Nature-Based Solutions: Spatial Analysis and Optimization of Major Drainage Systems in Plain Lake Cities

Xueyuan Wang [1], Jianing Yu [2] and Yan Zhou *

[1] School of Architecture, Southeast University, Najing 210096, China; 597372322@qq.com
[2] School of Urban Design, Wuhan University, Wuhan 430070, China; 1552165559@qq. com
* Correspondence: joyeezhou@whu.edu.cn ; Tel.: +86 18607186199

Abstract: As a typical fast-growing plain city with the title of "city of hundreds of lakes", Wuhan, Hubei Province in China, boasts abundant regulating and storing water space. However, this city has suffered from frequent waterlogging and unbalanced storage due to rapid urbanization. To tackle the issue, this study is inspired by the idea of "Nature-Based Solutions" (NBS). Taking the major drainage system of Wuhan as an example, it explores the identification and construction of storage and drainage area as well as the planning strategies in the city scale, based on a sustainable urban stormwater system cycle compatible with artificial deployment and natural stormwater process. Then the drainage network and the natural force get a balance in the system. The results show that: 1) With the SCS-CN model and surface equal volume filling method, the spaces storing excess surface runoff were identified based on the urban stormwater process simulation under the topography and stormwater recurrence interval; 2) Combining the data of construction land, actual submergence area, and waterlogging points, the major drainage system with an emphasis on the restriction of surface elevation were organized. 3) The "storage and drainage function area of the major drainage system" was proposed as the NBS. The hierarchical distribution was adopted for layout optimization of urban land use in Wuhan, including the water storage and drainage area, strengthened self-drainage area, waterlogging reduction area, and low-intensity development area. Furthermore, it also offered references to the identification and improvement of waterlogging risk points of public facilities in built areas.

Keywords: drainage system; Nature-Based solutions; hydrologic process simulation; SCS-CN model; waterlogging risk assessment

1. Introduction

Since China's reform and opening up, Wuhan has entered a period of rapid substantial economic development. However, problems such as encroachment of green space and lakes and hardening of the riparian buffer zone appear in urban built-up areas. The urban basement gradually changes from soft green space to hard pavement, the seepage of the urban surface is weakened, the runoff is increased, and during the rainstorm, rainwater is easy to accumulate in the low-lying lands [1-2]. Different from river flood and mountain flood, Urban waterlogging, which causes the rain flood disaster in plain cities, is caused by heavy rainfall which exceeds the comprehensive capacity of urban space storage and pipe network drainage [3]. There are a few restrictive factors in the development of plain cities. With the increase of construction density, the production and living network of the plain city is intertwined with high density, and the interaction among subsystems makes the urban system sensitive and fragile. Therefore, when the city has suffered a rainstorm, disaster loss will increase with the degree of urban development.

A major drainage system is a sustainable spatial means to deal with waterlogging disasters. Xie Yingxia proposed to build a major drainage system in China to deal with urban waterlogging [4]. The theory originated from Britain: the small drainage system is generally the rainwater pipe network constructed under the standard of low recurrence interval, which is used to reduce the impact of high frequency and low-intensity rainfall events [5-7]. The major drainage system is a structured system based on higher recurrence interval and more varied spatial entity combination modes [8], which is used to discharge the runoff of extreme rainstorm, and under the stormwater runoff beyond the capacity of small drainage systems [9].

To deal with this problem sustainably, after the rise of the concepts of resilient city and healthy city, a new concept " Nature-based Solution " (NBS) has gradually come into the field [10]. The solution of the drainage system and nature represents two different treatment concepts, engineering, and naturalization [11]. The engineering method emphasizes the control of grey facilities such as rainwater pipe networks, while the natural method emphasizes the ecological restoration and improvement for the site toughness [12]. The explanation of the NBS concept is neither to advocate the return of the original nature, nor to form the ecological governance strategy by the superposition of new artificial technologies, but to use scientific and technological forces to reunderstand and use the natural system [13-14]. Replace artificial technology with natural forces as the core part of the solution.

