Study on target zoning and value of annual runoff total control in Sanya sponge city

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Abstract. In order to repair the ecological environment of Sanya City, serve the construction of a sponge city in the location, and increase the core competitiveness of tourist cities, this paper, based on the compilation of the special plan for Sanya’s sponge city, uses the target decomposition three-level method to conduct target zoning research on the annual runoff total control rate. It analyzes the values and restrictions of the target decomposition of the sponge city construction area and zoning. The results show that, influenced by natural geographical and climatic conditions and urban construction, the annual runoff total control rate of construction in Sanya sponge city is 60%, and the corresponding design rainfall is 25.30mm. Decomposing the current situation and planning of construction land in the block, it can be concluded that the annual runoff control rate in Yuechuan area is 87%, which exceeds the total runoff control target set in the Guidelines. The runoff control rate in the Donghe area is 46.61% to 80%, and the runoff control rate in the Xihe area is the lowest at 46.78% to 56.86%. The research results are expected to provide the scientific basis for the construction of Sanya sponge city.

Key words: Sponge City; Total Runoff Control Target; Regionalism; Value Decomposition; Sanya City

1. Introduction

The acceleration of urbanization and global climate change have led to waterlogging problems in many domestic cities. Urbanization causes surface hardening and changes the underlying hydrological characteristics of the original area fundamentally. It is a man-made factor resulting in urban waterlogging and can be controlled through sponge city construction. In 2014, the Ministry of Housing and Construction issued the “Technical Guidelines for the Construction of Sponge City-Construction of Rainwater System for Low Impact Development (for Trial Implementation)” (hereinafter referred to as the Guidelines) and proposed the control target requirements for the construction of a sponge city. In October 2015, the general office of the State Council issued the “Guiding Opinions on Promoting the Construction of Sponge City”, requiring all cities to carry out the construction of a sponge city according to the medium-term and long-term targets. These were to be realized by 2030, in order that more than 80% of the urban built-up areas would meet the target requirements. The annual total runoff control rate is the core index of sponge city planning and construction. It plays an important guiding role in the construction and implementation of a sponge city. The Guidelines point out that the control
objectives of sponge city construction include annual total runoff, peak flow, non-point source pollution and rainwater resource utilization. The primary control objective is annual total runoff, and the other three control objectives can be partially achieved through annual total runoff control objectives.

With the promotion of sponge city construction, many experts and engineering technicians have carried out research on the target zoning and values of annual runoff total control in sponge cities based on their actual construction.[1-3] Chen Xiaolong et al.[4] used the Monte Carlo stochastic algorithm to calculate the layout scale and intensity scheme of large-scale plot-level facilities, and obtained a feasible scheme meeting the constraints of the overall goal of sponge city construction. Liu Junjie et al.[5] used the main design parameters to quantitatively analyze the benefits of a sunken greenbelt sponge city in a certain area of Shanghai. It is believed that when the effective water storage depth of a sunken greenbelt is 0.6m, the annual total runoff control rate is about 91.5%. Zhang Cheqiong[6] focused on the regional differences and adopted the multi-factor weight comprehensive scoring method to comprehensively evaluate the suitability of sponge city construction in different regions. This research put forward the target total annual runoff control rate with different plots. Su Zhenyu and others[7] adopted the top-down method to decompose and study the total annual runoff control targets in different urban areas during the construction of a sponge city, based on the survey results of land use, soil and groundwater in the Kunming urban area. They put forward the total annual runoff control scheme for the construction of a sponge city in Kunming. Miao Wei et al.[8] studied the annual runoff total control rate in the central urban area of Shenyang and determined the rate applicable to the location.

The annual runoff control rate target runs through the whole process of a sponge city and is the core index for the construction of a sponge city, which needs scientific and reasonable research and determination. Therefore, combined with the preparation of the special plan for the Sanya sponge city, this paper investigated the total annual runoff control rate. Starting from the annual runoff control rate target for sponge city construction in Sanya, the three-level target decomposition method[9] was used to decompose the urban construction area. The values of the target decomposition for a sponge city construction area and sub-areas were analyzed, and the limiting conditions of the values discussed. This research was undertaken in order to provide a scientific basis for the construction of a sponge city in Sanya.

2. General situation of the Sanya sponge construction area
Sanya[10] is located at the southernmost tip of Hainan (latitude 18°09’ ~ 18°37’north, longitude 108°56’ ~ 109°48’east). It is the central city and transportation hub in the southern part of Hainan Province, and is also one of the most important ports for foreign trade on China’s southeast coast. Sanya has a total land area of 1,919.58km², a total sea area of 6,000km², and a planned area of 37km², with a permanent population of 8,216,000 in 2018. The terrain is high in the north and low in the south, with high mountains and rolling hills in the north and an east-west distribution on the coastal bank of the southern plain. The rivers in the region have formed three relatively independent natural water systems in the east, center, and west according to the topography. It belongs to the tropical marine monsoon climate, with high temperatures and heavy rain, frequent typhoons, clear rain and drought, and insufficient water resources. The sponge construction area is in the fan-shaped area where the East River and the West River of Sanya meet. It is the most important coastal second-line hinterland in Sanya city and the important supporting hinterland of Daya Bay’s “Beautiful Restaurant”. The red area in Figure 1 is the Sanya sponge construction planning area.

