Analysis of hydrodynamic influence before and after the demolition of Fenghuang Two Island

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Abstract: In this paper, the hydrodynamic survey data around Fenghuang Island in March 2018 and April 2022 were collected to analyze the impact of the demolition of Fenghuang 2 Island on the hydrodynamic of Sanya Bay. The results show that the tidal pattern of the Sanya Bay is irregular diurnal. The current velocity outside the mouth of the Sanya River is slightly lower than that in Hanoi. The mean current velocity near the shore gradually increases to the open sea, and the mean current velocity in Hanoi and the mouth is significantly lower than that in other sea areas. Before the demolition of Fenghuang II Island, due to the weakening of the shield effect of Fenghuang II Island on the southbound waves, the northwest coastal sand transport capacity was enhanced, resulting in the change of the sand content of the surrounding stations of Fenghuang II Island.

1. Introduction

The river network in estuarine area is the channel connecting the mainland and the ocean, which is jointly affected by runoff and tide [1]. The nonlinear interaction among tides, runoff and estuarine morphology leads to the deformation of tidal waves in the process of landward propagation [2,3]. In the area where the diameter and tide interact together, the river level is composed of the mean water level and tide level [4], and the residual water level represents the intensity of runoff action to some extent, while the amplitude of tidal wave represents the intensity of tidal power [5].

Phoenix Island is an artificial island formed by reclamation in the sea reef. Sanya Phoenix Island Phase II project mainly includes shore wall caisson wharf and artificial island. The waterfront of the wharf is 1,610m (including 105m east shore protection), and the sea area is about 49.41hm2, which is connected to an island through a channel with a length of about 400m.

Phoenix Island is located at the mouth of the Sanya River. Due to the change of water flow and the reduction of water exchange capacity caused by the island filling, the adverse consequences such as the erosion of the western coastline of the Sanya Bay and the worsening of the pollution of the Sanya River have been shown. As a result, the demolition of Phoenix Two Island began in 2021 and was completed in March 2022.

In this paper, the hydrological survey data collected around Fenghuang Island in March 2018 and April 2022 were used to analyze the changes of the hydrological dynamics of Sanya Bay before and after the demolition of Fenghuang Two Island.

2. Research area and data source

The Haikou Marine Environment Monitoring Center Station of the State Oceanic Administration carried out hydrological survey in the waters near the project in Sanya Bay during the spring tide period from 09 o’clock on March 26, 2018 to 10 o’clock on March 27, 2018. A total of 8 tidal current observation stations were set up. The locations of the current observation stations are shown in Table 1. The data of tide level are analyzed by referring to the data of the long-term tide level observation station set up in Sanya Bay by Sanya Marine Environmental Monitoring Station of the State Oceanic Administration and the tide meter set up at station No. 1 near the project in Sanya River.

The hydrodynamic data are cited from the Spring Observation Results Report of Environmental Impact Tracking Monitoring of Sanya Phoenix Island Phase II Project Demolition (July 2022) by Haikou Environmental Monitoring Central Station of the State Oceanic Administration. The monitoring time is April 21 and April 22, 2022. During spring tide period, Marine hydrodynamic monitoring is carried out on a total of 6 current stations (including suspended sediment) and 2 tide stations. The longitude, latitude and distribution of specific stations are shown in Table 2.

Table 1 Table of hydrological survey stations

<table>
<thead>
<tr>
<th>Station number</th>
<th>Longitude (E)</th>
<th>Latitude (N)</th>
<th>Observation item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>109°30'25.91&quot;</td>
<td>18°13'42.83&quot;</td>
<td>Tide, velocity, flow direction, temperature, salt, suspended</td>
</tr>
</tbody>
</table>

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that in other sea areas.