The explanation of the NBS concept in this paper is not to advocate the return to the original nature, nor the superposition of new artificial technologies to form an ecological governance strategy but to use the power of science and technology to re-understand the natural system and use nature itself, the use of natural forces instead of artificial technologies as the core of the solution that does the real work. Based on the practical background of the plain city and its waterlogging, this paper tries to construct a major drainage system based on the concept of NBS combining with the theory and method of the two, which can reduce the pressure of the artificial rainwater pipe network and solve the problem of waterlogging in the city sustainably. the system is operated by the combination of storage and drainage on the ground surface, which largely depends on the potential energy of movement generated by the natural vertical space of the city, the hydrological process, cover type, elevation, and blue-green spatial fabric determine the layout of major drainage function area to a great extent [15-16], so it is important to analyze the occurrence space and process of urban storm flood.

In this paper, based on hydrological process simulation, combined with ArcGIS, RS, GPS platform, the relationship between spatial pattern and rainfall flood process is established. Based on the factors overlay analysis, the simulated rainfall flood area and the height of ponding water, the construction status, and the actual remote sensing data, the monitoring of the waterlogging point and waterlogging area are integrated. Through the simulation risk assessment of urban stormwater inundation, the functional area of the major drainage system is constructed. And the optimal control strategy of urban green space system and water system planning in Wuhan was analyzed, as well as Wuhan Present Situation Construction Land and the public facility existence risk spot solution enhances the city space to adjust the storage ability in the spatial planning aspect, alleviates the city waterlogging question.

2. Methods and Materials

2.1. Construction Method of the Major Drainage System in Plain Lake City

The artificial drainage planning for most cities in China usually includes the determination of system, zoning, determination of relevant formulas and parameters, the layout of the pipe network and pumping station, etc. Such a planning and design process is more suitable for cities with land connectivity and drainage not limited by surrounding rivers and lakes.The plain water network area, represented by Wuhan, is required to construct a major drainage system that is suitable for the base of the water network and responds to the vertical space of the city due to the particularity of the natural conditions and drainage space of the internal rivers and lakes.

One of the characteristics of Wuhan is that the water level of the Yangtze River is higher than the land elevation during the rainstorm. To prevent the river from flowing back into the construction land, it is necessary to have the key whole hydrological network, regional regulation and storage lowland, and local concave green space in Wuhan. The low-lying water storage space reserved in this way can realize the drainage of rainwater by gravity. But due to the difficult reversibility of land construction and the economic constraints of high-density development, cities can't carry out spatial planning from the perspective of self-discharge. Therefore, based on the vertical space of the real rain flood process, it is necessary to identify the key areas and form a complete major drainage system combined with self drainage, storage and drainage, and forced drainage.

The large-scale drainage system of the Plain lake-type city includes at least the lake, reservoir, and canal system, regulation, and storage facilities, and the artificial multi-function drainage and discharge channel, etc. The pattern matching of the rainfall-flood process in the natural water area of the original urban basement will directly affect the layout of the whole major drainage system. To realize self-discharge and storage discharge in plain lake city by regulating and storing urban river-lake water system, it is necessary to calculate the required capacity of storage discharge through the planning and design of heavy rain standard in high recurrence period, and reasonably organize the space for the occurrence of rainfall-flood process, spatial planning combined with vertical adjustment.

The major drainage system of plain lake city at least includes Lake Reservoir River system, storage facilities, the artificial transformation of the multi-functional drainage channel, etc. The pattern matching of the rain flood process in the natural water area of the original urban basement will directly affect the layout of the storage and drainage division of the overall drainage system. Plain lake city relies on the regulation and storage of urban rivers and lakes to complete self-discharge and storage and discharge. It needs to calculate the capacity required for storage and drainage through the planning and design of Standard for heavy rain in low return period, reasonably organize the occurrence space of rain flood process, and carry out spatial planning combined with vertical adjustment.

2.2.Identification method of the functional area of storage and drainage of the major drainage system based on rainfall-flood process

The surface runoff is calculated by subtracting the estimated pipe network discharge, the interception of plants and structures, and the infiltration of different land cover types from the rainfall of different intensities. The surface runoff and surface elevation are combined to simulate the rainfall flood process, and the Confluence Area of stormwater and height under different recurrence conditions are obtained. SCS-CN is a method developed by United States Soil Conservation Service to simulate flood peaks and surface runoff in small watersheds due to extreme precipitation weather.