3. Research Methods

3.1. Three-level Method of Target Decomposition[9]
Some text. The purpose of the study was to decompose the total annual runoff control target into specific plots. Low Impact Development (LID) measures are closely related to soil and groundwater,
and hydrological grouping of soil plays a decisive role in the infiltration capacity of rainwater runoff.[11] It is difficult to analyze the hydrological grouping of soil in an actual construction, so in an actual calculation, the hydrological grouping of generalized soil is divided into four layers of land-use forms of different scales. These are the basin or region, drainage subsystem, block and road, parcel and road section.[12] Then, the three-level method of target decomposition is adopted to design the target of annual runoff total control rate for these four layers of land. According to the land use attribute and construction classification, considering the feasibility and demand, the plots are classified, and the target of annual runoff total control rate for each type of plot is artificially assigned. The Schematic diagram of target decomposition three-level method is shown in the Figure 2.

![Figure 1. Location relationship diagram.](image)

![Figure 2. Schematic diagram of target decomposition three-level method.](image)
4. Results and Discussion

4.1. Target Zoning of Annual Runoff Total Control in China

In order to better guide each region to reasonably determine the total amount of runoff control target, the mainland region of the country is roughly divided into five regions (as shown in figure 3), according to the statistical results of rainfall in each city and the relationship between the corresponding annual total amount of runoff control rate and the designed rainfall. Each region should refer to this limit and determine the total amount of runoff control target in the region according to local conditions. The details are[13]: region I (85% ≤ α ≤ 90%), region II (80% ≤ α ≤ 85%), region III (75% ≤ α ≤ 85%), region IV (70% ≤ α ≤ 85%), and region V (60% ≤ α ≤ 85%) (α is the annual total runoff control rate).

![Figure 3. National annual total runoff control target zoning map.](image)

4.2. Zoning of Annual Runoff Total Control in Sanya Sponge City

4.2.1. Sanya Runoff Control Target. Following the LID design principle, the annual runoff total control rate proposed in the Guidelines was used to calculate the designed rainfall, deducting the daily rainfall less than or equal to 2mm, and then the rainfall data with daily rainfall above 2mm was deducted from small to smaller. The data was sorted into ascending order, which was denoted as P1, P2, ..., Pn, and then the annual runoff total control rate corresponding to each daily rainfall data was calculated. Consequently, the corresponding relationship between the daily rainfall and the annual runoff total control rate is obtained. A map was drawn, and finally the regional map of the total annual runoff control rate of China’s sponge city and the statistical analysis was combined to calculate the precipitation data of Sanya City in the past 30 years (1985-2016). This determined that the total annual runoff control rate of Sanya City is 60%. The corresponding design precipitation is 25.30mm (as shown in figure 4). At the same time, based on the current situation of runoff, the functional division of the sponge city construction area was determined based on the soil hydrology grouping, and the overall goal of each district can be proposed (as show in table 1).
4.2.2. Partition Target Decomposition of Total Runoff Control According to the specific situation of Sanya sponge city construction zoning, considering the total annual runoff control target of Sanya city, differentiated control was carried out for each zoning. Combined with the proportion of construction land area in each runoff control zoning and its suitability, the runoff control target decomposition in each zoning was proposed under the condition of meeting the overall control target of Sanya sponge city construction.

Natural catchment paths within the pilot area were simulated through ArcGIS hydrological analysis. According to the simulation results, combined with the river water system, ditches, rainwater network distribution, topography, and other elements, the three areas were divided into 21 catchment zones (as shown Figure 5). The construction situation, underlying surface drainage pipe network, waterlogging situation, water environment quality, water system, and other factors of each catchment area were analyzed to determine the type and volume of sponge facilities, and determine the runoff control targets for each of the 21 areas for the construction of each catchment zone. Table 2 shows that the annual runoff control rate of the eight sub-regions in Yuechuan is 87%, which exceeds the total runoff control target set in the Guidelines. The runoff control rate of the ten sub-regions in Donghe is maintained between 46.61% and 80.00%, while the runoff control rate of the three sub-regions in Xihe is the lowest, between 46.78% and 56.86%, which is lower than the total runoff control target set in the Guidelines.

