Research on Hydrodynamic Force Enhancement and Water Environment Protection Measures of Dachan Bay, Shenzhen

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ABSTRACT: With the research purpose of protection of water environmental quality in Dachan Bay Area in Shenzhen City, especially in National Development Zone in Qianhai Area, this paper establishes a horizontal two-dimensional water quality model of Dachan Bay and its branches by the use of WQ Module of Delft 3D. And this paper respectively simulates distribution of water quality in full high flow year, normal flow year and low flow year before and after the implementation of protection measures, predicts the effect of the water environment protection measures and focuses on the analysis of two kinds of hydrodynamic force enhancement patterns, that is, “water replenishing in dead zones” and “pollution discharge at back doors”, and finally recommends water environment protection measures with the core of “pollution discharge at back gates” by taking full advantage of natural dynamic, thus obtaining a better effect than that of the traditional “water replenishing in dead zones”.

Keywords: water environment protection; hydrodynamic force enhancement; water quality modeling; Dachan Bay

1 INTRODUCTION

Dachan Bay is an important part of the east coast of Lingdingyang Bay.

Figure 1. Watershed system map

It's located at the bay mouth which lies to the southeast of Fanshi Waterway of the Pearl River Es-

tuary, to the south of Shenzhen Airport and to the north of Shenzhen Mawan Port Area. The east side and north side of Dachan Bay Area are close to the downtown of Bao'an District; the west side of it is a newly-developed port area which is a reclamation filled and formed by Dachan Island and Xiaochan Island; the southeast side of it is close to the downtown area of Nanshan District, where Qianhai Area exactly located at (as shown in the blue part of Figure 1). On August 26, 2010, the State Council approved to build Qianhai Area as an “Innovation Cooperation Demonstration Zone in Modern Service Industry of Hong Kong–Guangdong”. Qianhai Area will become an important node in the construction of world-class metropolitan district in Guangdong–Hong Kong–Macao, an important platform to achieve Guangdong–Hong Kong–Macao cooperation countries' strategies, and a new center for Shenzhen to play a leading and exploratory role [1]. The basin area of Dachan Bay is nearly 70km². The land area of the cooperation zone in Qianhai Area is 14.92km², accounting for 21% of the basin area of Dachan Bay. Its water environment is mainly affected by the upstream basin at Dachan Bay. “Water” issues of Qianhai Area must be researched and solved in the whole basin. The water system of the basin area at Dachan Bay is shown in Figure 1 [2].

2 ANALYSIS OF WATER ENVIRONMENT STATUS AT DACHAN BAY

According to the requirements of *Overall Plan of Shenzhen–Hong Kong Cooperation Zone in Modern Service Industries of Qianhai Area—Research on*

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Table 1. Actual measurements of water quality at Dachan Bay Area and its tributaries (Unit: mg / L)

Location	DO	COD	BOD ₅	NH ₃ -N	TP	Reactive phosphate	TN	Inorganic nitrogen	Salinity
Xixiang Estuary	1.4	369	138	6.7	0.97	0.48	8.29	7.16	6.0‰
Xinzhen Estuary	<0.2	156.5	56.5	12.6	1.55	1.02	13.56	12.65	0.5‰
Shuangjie Estuary	0.32	120.5	30	11.94	1.5	1.24	12.95	11.98	2.0‰
Bay Center	6.35	2.66	14	1.64	0.24	0.21	3.95	2.45	9.0‰
Bay Mouth	5.58	1.95	8	1.67	0.23	0.08	3.86	2.63	9.0‰
Surface Water (V-class Standard) ^[4]	2	40	10	2	0.4	/	2	/	/
Seawater (IV-class Standard) ^[5]	3	5	5	/	/	0.045	/	0.5	/

Water System, the tributaries of Dachan Bay should reach the Surface Water V-class Standard, and the water quality of Bay Area should reach Seawater IV-class Standard. However, viewing from the situation of water environment monitoring at Dachan Bay and its tributaries, the current situation of water environment at Dachan Bay is relatively bad, which is specifically embodied in the following aspects:

(1) The upstream is an old urban area with typical features of confluence of rainwater and sewage characteristic

Dachan Bay Area undertakes the dewatering tasks in upstream Nanshan and a part of old urban area of Bao'an. The current situation is that the population in upstream old urban area is dense. Due to delay in the construction of public facilities, the confluence of rainwater and sewage is severe, and the reconstruction is considerably difficult.