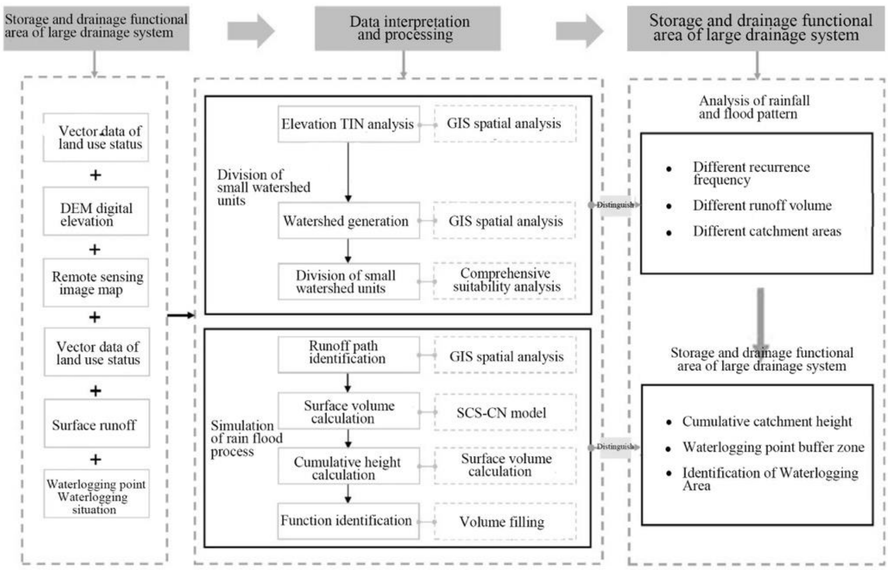

Figure 1. method of storage and drainage functional area of large drainage system.

Several small watershed units were divided according to the direction of runoff and the present situation of the construction. Finally, the results of waterlogging interpretation and wet points are added to define the buffer risk zone, green water system, and construction land status, and the comprehensive rainfall and flood pattern analysis are carried out to obtain the functional area of the major drainage system (Figure 1).

2.3 Study Area and Data

The plain city water network is formed by the sediment carried by the river, the water network interweaves, and the water area occupies a high proportion, the size river course densely distributed in the city. Located in the middle reaches of the Yangtze River and the east of Jianghan Plain, Wuhan is a typical plain Lake City with a total area of 803.17 square kilometers at a normal water level. the urbanization rate is about 80.49%, and the spread of urban construction land caused a serious problem of out-of-control regulation. In July 2016, about a week of accumulated precipitation caused water accumulation over large areas of the city and resulting in several systematic disasters, with some communities still holding water for up to a week after the rain. The Point Lakes and linear rivers in the Wuhan area are the core of a city's regulation and storage. The pattern of the lakes and the vertical spatial organization of the water network within a city will directly determine the city's natural runoff capacity. Wuhan is an ideal research object for simulating the rainfall-flood process and applying the major drainage system to enhance the capacity of urban rainfall-flood regulation and storage.Land use is based on the interpretation of Landsat 30m remote sensing images, and land use classification based on the LUCC classification system, the land use types can be classified into 6 primary types including agriculture, forest, grass, water, construction and unused, and 25 secondary types including shrub forest, sparse forestland, other forestland and grassland with high, middle and low coverage.(Figure 2 Figure 3 Figure 4) Waterlogging points on construction land in Wuhan were obtained from Wuhan Water Bureau. (Figure 5)According to the Wuhan Drainage and Waterlogging Control System Planning and Design Standards (2013), 24-hour rainstorm intensity value (Table 1) and waterlogging prevention standard reference (Table 2) are determined.

Figure 2. data of Wuhan.

Figure 3. definition remote sensing image of Wuhan.

