Analysis of the Influence of the Shibahu Channel on Water Level and Sediment in the Lower Reach Yellow River

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Abstract. It is necessary to study and analyze the Shibadu flow path as a prospective alternative flow path for the Yellow River diversion. In this paper, the established two-dimensional mathematical model is used to calculate the Shibadu flow path and analyze the water level characteristics of the Shibadu inlet channel and the influence of the ocean tide level on the upstream water level and on the sediment transport. From the calculation results and water-sediment characteristics, it can be seen that: the Shibahu diversion is located in a bend, so it has a high resistance to the upstream water flow, resulting in a small change in the upstream water level at the diversion, a high upstream water level, and a significant decrease in the water level after the diversion; the range of the spread of the sediment movement in the Shibahu is small, and coupled with the weak ocean dynamics, the ability to transport sediment to the outer sea is poor, resulting in the inlet sediment near the mouth gate. The variation of sediment entering the sea during the rising tide and the falling tide is the same and different: the sediment concentration increases at a certain distance during the rising tide, but not during the falling tide. Both cases are about 41km away from the entrance, sediment began to settle.

1. Introduction
For the study of flood propagation in the lower reaches of the Yellow River, the use of measured information and the establishment of one-dimensional mathematical models for analysis are more frequent. Chen Xiongbo [1] proposed to combine the layout of existing engineering measures, river topography and sea area characteristics, and set up the layout plan of engineering measures that is conducive to the stability of flow path for 100 years without affecting flood control safety. Wang Kairong [2] pointed out the major hidden danger brought by the future permanent fixed estuarine flow path look you to the flood control safety of the lower Yellow River, and clarified that the main purpose of the future estuarine comprehensive management lies in flood control and disaster reduction, rather than fixed estuarine flow path. Li Jiwei [3] proposed that a reasonable inlet flow path is conducive to reducing flood control pressure in the lower Yellow River, and the construction of tidal control projects combined with the adjustment of the inlet flow path can improve the tidal protection capacity of the estuary. Shi Changxing [4] proposed that in recent years, as scouring slows down and the downstream tends to develop towards sand transport equilibrium, the degree of influence of...
estuarine extension siltation increase on downstream scouring and siltation process will relatively increase, and the long-term slow but accumulating estuarine extension in making the downstream turn to bottom strength siltation state. Chen Xiongbo [5] proposed that the near-shore sand transport capacity of the Bohai Sea should be considered in the selection of the downstream diversion of the Yellow River into the sea. Wang Wanzhan [6] considered that the diversion of the flow path of the Yellow River into the sea may produce source-tracing scouring under certain conditions.

The Yellow River estuary continues to extend due to the long term with a large amount of sediment flowing through and siltation, which poses a threat to the Yellow River flood control, and the Yellow River has to be artificially diverted every 50 years. At the present stage, the main use of the Qingshuigou channel, when the Qingshuigou channel ends, priority is given to the activation of the alternate flow path of the Diaokou River, and the Shibahu channel is used as the alternate channel in the long term. In this paper, a two-dimensional mathematical model is established to calculate the water level characteristics of the Shibahu, and the influence of the ocean tide level on the upstream water level and sediment transport is analyzed.

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

The equations of motion:
\[
\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + g\frac{\partial Z}{\partial x} + \frac{g n^2 U\sqrt{U^2 + V^2}}{H^{5/3}} - f V - \varepsilon \left(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}\right) = 0
\]
\[
\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + g\frac{\partial Z}{\partial y} + \frac{g n^2 V\sqrt{U^2 + V^2}}{H^{5/3}} + f U - \varepsilon \left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right) = 0
\]

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; \(\varepsilon\) is turbulent viscosity coefficient; \(C\) is Chezy’s coefficient; \(C\) is calculated by Chezy’s formulation:
\[
C = \frac{1}{n} \frac{1}{R^{5/6}}
\]

\(n\) 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 and it is calculated by the formulation:
\[
Z(x, y, z)_{\Gamma_1} = Z^*(x, y, t)_{*0} + \sum f' H \cos(qt + G(v_0 + \mu) - g')
\]
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, i.e.:
$$\mu|_{\Gamma_2} = v|_{\Gamma_2} = 0$$
in which, $\Gamma_2$ expresses closed boundary; $\vec{n}$ expresses normal unit vector.