For Bao'an District, the existing drainage system is mainly the confluence of rainwater and sewage. A part of streets are constructed with main drainage pipes according to the distributary systems. However, the connected branches are relatively disordered, which are usually mixed connected with rain pipe and sewage pipe. According to the existing statistics, the current rainwater and sewage separation rate in Bao'an District is about 25%. For Nanshan District, it has formed a relatively complete rainwater and sewage system. The coverage rate of municipal drainage network is more than 85%, but the rainwater and sewage separation rate is not high. According to existing statistics, the current rainwater and sewage separation rate is about 55%. ^[3]

(2) Water quality is poor in Dachan Bay Area and its tributaries

The water quality is very poor in Dachan Bay Area and its tributaries ^[4]. The actual measurements of water quality in the bay area and its tributaries are shown in Table 1.

As can be seen from the table 1, the water quality at the Bay Mouth of Xixiang Estuary and Xinzhen Estuary is far worse than that of the Surface Water (V-class Standard). For the water quality at bay center and bay mouth, BOD, reactive phosphate, inorganic

nitrogen and other indicators are far worse than that of Seawater (IV-class Standard).

(3) Dachan Bay belongs to a semi-closed bay with weak tidal dynamic and poor water exchange capacity ^[5]

Dachan Bay itself belongs to a semi-closed bay with poor water exchange capacity. Moreover, affected by the irregular semi-diurnal tide at the Pearl River Estuary, water flows back and forth in bay, and hydrodynamic force is further weakened. In particular, the annular water corridor at the bay tip of Dachan Bay and Qianhai Planning water system is a pollution accumulation area with the weakest hydrodynamic force.

(4) Deposit is severe in Dachan Bay Area, seriously affecting the water quality.

The deposit is severe in Dachan Bay Area ^[6]. When tide falling, the sludge at bay mouth exposes, which affects the landscape of bay area. What's more, it is also an important endogenous factor to cause poor water quality in the bay area.

3 WATER ENVIRONMENT PROTECTION PROGRAMS AT DACHAN BAY

In view of "disordered upstream, dirty bay area, weak force and more deposit" at Dachan Bay, based on the previous research on the flood control and drainage program ^[6], an overall program of water quality protection is proposed from the following five aspects.

(1) Improvement of the pollution interception system: for Nanshan District, the closure of sewage in upstream riverway in a dry season and the first (light) rain in a rainy season can be transported to Nanshan Sewage Treatment Plant by the use of the annular pollution interception culvert in Qianhai Area, so as to discharge into a deep sea after treatment. For Bao'an District, the closure of sewage in upstream riverway in a dry season and the first (light) rain in a rainy season can be transported to a Sewage Treatment Plant by the use of the newly developed annular waterway in Bao'an District, so as to discharge after treatment. Finally, 100% of sewage is intercepted during dry

season, while the first (light) rain is intercepted during rainy season.

(2) Reconstruction of rainwater and sewage distribution: Through the construction of rainwater and sewage distribution and the radical reform and reconstruction in Bao'an District and Nanshan District, we can achieve a goal of rainwater and sewage separation at the periphery of the cooperation zone in Qianhai Area and upstream basin.

(3) Enhancement of hydrodynamic force: Hydrodynamic enhancement can be achieved through hydrodynamic improvement project of Qianhai Bay.

(4) Re-use of recycled water: Through implementing the upgrading and reconstruction project for the sewage treatment plant, increasing the riverway water replenishing during dry season and maintaining the ecological basic flow, especially in Qianhai Area, we can improve the water quality of the corridor water replenishing of Nanshan Sewage Treatment Plant's tail water through the constructed wetlands and pump station engineering.