The average velocity near shore is 39.6 cm/s, and the velocity outside the mouth is slightly lower than that in Hanoi. The average velocity in the surveyed sea area ranges from 7.1 cm/s to 35.3 cm/s during spring tide. The average flow velocity of other stations is less than 0.2 m/s. The current velocity of other stations is 35 cm/s and occurred at 22:00 on April 21, with a maximum of 34.7 cm/s. The average flow velocity of rising tide and falling tide at station No. 1 is 36.8 cm/s, and the average flow velocity of low tide ranges from 7.3 cm/s to 33.6 cm/s. The average flow velocity of middle tide was slightly higher than that of high tide at stations 5#, 6#, and the measured maximum ebb velocity is 81.2 cm/s, which occurred on the surface of the 4# station. The measured maximum ebb velocity is 54.0 cm/s at the bottom of station 6#, and the measured maximum ebb velocity is 81.2 cm/s at the surface of station 4#.

3.2 Results before demolition

The results of the survey:
1) During the survey period, there was only one high tide and low tide, the difference of tide was 124 cm, and the duration of high tide was obviously longer than that of low tide. The tidal pattern of the project area was irregular diurnal tide.
2) During spring tide, the current velocity at Sanya Estuary station (1#–3#) is small, while the current velocity at other stations is large. The maximum velocity of each layer in (1#) of Sanya River is about 16 cm/s, and the maximum velocity of each layer is similar. The maximum velocity at station 2 is slightly lower than that at station 1. The maximum current velocity of station 3 at the northwest side of Phoenix Island is about 18 cm/s, and the surface layer is slightly smaller than other layers. The maximum velocity of the 4# station on Hailai reached the maximum, while that of the 6# station was slightly smaller. The measured maximum velocity was 81.2 cm/s, which occurred on the surface of the 4# station. The measured maximum ebb velocity is 54.0 cm/s at the bottom of station 6#, and the measured maximum ebb velocity is 81.2 cm/s at the surface of station 4#.
3) In terms of the average tide time of each station, the average velocity of the surveyed sea area was between 7.1 cm/s and 35.3 cm/s during spring tide. The average flow velocity of all stations in Hanoi and Koumen was similar, and the flow velocity outside the mouth was slightly lower than that in Hanoi. The mean offshore velocity increases gradually. The average velocity in river and mouth is significantly lower than that in other sea areas. The average velocity of vertical lines at each station ranges from 7.3 cm/s to 33.6 cm/s. The average flow velocity of high tide in the surveyed area ranges from 6.3 cm/s to 36.8 cm/s, and the average flow velocity of low tide ranges from 8.5 cm/s to 34.7 cm/s. The average flow velocity of high tide is slightly lower than that of low tide at stations 1, 2 and 3 in the northwest of Hanoi. The average flow velocity of the middle tide was slightly higher than that of the low tide, while the lower tide was the opposite. At station 6#, the average flow velocity of rising tide at surface is slightly lower than that of falling tide, while the average flow velocity of rising tide and falling tide at middle level is the same.
4) During spring tides, the current in the Sanya River and near Koumen (1#–3#) shows the characteristics of rotating current; The inner and outer seas of Sanya Bay (4#–6#) showed reciprocating flow characteristics, and the flow direction was northwest to southeast during the investigation period, basically parallel to the coastline.
5) The flow direction of tidal current at station No. 3 changed greatly at different depths, while the flow direction of other stations at different depths maintained a good consistency with little change. During the observation period of station No. 1, the flow direction of station in Hanoi, while the minimum sediment content was 0.00108 kg/m³, which appeared in the surface of C3 station. The average sediment content of each station and each layer ranges from 0.004719 kg/m³ to 0.022383 kg/m³.

### 3. Results and discussion

#### 3.1 Hydrodynamic analysis of Fenghuang Two Island after demolition

The survey results show that the surveyed sea area is irregular diurnal tide type, and the high tide level of C4 station is 131 cm (national 85 base level, the same below), which occurred at 13:10 on April 21. The low tide was -35 cm and occurred at 22:00 on April 21, with a maximum range of 166 cm and a low tide of about 9 hours. During the corresponding tide observation period, the high tide level of Sanya tidal station was 45 cm, which occurred at 14:12 on April 21. The low tide was -10 cm and occurred at 23:26 on April 21. The maximum range was 155 cm and the low tide lasted about 9 hours.