2.3. Model validation
The boundary conditions and validation of the model can be found in [7]-[10].

3. Calculation and analysis
According to the measured data of the lower Yellow River, the influence of sediment deposition at the estuary of the Yellow River on the lower Yellow River is mainly located below the Luokou section of the lower Yellow River. The classic 3000 m³/s flow and sediment concentration of 35kg/m³ conditions were used for the Luokou section of the lower Yellow River to analyze the 18 households of the standby flow route of the Yellow River into the sea. Select the Shibahu and the Qingshuigou two flow path for comparison: select the same river section point in the upstream section of the intersection of the two flow path for analysis; In the downstream section of the intersection, a certain number of cross-section river points are selected for water level analysis. As shown in Fig.1.

3.1. Water level analysis

3.1.1. The effect of diversion on water level
As can be seen from Fig. 2, at the intersection of the Qingshuigou and the Shibahu, which is 200km from the Loukou, the resistance to upstream water flow is high due to the diversion of the Shibahu to a curved channel. Compared with the Qingshuigou, the change of water level is little in the upstream of the Shibahu, and the water level in the upstream is high, and the water level drops significantly after the diversion. As an alternate flow path of the Yellow River, the Shibahu has a fast flow velocity and sediment does not settle easily in the channel because of its short and narrow flow path.
3.1.2. Effect of rising tide on downstream water level

The ocean dynamics of the sea near the mouth of the estuary are weak, and the influence of the rising tide on the runoff of the estuary into the sea is small, and the obvious influence is about 15km above the mouth of the estuary.

3.2. Sediment Analysis

It can be seen from Fig. 4 and Fig. 3 that due to the practical use of the Qingshuigou flow for more than 30 years, the sand spit is prominent in the Laizhou Bay. The entrance of the Shibahu estuaries to the sea is surrounded by land on the north, south and west sides, connected with the Laizhou Bay, which reduces the scope of the diffusion of sediment movement into the sea. It can be seen from Fig. 3 that due to the weak marine power such as tidal current, the ability to transport sediment to the outer sea decreases, and the sediment entering the sea moves only in the nearby sea area, resulting in sediment deposition near the entrance.
Several points between the farthest point of influence on sediment entering the sea and the entrance of the sea are analyzed when rising tide and falling tide are taken. As shown in Fig.5, the water and sediment concentrations at rising and falling tides begin to vary at about 31 km from the entrance. When the tide falls, due to tidal current, 31-42 km away from the estuary, the sediment concentration of water rises; When the distance is 42-61km, the sediment concentration drops sharply due to tidal current, and the sediment begins to settle rapidly; after 61 km, the sediment settles slowly. When the tide rises, due to the tidal current, according to the estuary 40 km sediment began to settle; the distance is about 40-61km, the sediment content decreases rapidly and the sediment settles rapidly; after 61 km, the sediment settles slowly.
4. Conclusion
According to the above analysis, the diversion of Shibahu is located in a bend, which has a large resistance to the upstream flow, resulting in a small change in the water level at the upstream of the diversion. The upstream water level is higher than the upstream water level of the Qingshuigou, and the water level at the downstream of the diversion decreases significantly. The estuaries of the Shibahu are surrounded by land on three sides, only one side connected with Laizhou Bay, reducing the scope of diffusion of sediment movement into the sea. Due to the weak marine power at the entrance of the sea, the ability of transporting sediment to the sea is reduced, and the sediment into the sea moves only in the nearby sea area, resulting in the deposition of sediment into the sea near the entrance. The variation of sediment entering the sea during the rising tide and the falling tide is the same and different: the sediment concentration increases at a certain distance during the rising tide, but not during the falling tide. Both cases are about 41km away from the entrance, sediment began to settle.

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