(5) Sediment and desilting in bay area: Through the desilting project in Qianhai Bay Area, we can achieve the reduction of endogenous pollution in bay area.

The layout of an overall program of its water environment protection engineering is shown in Figure 2:

Figure 2. Layout of an overall program of basin water environment protection engineering

4 HYDRODYNAMIC FORCE ENHANCEMENT SCHEME COMPARISON

The scheme implementation of water environment

protection at Dachan Bay can greatly improve water environment in Dachan Bay Area, especially in Qianhai Area, which not only controls over release of sediment pollution in the bay area, but also cuts down more than 90% of the bay load. However, during heavy rainy season, there are still pollutants into the bay, which form pollution accumulation in the bay tip area, the offshore water of Bao'an District and the partial region of Qianhai Area and other locations with weaker hydrodynamic force. How to quickly restore the water quality is still the focus of this research.

According to the actual situation, there are two main ways to restore the water quality. One is the water replenishing in a dead zone [7]: It's a method mainly by using the pump stations and other engineering measures and pumping water from the Lingdingyang Bay to the bay tip area or other areas which are with weaker hydrodynamic force to promote the water exchange and strengthen the hydrodynamic force, so as to timely exchange and scatter pollutants, and finally ensure the water environment. The other one is "pollution discharge at back gates": This is a method which mainly utilizes the natural tidal dynamics. When the tide rises, it is used to open gates between the area with weaker hydrodynamic force and the adjacent pollution interception system, then push the sewage into the sewage interception system, and finally treat the sewage in the sewage treatment plant or discharge it into the Lingdingyang Bay through other channels.

In order to compare these two working conditions, we establish the observation points as shown in Figure 3. The observation points are located at the bay tip area with a weaker hydrodynamic force (W1-W3), the offshore water of Bao'an District (W4), and the annular corridor of Qianhai Area (the upper ring and the bottom ring). The water exchange capacity of each observation point is expressed by the half-exchange cycle. When the water replenishing and the water pumping are 10m³/s, the results are shown in Table 2.

Figure 3. Layout of measuring points

Table 2. Statistical table of half-exchange cycle of two kinds of hydrodynamic force enhancement measures (Unit: d)

Location	Point No.	Status	Water replenishing in dead zones	Pollution discharge at back gates
Bay tip area	w1	9.63	0.58	0.70
	w2	4.71	0.79	0.73
	w3	3.38	0.79	0.75
	w4	2.92	0.71	0.64
Longitudinal corridor	Super ring	17.13	17.13	4.21
	Bottom ring	10.51	10.51	8.02

As can be seen from the table, compared with the water replenishing in dead zones, the effect of pollution discharge at back gates is better. Under the same scale, for the working conditions of pollution discharge at back gates, only the half-exchange cycle in local area of the bay tip area is slightly longer than that of the environment water replenishing, but the half-exchange cycle in other areas is shorter than that of the environment water replenishing. Especially for the longitudinal corridor, the effect of pollution discharge at back gates is remarkable.

5 EFFECT ANALYSIS

Water quality modeling is carried out by the use of WQ Module of Delft 3D. According to different water exchange modes, the annual changing process of pollutant content under the present working condition, the working condition of water replenishing in dead zones and the working condition of pollution discharge at back gates is respectively calculated under different conditions of typical year (the high flow year, the normal flow year and the low flow year). Wherein all hydrodynamic boundaries are measured value; upstream boundary is the measured bay review of each river in different typical years. The pollutant load in the downstream boundary sea area is zero. The initial filed is obtained through remote sensing analysis comparison with measured values. According to the calculation results, we divide the entire bay area into the bay mouth area, bay center area, offshore water of Bao'an District, offshore water of Qianhai Area, bay tip area, transverse corridor of Qianhai Area, and annular corridor of Qianhai Area. We take the corresponding measuring points with the water quality goal of seawater (IV-class Standard), and respectively calculate the number of days of standard-exceeding of each pollutant and the number of days of comprehensive standard-exceeding.