During spring tides, the current velocity at Sanya Estuary is relatively small, with the maximum velocity less than 0.2 m/s. The current velocity of other stations is relatively high, especially the maximum current velocity of all offshore stations is higher than 0.5 m/s. The average velocity in the surveyed sea area ranges from 7.1 cm/s to 39.6 cm/s, and the velocity outside the mouth is slightly lower than that in Hanoi. The average velocity near shore gradually increases to the open sea, and the average velocity in Hanoi and the mouth is significantly lower than that in other sea areas.

During spring tide, the maximum sediment content was 0.03273 kg/m³, which appeared in the middle of C1 and C2 stations.
tidal current at each layer was mainly northwest and southeast. During the observation period of #2 station, the tidal current of all layers was mainly in the Near east-west direction. During the observation period, the flow direction of layers 4#–6# is NW - SE, and the flow velocity of rising tidal current is larger than that of falling tide. The velocity of each layer at stations 1# and 3# varied greatly and the direction was disorderly, while the velocity of each layer at other stations was relatively regular and the direction was stable.

6) During spring tide, the residual current in the investigated sea area varies greatly, and the residual current at station 4# is large, with its value between 12.5cm/s and 18.2cm/s; The residual flow velocity of other stations is small, ranging from 0.3cm/s to 5.9cm/s. The direction of 4# residual current is very stable at different depths, which are northwest direction and southwest direction respectively. The residual flow direction of other stations varies greatly at different depths. The residual flow velocity of stations 1#–2# is the same. The 3#–5# stations decreased with increasing depth. The middle layer of station 6# has the lowest residual current velocity.

7) During spring tide, the maximum sediment content is 0.0265kg/m³, which occurs at station 1#. The minimum sediment content is 0.0025kg/m³, which is 3# station. The average sediment content of each station and layer ranges from 0.0057kg/m³ to 0.0132kg/m³. The sediment content of the inner and outer sea areas of Sanya River is significantly higher than that of other sea areas. In the vertical direction, the sediment content of each station does not change with the depth.

8) The maximum net sediment transport per single width in Sanya Bay during spring tide is 2151kg/(m•d), which occurs at Station 4#. The minimum net sediment transport per single width is 8kg/(m•d), which appears at station 1#, and the difference between the two is about 268 times. The net sediment transport in single width gradually increases from the Hanoi to the shore outside the mouth, which is consistent with the distribution of current velocity characteristics. Except for station No. 4, the net sediment transport in single width of other stations was small. The single width net sediment transport direction of each station is basically consistent with the main direction of other streams.

3.3 Comparative analysis of hydrologic and dynamic characteristics before and after island demolition

3.3.1 Tide level

Monitoring results from March 26 to 27, 2018: During the investigation period, there was only one high tide and low tide, the tidal range was 124cm, and the duration of high tide was significantly longer than that of low tide. The tidal pattern of the project area was irregular diurnal tide.

Comparison results: The tidal pattern of the project area is irregular diurnal tidal pattern. During the two survey periods, the duration of high tide is obviously longer than that of low tide, but the difference of tidal range between the two survey periods is 31cm.

3.3.2 Ocean current

1) Monitoring results from March 26 to 27, 2018: During spring tide, the current velocity at Sanya Estuary station (1#–3#) was low, while the current velocity at other stations was high. The maximum velocity of each layer in (1#) of Sanya River is about 16cm/s, and the maximum velocity of each layer is similar. The maximum velocity at station 2 is slightly lower than that at station 1. The maximum current velocity of 3# station on the northwest side of Phoenix Island is about 18cm/s, and the surface layer is slightly smaller than other layers. The maximum velocity of the 4# station in Haihai reached the maximum, while that of the 6# station was slightly smaller. The measured maximum velocity was 81.2cm/s, which occurred on the surface of the 4# station. The measured maximum ebb velocity is 54.0cm/s at the bottom of station 6#, and the measured maximum ebb velocity is 81.2cm/s at the surface of station 4#.

