Warning Water Level Determination for Luchaogang of Shanghai

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Abstract. Based on “specification for warning water level determination” (GB/T17838-2011), long-term tidal data at Luchaogang are used to determine warning water level along the Luchaogang Coast. The influence of Seawall defense standards, the social and economic situation behind the dikes, and historical storm surge disasters are also taken into account to calculate the warning water level. Four levels, Red, Orange, Yellow and Blue, of warning water level are obtained with the value of 5.40m, 5.13 m, 4.87 m and 4.60m, respectively. The results are verified against the observed daily high water levels in 1977-2010. It reveals that the extreme water levels occurs mostly during typhoon period.

Introduction

Warning water level (WWL) is the water level reaching the particular level around which coastal flooding or disaster may occur [1]. At this moment, coastal authorities need to enter a state of alert and disaster relief. Thus, to investigate the WWL is one of the fundamental tasks to set up Marine disaster prevention and mitigation forecast system. It is important to support flood control department to make judgment of flood or danger and to report an alert in time. Therefore, it is necessary to determine the WWL along coasts to provide a scientific basis for decision-making of disaster prevention and reduction.

In this study, the Luchaogang coast (see figure 1 for the location) is selected as the study area to determine the WWL. Luchaogang is Shanghai’s famous fishing port and border region. Its surrounding inland coastal areas have Lingang town, Donghai Bridge and Yangshan Deep-water Port, Pudong Airport and other major production, living and service function, as is high representative for coastal area. Data, including water levels, wave parameters, social and economic situation, around Luchaogang are used to determine the WWL for the coast.
Data and Method

Tidal Water Levels and Wave

The yearly highest water level data at Luchaogang from 1977 to 2010 are collected to determine to design high water levels with different return period. The hourly water level data at this station in 2010 also used to analyze and get acquainted with the tidal characteristics. Table 1 lists the tidal water level characteristics at Luchaogang. From Table 1 we can observe that the highest water level occurred in this area is about 5.22m (Wusong Datum) during typhoon Sinlaku period in 2002. The mean tidal range is about 3.28m and with the maximum of about 5.55m.

Table 1. Tidal characteristics at Luchaogang [2].

<table>
<thead>
<tr>
<th>Items</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum tidal range</td>
<td>5.55 m</td>
</tr>
<tr>
<td>Mean tidal range</td>
<td>3.28 m</td>
</tr>
<tr>
<td>Highest high water level</td>
<td>5.22 m</td>
</tr>
<tr>
<td>Lowest low water level</td>
<td>-0.88 m</td>
</tr>
<tr>
<td>Mean sea level</td>
<td>2.02 m</td>
</tr>
</tbody>
</table>

The wave observation data at Dajishan station (see figure 1 for location) are collected to get the wave characteristics around this area. The design wave parameters [3] along the coast are also used for further correction of WWL.
Site Situation Behind the Coastal Defense

There are important port area of Shanghai Port, Pudong International Airport, large manufactory and Lingang city behind the defense of the Luchaogang coast. The height of the sea wall in the study area is 9.07m. The design standard of the sea defense can survive under extreme high water level once in 100 or 200 years. Therefore, this area is defined as particular important coast.

WWL calculation Method

The design high water level is determined by static analysis. The Pearson-III type empirical curve is used to obtain the high water level with different return years.

According to “specification for warning water level determination”(GB/T17838-2011), the WWL can be calculated as follows,

Blue WWL \[ H_b = H_s + \Delta h_b. \]  \( (1) \)

Yellow WWL \[ H_b = H_b + (H_r - H_b)/3. \]  \( (2) \)

Orange WWL \[ H_o = H_b + 2(H_r - H_b)/3. \]  \( (3) \)

Red WWL \[ H_r = H_d + \Delta h_r. \]  \( (4) \)

In which, \( H_s \) is the high water level with return period of 2~5years. \( H_d \) is the lowest high water level along the study coast. \( \Delta h_b \) or \( \Delta h_r \) is the correction value which is related to the nature condition, the design standard and the social & economy behind the dikes. Normally \( \Delta h \) equals to the sum of \( h_1, h_2 \) and \( h_3 \). \( h_1 \) is correction value calculated by the wave condition in front of the defense. \( h_2 \) and \( h_3 \) are the correction value related to the standard of the defense and the importance behind the defense.