The layout of measuring points is shown in Figure 4, and the results are shown in Table 3.

As can be seen from the Table 3: In each pollutant, the pollution of the inorganic nitrogen is most serious with the most number of days of standard exceeding, followed by the reactive phosphate; the number of

days of standard exceeding is the most in the high flow year, the least in the low flow year and normal in the normal flow year; water environment is very bad under current conditions. After implementation of two kinds of water quality protection program, the number of days of standard exceeding significantly reduces. Compared with these two kinds of water exchange mode, the mode of pollution discharge at back gates is slightly better.

Figure 4. Layout plan of water quality statistical points

6 CONCLUSION

Considering from the actual situation of Dachan Bay, a comprehensive plan of water environment production with the core of pollution discharge at back gates is proposed by taking full advantage of the natural tidal power and the existing interception system. Compared with the mode of pollution discharge at back gates and common water replenishing in dead zones, it not only reduces the construction of pump stations from the project, but also achieves better results, thereby proposing a new idea for water environment protection program of the semi-enclosed bay.

Table 3. Statistics of the number of days of standard-exceeding of water quality in each program (Unit: mg / L)

Program	Location	Project											
		COD			Inorganic nitrogen			Reactive phosphate			Total		
		High flow year	Normal flow year	Low flow year	High flow year	Normal flow year	Low flow year	High flow year	Normal flow year	Low flow year	High flow year	Normal flow year	Low flow year
Status	1	0.2	0.0	0.0	3.2	2.0	0.0	1.1	0.7	0.0	3.2	2.0	0.0
	2	1.1	0.8	0.0	5.0	3.9	0.9	2.5	1.3	0.0	5.0	3.9	0.9
	3	3.0	1.1	0.0	8.5	6.7	3.1	4.7	2.9	0.0	8.5	6.7	3.1
	4	8.0	3.6	2.1	39.2	37.2	19.2	13.0	12.8	6.0	39.2	37.2	19.2
	5	4.5	4.2	3.4	200.1	151.2	100.2	22.3	18.1	10.2	200.1	151.2	100.2
	6	4.3	2.2	0.8	10.2	8.7	5.3	7.1	4.0	1.2	10.2	8.7	5.3
	7	4.9	4.4	4.0	209.7	155.3	105.8	30.4	24.1	12.9	209.7	155.3	105.8
Water replenishing	1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	2	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0
	3	0.0	0.0	0.0	2.1	1.7	0.0	0.0	0.0	0.0	2.1	1.7	0.0
	4	2.0	0.9	0.0	9.8	9.3	4.8	3.3	3.2	0.8	9.8	9.3	4.8
	5	1.1	0.0	0.0	52.5	37.8	1.5	5.6	0.8	0.0	52.5	37.8	1.5
	6	2.3	1.5	0.0	3.6	2.3	0.0	0.0	0.0	0.0	3.6	2.3	0.0
	7	2.3	0.0	0.0	55.2	42.3	5.9	6.1	2.5	0.0	55.2	42.3	5.9
Open back gate	1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	2	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
	3	0.0	0.0	0.0	1.8	1.4	0.0	0.0	0.0	0.0	1.8	1.4	0.0
	4	1.6	0.8	0.0	8.1	7.9	4.0	2.8	2.7	0.6	8.1	7.9	4.0
	5	0.9	0.0	0.0	42.7	31.2	1.2	4.5	0.7	0.0	42.7	31.2	1.2
	6	1.2	0.0	0.0	3.1	2.0	0.0	0.0	0.0	0.0	3.1	2.0	0.0
	7	1.0	0.0	0.0	32.2	26.0	3.2	2.3	1.5	0.0	32.2	26.0	3.2

Note: the area code in Table respectively represents: 1. Bay Mouth Area; 2. Bay Center Area; 3. Offshore Water of Bao'an District; 4. Offshore Water of Qianhai Area; 5. Bay Tip Area; 6. Transverse Corridor of Qianhai Area; 7. Annular Corridor of Qianhai Area (as shown in Figure 4).

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