siltation into the sea, and the evolution of estuarine sand bar is affected by the effect of runoff and Marine dynamics. Considering the wide distribution range of sediment diffusion and siltation, several line segments near the estuary gate were selected, and several points on each line segment were selected for analysis. In addition, due to the great influence of runoff on the sand bar, the estuary is divided into several river sections according to the bending degree and direction of the main stream of the estuary, as shown in Fig. 1. This paper mainly analyzes the evolution of the H03-H02-H01-S11-S12 barrier sand in the direction of the river entering the sea.

![Selected Point Location of Sand bar evolution research](image_url)

The water-sediment process was calculated as follows: the flow rate was 500m³/s, the sediment concentration was 35kg/m³, and the siltation and diffusion process of the sediment entering the sea within 100 days was calculated. The seabed change and the siltation and scour thickness process were
recorded once every ten days, which were equivalent to the weight of the sediment entering the sea respectively being 150 million tons, and the sediment entering the sea was about 0.15 million tons each time. The analysis of sediment movement, barrage sand evolution and seabed scouring and silting is as follows:

3.1. Analysis on the process of seabed siltation and continuous expansion of sand bar

3.1.1. Isoline analysis of deposition thickness

Fig. 2 is the process map of sediment deposition thickness into the sea, and Fig. 3 is the distribution map of sediment deposition thickness along the direction of flow into the sea. The process of sediment deposition can be seen from the figure. The maximum deposition thickness is 1.4 m, 2.6 m, 3.0 m and 3.25 m after the sediment entering the sea is 37.5 million tons, 75 million tons, 112.5 million and 150 million tons. It can be seen from the chart that with the sediment entering the sea, the seabed on the one hand is rising in the vertical direction, on the other hand, it is also advancing to the deep sea vertically.

3.2. Analysis of seabed silting process

Fig. 4 shows the formation process of blocking sand and the process of river bed silting up. It can be seen from the figure that with the sediment entering the sea, the river bed on the one hand increases in the vertical direction, on the other hand, it also advances to the deep sea vertically.
3.3. Sediment movement near the sand bar

3.3.1. Variation of velocity in one day
Fig. 5 shows the flow velocity variation along the path in a day, and each of them first represents the flow velocity variation along the path at a time. It can be seen from the chart that in the vicinity of 282500 m, the flow velocity at each time is the smallest, and the variation range of the flow velocity is the smallest. The main reason is that at this point, the runoff into the sea is affected by the peak of the rising tide, and the flow velocity is the smallest, which becomes the retention point. Under this detention point, with the increase of the distance from the detention point to the outer sea, the variation range of the flow velocity gradually increases and tends to be flat, indicating that the point close to the detention point is still greatly affected by the runoff into the sea. With the increase of the distance from the detention point, the effect and influence of the tide are increasing.

3.3.2. Analysis of temporal and spatial variation of sediment concentration
Fig. 6 shows the temporal variations of sediment concentration and velocity near the entrance. It can be seen from the figure that on the one hand, the flow velocity and sediment concentration show periodic changes; On the other hand, there is a reverse relationship between flow velocity and sediment concentration, that is, when the flow velocity is the largest, the sediment concentration is the smallest, and when the flow velocity is the smallest, the sediment concentration is the largest. It further shows that when the flow velocity is small, the ability of the flow to carry sediment is small, and the sediment cannot be taken away by the flow, and the sediment content of the flow is large. Fig.
Figure 6. Variation of velocity and sediment concentration near the entrance with time

Figure 7. Distribution of sediment concentration and riverbed elevation at typical time

4. Conclusion
The sediment inflow into the sea is calculated by using the validated two-dimensional numerical model of estuarine and rivers. In this paper, the variation and development process of the sediment form with time and space are analyzed from the following aspects: the process of sediment deposition thickness into the sea, the distribution chart of sediment deposition thickness along the direction of water flow into the sea, the process chart of seabed deposition height, the variation of intraday flow velocity along the sea and the analysis of the temporal and spatial variation of sediment concentration, etc. The calculated and analyzed results are consistent with the measured data, which further illustrates the reliability of the mathematical model.

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