Result

High Water Levels

Based on the data series of yearly highest water at Luchaogang, the high water level with different return period is determined by Pearson-III type empirical curve, see table 2 [3].

<table>
<thead>
<tr>
<th>Return period (year)</th>
<th>2</th>
<th>3</th>
<th>5</th>
<th>10</th>
<th>100</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level</td>
<td>4.72</td>
<td>4.80</td>
<td>4.97</td>
<td>5.15</td>
<td>5.70</td>
<td>5.87</td>
</tr>
</tbody>
</table>

Wave Run-up

The largest wave height occurs in SE direction [3]. The wave run-up along Luchaogang coast is listed in table 3 [3]. In table 2 \( R_{2\%} \) and \( R_{13\%} \) are wave run-ups calculated based on \( H_{2\%} \) and \( H_{13\%} \) with respect to situation of overtopping and non-overtopping of the dike crest.
As the lowest standard of the sea defense in the study area is against high water level once in 100 years. Therefore, the return period of 3 years for $H_s$ can be determined according to the specification. Thus, $H_s$ is equal to 4.8m. The range of wave run-up in the study area is about 1.81-2.76 m according to table 3. The mean run-up value of 2.00m is used. Then $h_1$ is about -0.30m, which accounts for -15% of the run-up. The difference between the sea wall height and $H_s$ is in an order of 4.30m, as can be regarded as well protection facilities. The value of 0.20m can be determined for $h_2$. Because the protection area is extreme valuable, -0.10m is used for $h_3$. Consequently, Blue WWL can be calculated as Eq. (1), $H_b=4.80+(-0.30+0.20-0.10)=4.60$ m.

When the Red WWL is taken into account, the value of 5.70m is used for $H_d$ due to the lowest design standard of high water level once in 100 years. Similarly, values of -0.40m, 0.20m and -0.10m can be determined for $h_1$, $h_2$ and $h_3$, respectively. Then the Red WWL can be calculated based on Eq. (4), $H_r=5.70+(-0.40+0.20-0.10)=5.40$ m.

The Yellow and Orange WWLs are about 4.87m and 5.13m.

### Verification of WWL

The obtained WWLs are verified against the observed water level at Luchaogang. The occurrence of water level higher than WWLs in 1977-2010 are counted in table 4.

From table 4 we can find that the occurrence of water level higher than the Red WWL is only one time. It happened during typhoon 9711 (Winnie) period with the water level of 5.68m. During that period typhoon, spring tide and heavy rain fall influence Shanghai at the same time. The extreme situation caused tremendous loss of properties of the city. There are four times that water level higher than Blue WWL. They happened during typhoon 0608 (Saomai) and 0813 (Sinlaku) periods. They also caused larger loss to Shanghai city. The water levels higher than Yellow WWL mostly occurred during typhoon 9417 (Fred), 9608(Heb) and 0417 (Chaba) periods. These typhoons also influence Shanghai city, but they affected slightly. There are 19 times of water levels higher than Blue WWL in 2010. These are caused by the influence of three typhoons and 5 storms. When water level was higher than Blue WWL, there was no hazard occurred. And it was only in the state of alert. In conclusion, the WWL determined in this study is proper for Luchaogang area.

### Conclusion and Future Work

In this study the WWLs at Luchaogang are determined based on the analysis on hydrodynamics, coastal defense, social & economic situation and historical tidal disasters. Four different level of WWL are determined. The Blue WWL indicates water level is high and need to report for alert. The Red WWL means the water level is too high that counter measure should be implied for disaster reduction. The situations for Yellow and Orange WWL is in-between. Four WWLs are about 4.60m,
4.87m, 5.13m and 5.40m for Blue, Yellow, Orange and Red, respectively. The water level higher than the WWLs occurs mostly during typhoon period.

The WWLs should be kept update with the change of the circumstance. Normally it should be recalculated for every 5 years. According the specification, return period of 2 years for wave run-up correction is used both for Blue and Red WWLs. However, the extreme situation happened mostly accompanied with large wind and waves. Therefore, the return period of wave run-up correction should be carefully selected in the future study.

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Reference