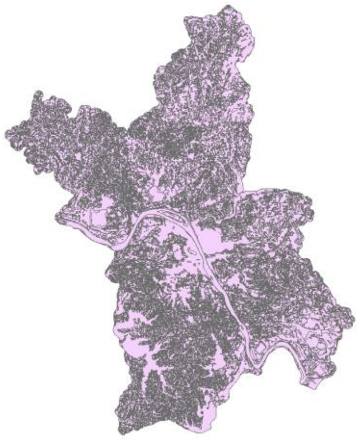

Figure 4. use in Wuhan.

Table 1. Rainstorm intensity of Wuhan.

Return period (year)	1	5	10	20	30	50	100
24 Hourly rainfall (mm)	95	162	205	249	273	303	344

Table 2. Waterlogging standards for Wuhan.

Fortification object	Design storm return period (year)	Return period of rare rainstorm (year)
General areas and road sections	10	50
Important areas and sections	20	100

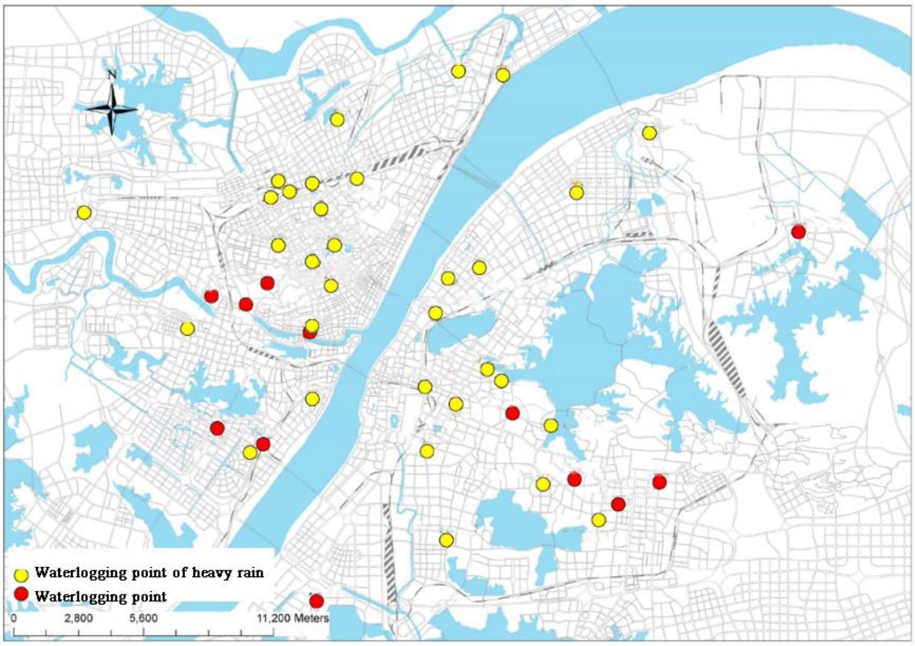

Figure 5. points of construction land in Wuhan in 2018.

The surface runoff coefficient represents the ratio of the total amount of runoff to the total amount of precipitation in the same period and represents the ratio of precipitation to runoff. Combining with the Outdoor Drainage Design Code GB50014-2006, the values of the surface runoff coefficient under different land-use types were determined (Table 3).

Table 3. Classification of land use types in Wuhan.

Primary type	Secondary type	Primary type	Secondary type
Cultivated land	paddy field	waters	Permanent Glacial Snow
	dry land		Beach
woodland	Woodland		beach land
	shrubwood	Urban and rural, industrial and mining, residential land	Urban land
	Sparse woodland		Rural settlements
	Other woodland		Other construction land
grassland	High coverage grassland	Unused land	sand
	Medium coverage grassland		gobi
	Low coverage grassland		Saline alkali land
waters	Rivers and canals		Marshland
	lake		Bare land
	Reservoir pond		Bare rock

3 Results

3.1. Simulation results of rain flood process and identification of storage and discharge areas

In the process of rainfall-flood simulation, the scale of the urban hydrological process coordinated with urban spatial scale is determined to ensure the integrity of all small watershed units and inclusion in the Wuhan, and finally, the study area is divided into 15 small basins. Based on the surface runoff coefficient and land use data, the surface runoff Q, Submergence Volume V, water storage range (Figure 6), and accumulative elevation H of each small watershed unit in Wuhan were calculated. The flood and rain patterns of each small watershed unit were determined by overlay analysis. Finally, the main body of the storage and drainage area of Wuhan's major drainage system was integrated (Figure 7).