Comparative results:

- The survey showed that the maximum velocity of Koumenwai Station 2# was 31.5cm/s higher than that of station 1#; the maximum velocity of Waihai Station 6# reached the maximum, and the measured maximum velocity was as high as 109.1cm/s; the maximum velocity of Waihai Station 4# was 69.3cm/s, which was different from the survey results in 2018.

- (2) The measured maximum flow velocity of high tide is 98.9cm/s, which occurs in the middle layer of No. 6 station. The measured maximum ebb tide velocity is 109.1cm/s, which occurs at the surface layer of station 6#. The maximum ebb tide velocity at station 6# is larger than the survey results in 2018, and the ebb tide velocity at station 6# is larger than that at station 4#.

- The other conclusions above are basically consistent.

2) Monitoring results from March 26 to 27, 2018: In terms of the average tide time of each station, the average velocity of the surveyed sea area was between 7.1cm/s and 35.3cm/s during spring tide. The average flow velocity of all stations in Hanoi and Koumen was similar, and the flow velocity outside the mouth was slightly lower than that in Hanoi. The mean offshore velocity increases gradually. The average velocity in river and mouth is significantly lower than that in other sea areas. The average velocity of vertical lines at each station ranges from 7.3cm/s to 33.6cm/s. The average flow velocity of high tide in the surveyed area ranges from 6.3cm/s to 36.8cm/s, and the average flow velocity of low tide ranges from 8.5cm/s to 34.7cm/s. The average flow velocity of high tide is slightly lower than that of low tide at stations 1, 2 and 3 in the northwest of Hanoi. The average flow velocity of the middle tide was slightly higher than that of the low tide, while the lower tide was the opposite. At station 6#, the average flow velocity of rising tide at surface is slightly lower than that of falling tide, while the average flow velocity of rising tide and falling tide at middle level is the same.
In this survey, the average velocity of the sea area ranged from 5.3cm/s to 52.4cm/s, the average velocity of the vertical line of each station ranged from 6.6cm/s to 43.2cm/s, the average velocity of the high tide range from 4.5cm/s to 64.9cm/s, and the average velocity of the low tide ranged from 3.8cm/s to 56.2cm/s. Wider than the 2018 survey results; The variation of average ebb and flow velocity with depth at each station is different from the survey results in 2018.

3) Monitoring results from March 26 to 27, 2018: During spring tide, the current in the Sanya River and near Koumen (1#~3#) showed the characteristics of rotating current; The inner and outer seas of Sanya Bay (4#~6#) showed reciprocating flow characteristics, and the flow direction was northwest to southeast during the investigation period, basically parallel to the coastline.

Comparison results: The results of this survey are basically consistent with those of the 2018 survey.

4) Monitoring results from March 26 to 27, 2018: the trend direction of tidal current at different depths changed greatly at station # 3, while the trend direction of tidal current at other stations at different depths maintained a good consistency with little change. During the observation period at Station # 1, the trend direction of tidal current at each layer was mainly northwest and southeast. During the observation period of # 2 station, the tidal current of all layers was mainly in the Near east-west direction. During the observation period, the flow direction of layers 4#~6# is northwest to southeast, and the rising tidal current velocity is larger than that of falling tide. The velocity of each layer at stations 1# and 3# varied greatly and the direction was disorderly, while the velocity of each layer at other stations was relatively regular and the direction was stable.

Comparison results: The survey showed that the tidal current flow direction at stations 1# and 2# changed greatly at different depths, while the tidal current flow direction at other stations at different depths maintained a good consistency with little change. The tidal current near the mouth gate (Station 3#) mainly showed a northwest - southeast direction, sometimes a northeast - southwest direction, which was different from the monitoring results in 2018. During the observation period, the flow direction of each floor of Station 4 was basically manifested as a northwest - southeast direction, while the flow direction of each floor of station 5#~6# was basically manifested as a northwest - southeast direction, which was basically consistent with the monitoring results in 2018.