Table 2. Target decomposition of annual runoff control rate in sponge city zone of Sanya city.

| Serial number | Name     | Land area (ha) | Annual runoff control rate(%) |
|---------------|----------|----------------|-------------------------------|
| 1             | Donghe-1 | 110.82         | 54.94%                        |
| 2             | Donghe-2 | 26.83          | 46.61%                        |
| 3             | Donghe-3 | 64             | 47.82%                        |
|   |     |      |      |
|---|-----|------|------|
| 4 | Donghe-4 | 14.68 | 59.38% |
| 5 | Donghe-5 | 53.74 | 57.46% |
| 6 | Donghe-6 | 94.29 | 65.28% |
| 7 | Donghe-7 | 85.44 | 67.87% |
| 8 | Donghe-8 | 79.59 | 61.18% |
| 9 | Donghe-9 | 231.06 | 80.00% |
|10| Donghe-10 | 78.22 | 56.26% |
|11| Xihe-1 | 156.13 | 56.86% |
|12| Xihe-2 | 147.69 | 48.74% |
|13| Xihe-3 | 31.33 | 46.78% |
|14| Yuechuan-1 | 96.52 | 87.00% |
|15| Yuechuan-2 | 86.81 | 87.00% |
|16| Yuechuan-3 | 67.92 | 87.00% |
|17| Yuechuan-4 | 81.16 | 87.00% |
|18| Yuechuan-5 | 68.79 | 87.00% |
|19| Yuechuan-6 | 74.01 | 87.00% |
|20| Yuechuan-7 | 56.03 | 87.00% |
|21| Yuechuan-8 | 103.27 | 87.00% |
|22| Total | 1808.33 | 70.13% |

**Figure 5.** Target decomposition diagram of regional annual runoff control rate.
4.3. Discussion

4.3.1. Analysis of runoff control objectives in Sanya City. The target of runoff control in the Sanya sponge city is 60%, which is based on the requirements of the Guidelines and the actual natural geographical and climatic conditions of Sanya City. Judging from the rainfall and hydrological conditions, Sanya City is located in a tropical monsoon climate zone with a large amount of rainfall and a large number of rainfall days. Hence, it belongs to a region with abundant rainfall. According to the statistics, the average rainfall over the past 30 years has been 1,392.20mm, while the evaporation rate in Sanya is relatively high in all months of the year, and the average evaporation rate for many years has been much larger than the average rainfall for many years. Considering the utilization rate and maintenance of sponge facilities in the dry season, Sanya’s annual total runoff control rate target should not be too high.

Judging from the current urban problems, the construction area of the sponge city is relatively small, and the problems in the current water environment, water resources and water safety are not prominent. Therefore, the construction of a sponge city is mainly based on the total amount of control of runoff, taking into account the control of runoff pollution. Zoning implementation can appropriately improve the construction objectives according to the construction conditions of different regions. At the same time, referring to the targets of other sponge cities in China, the design rainfall corresponding to total runoff control is mostly between 20–30mm and 30mm, and the design rainfall in some new areas is controlled to exceed 30 mm. In summary, considering the factors such as potential for implementation and drawing on the mature experience of other cities, it was determined that the total annual runoff control rate of sponge city construction in Sanya is 60.00%, and the corresponding design rainfall is 25.30mm.

4.3.2 Analysis of Differences in Target Decomposition of Runoff Control Zones According to the third-level decomposition method of runoff control rate target, the sub-area targets are decomposed according to the construction conditions and land use status of different regions. The Yuechuan area is located in the northern part of the city. It is located in the fan-shaped area of the intersection of the Donghe river and the Xihe river in Sanya. It is adjacent to the Chengbei high-speed railway and has abundant natural elements and superior natural conditions. According to the current situation of land use and planning, the annual total runoff control rate target is 63.50%, the corresponding design rainfall is 28.4mm, and the annual runoff control rate of eight sub-zones is 87%.

The Xihe area is located in the southwest of Sanya and on the west side of the Xihe River. The current land use is mainly residential and public facilities, which are basically the current built-up areas. The overall reconstruction is difficult, with high development intensity, high building density, and a low proportion of public spaces such as green squares. It was determined that the annual total runoff control rate is 46.00%, the corresponding design rainfall is 15.70mm, and the three sub-regional runoff control rates are between 46.78% and 56.86%.

The Donghe area is located on the east side of the Xihe River in Sanya. It is a built-up area with commercial and residential functions and the old urban areas are difficult to reconstruct as a whole, mainly with organic renewal. The development intensity of this area is high. It was determined that the total annual runoff control rate is 54.50%, the corresponding designed rainfall is 19.8mm, and the runoff control rate of ten sub-districts is maintained at 46.61%–80.00%.

5. Conclusion

Based on the compilation of the special plan for a sponge city in Sanya, this paper studied the annual total runoff control rate of a sponge city, decomposed the urban construction area using the target decomposition three-level method, analyzed the values of the target decomposition of the sponge city construction area and sub-areas, and discussed the limiting conditions of the values. It is considered that the value of the annual runoff control rate target for sponge city construction mainly depends on the local natural geographical and climatic conditions, and the detailed target needs to be decomposed
according to the current situation and planning of construction land in the block. The target decomposition and refinement method of annual runoff total control rate in a sponge city used in this paper cannot only provide reference for sponge city construction planning in Sanya city, but also can provide reference for other cities to carry out sponge city construction planning.

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