Quantitative assessment of water system design for Shenzhen New Marine City

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1.Introduction

Shenzhen New Marine City (SZNMC) is located at the left bank of the Pearl River estuary, right at the center of Guangdong-Hong Kong-Macao Greater Bay Area and Guangzhou-Shenzhen-Hong Kong Economic Belt (Figure 1, Left panel). Due to its unique geographical position, the Shenzhen Municipal Government (SZMG) considers the SZNMC as a new strategic hub to enhance the economic capacity, long-term competitiveness and sustainable development of Shenzhen.

In 2018, the Shenzhen Municipal Government organized an international Shenzhen New Marine City Urban Design Completion to seek ideas in developing the SZNMC into a marine city which is a water resilient, attractive, "future oriented", coastal city coping with environment, human society, economic and cultural development. It would be a demonstration of a new city design for the future, supporting the ambition of Shenzhen in blue economy development.

Deltares teamed up with the NL Urban Solutions and proposed a design based on a Dutch polder concept. The design principles include integrated design of land/water/sea, integrated design for both industry development and residence zone, with global and open visions. The design was awarded position 4 with other 2 designs, out of more than 100 design proposals from all over the world.

Although the sponge city and environment friendly design concept gained increasing awareness and acceptance, hardly any design and urban planning results had been quantitively assessed in terms of hydrological and environmental aspects.

This paper describes this innovative, award-winning design approaches in brief and highlights a quantitative assessment approach.

2. Material and Methodology

Our design for the SZNMC is the "polder" concept. A polder is a hydrologically separated area from the surrounding area, where both inland surface water level and ground water level can be controlled independent to the conditions of the surroundings. In a saline estuarine environment like SZNMC, proper control of groundwater levels is crucial for a healthy green environment within the reclaimed area. This can avoid a new reclaimed area in suffering from dry period when the ground water level dropped too low, as in the case of Singapore airport.

In the SZNMC, 9 highly polluted rivers enter the design area and need to discharge to the Pearl River Estuary (Figure 1). To assure good water quality in the New Marine City area, we propose to separate the inner water system from the entire water system, thus creating a "polder" system. To achieve this, a chain of model suites is developed to quantify the hydrological condition of the area.

(1) Firstly, a catchment model is set up to estimate possible runoff and peak flow from the whole catchment area.

(2) Secondly, an intercepting river on the north boundary to collect the runoffs from upstream to avoid possible pollution water from the catchment. To design and verify the design of river section, a Delft3D hydrodynamic model is set up to simulate peak velocity, water level, flow direction in the river. The model simulates the impacts of extreme flood conditions as derived from the catchment model in (1). At the upstream and downstream where the incepting river connected with the Pearl River, we use the tidal level difference extracted from a larger scale Pearl River Estuary model (which is an existing Delft3D model from HKEPD, PRE model).

(3) Thirdly, to design a proper leveling system, a water balance model is set up.

(4) Fourthly, within the polder area, an inland hydrology/hydrodynamic model is set up using the Delft3d Flexible Mesh model. Based on model simulations, water level on the streets (during/shortly after the heavy rainfall) and water level in the surface water channels, flow velocities, operation of hydraulic structures, operation of 2 pumping stations, which connects the internal and external water system, are controlled in real time to guarantee that the closed "polder" can have its own fresh water system, fully controlled in quality and quantity. Adequate water circulation inside the polder is maintained to avoid stagnancy, required flow velocity is maintained to eliminate dead ends, to ensure a good water quality, and to avoid mosquitos breeding.

(5) Fifthly, from outer sea, a wave model is used to provide wave conditions in front of the outer bank of the polder.

(6) Sixthly, a cross-shore XBeach profile model is applied to estimate stability of the outer bank and foreshore as caused by wave run up, using the boundary from the large scale wave model in (5).

3. Results

Results from the chain of modelling support our final design. The overall flow direction in this design is shown in Figure 1 A.

(1) The catchment model results show that, given the total areas (42 hectares) that drains to the channel following a precipitation of 80mm/hour, the peak discharge from the nine rivers are about 1,000 m^3/s in total (Figure 1 B).

(2) The inception river modelling shows that the peak flow velocity is less than 1m/s, given the tidal boundary conditions from the PRE model and considering the river inflow from the hydrology model. Thus it is safe to use this inception river to avoid potential pollution from upstream, especially during extreme rainfall events (Figure 1 C).

(3) The water balance model gives a proper design in leveling of foundation inside the polder (4 to 4.5 meter) and outer bank are defined (8 meter) (Figure 1 E-E' cross section). This will enhance the living quality by set the land platform closer to water surface, and results to have more water front areas.

(4) With a design area of 121.4 hectares, monthly average rainfall and evaporation (1,955mm/year participation, 1,200mm/year evaporation), water depth and required drainage capacity are computed (Figure 1 D, a water balance model calculation).

Water level inside the area is constant. water level fluctuations are designed to 1 meter maximal. The water supply is sufficient for internal use and can even be a drinking water supply for the outside area abstractions. In addition, fully controlled water quantity and quality management helps to avoid drought and deals with maintaining water quality(Figure 1 E-E' cross section).

(5) Regarding safety from extreme coastal storms (with 2-5 meters wave height at outer sea), the calculated wave heights only raise 0.2-0.4 meter in front of the outer bank the New Marine City. An Xbeach profile model shows that a mature mangrove belt could deduct 66% wave height (see Figure 1 F-F'), given the boundary condition from the large-scale wave model.

(6) We have combined nature, housing and economic developments in a nature inclusive design and create a dynamic and vibrant city. Using the model train to assess urban design quantitatively will give the designers more confidence and will support the final design of the New Marine City (Figure 1).

This paper gives a short overview of an innovative, award-winning design for Shenzhen New Marine City and highlights the approach, using a chain of numerical models. The quantitatively assessed results help designers to make a hydrological and environmental sound decisions in their design and the New Marine City will be a water resilient, eco-friendly city.

References

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Figure 1 Final design of the Shenzhen New Marine City with quantitative assessment