3.3.4 Hanging sand

1) Monitoring results from March 26 to 27, 2018: During spring tide, the maximum sediment content was 0.0265kg/m3, which occurred at station 1#. The minimum sediment content is 0.0025kg/m3, which is 3#. The average sediment content of each station and layer ranges from 0.0057kg/m3 to 0.0132kg/m3. The sediment content of the inner and outer sea areas of Sanya River is significantly higher than that of other sea areas. In the vertical direction, the sediment content of each station does not change with the depth.

Comparison results: The results of this survey showed that the maximum sediment content was 0.03273kg/m3, which appeared at station 1#. The minimum sediment content was 0.00108kg/m3, which appeared at station 3#. The maximum sediment content was larger than that of 2018, but the occurrence stations were the same. The average sediment content of each station and each layer was between 0.004719kg/m3 and 0.0265kg/m3, which occurred at station 1#. The minimum value of the average sediment content of each layer was smaller than that of 2018, and the maximum value was larger than that of 2018. Other conclusions were consistent with the monitoring results in 2018.

2) Monitoring results from March 26 to 27, 2018: (1) The maximum net sediment transport per single width in Sanya Bay during spring tide period was 2151kg/(m*d), which appeared at Station 4; The minimum net sediment transport per single width is 8kg/(m*d), which appears at station 1#, and the difference between the two is about 268 times. (2) The net sediment transport in single width gradually increases from the Hanoi to the shore outside the mouth, which is consistent with the distribution of current velocity characteristics. (3) Except for station No. 4, the net sediment transport in single width of other stations was small. (4) The single width net sediment transport direction of each station is basically consistent with the
main direction of other streams.

Comparison results: ②, ④ The conclusion is basically consistent with the survey results; Conclusion (1) The ratio of maximum to minimum net sediment transport in single width is about 268 times, which is significantly larger than the results of this survey. (3) Different from the results of this survey, the single width net sediment transport at 2# and 6# stations in this survey was significantly greater than that in 2018.

3.4 Analysis of differences

(1) Generally speaking, when the tidal range is large, the tidal current will be correspondingly large. The survey time is from April 21, 2022 to April 22, 2022, which belongs to the significant spring tide period. During the survey period, the highest measured tide level at Sanya Station is 145cm, 14cm higher than that at Sanya Station in 2018, and the tidal range is 31cm higher than that in 2018. The high tidal range may also be one of the reasons for the high current velocity.

(2) The tidal current may become very complicated due to the influence of coastal topography. The tidal current, velocity and flow direction at the channel, channel or bay mouth may vary greatly. During this survey, the demolition project of Phoenix Island Phase II was basically completed. C1 station is located in Hanoi and C2 station is located outside Koukou Gate, which may be sensitive to the surrounding terrain changes, so the current direction changes quickly and complicated.

(3) During this survey, according to the response of field investigators, there were frequent ships entering and leaving the C1 and C2 stations located in Hanoi and outside the entrance. Moreover, the water depth of these two stations was relatively shallow, and the sea area was greatly disturbed. The influence of external environment may also be one of the reasons for the rapid and complex changes in the direction direction of C1 and C2 stations.

(4) Single width net sediment transport is mainly affected by residual current size, suspended sediment content and station depth. Residual current size at C2 and C6 stations is larger than that in 2018, which may be the main reason for the larger single width net sediment transport at C2 and C6 stations than in 2018.

4. Conclusion

(1) After the demolition project of Phoenix Island Phase II was implemented, due to the weakening of the shield effect of Phoenix Island Phase II on southbound waves, the northwest coastal sand transport capacity was enhanced, resulting in the change of sand content at the surrounding stations of Phoenix Island Phase II.

(2) After the demolition of the second phase of Phoenix Island, the water exchange in Sanya Estuary and other surrounding sea areas tends to be frequent and smooth, and the effect of meteorological factors such as wind and pressure is more significant than before the demolition, thus having a certain impact on the current field in the surrounding sea areas.

(3) This tidal range is significantly larger than that before the demolition, which may be related to the fluctuation of tidal flux in the surrounding sea area, especially at the junction of Haihe River, after the demolition of Phoenix Island Phase II in addition to the astronomical tidal factor.

References