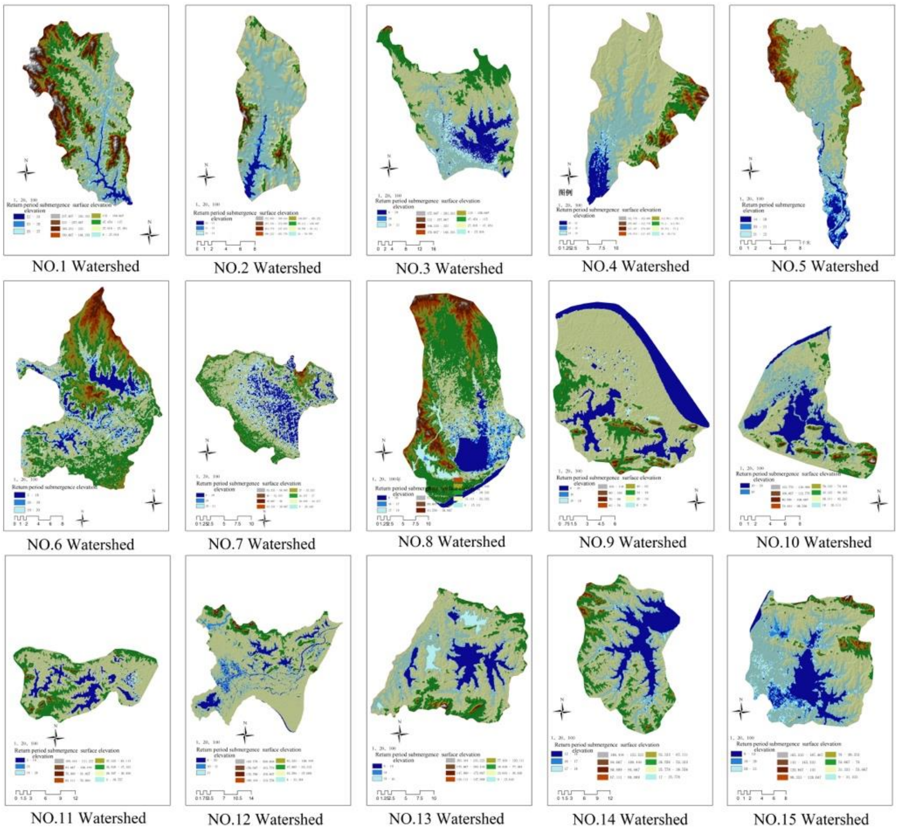

Figure 6. storage range of small watershed unit.

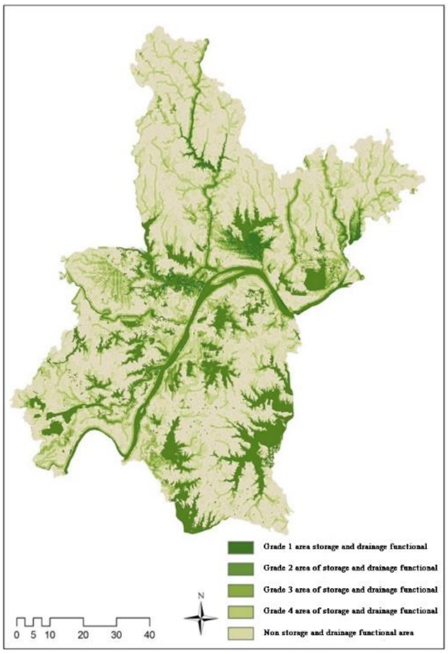

Figure 7. storage and drainage functional area of Wuhan.

3.2. Analysis of green space structure and storage and drainage capacity in Wuhan

Analysis of the green space structure in the storage and drainage area of Wuhan major drainage system under different heavy rainfall recurrence interval (Figure 8):The Green Space in the storage and drainage area of Grade 1 receives a large amount of rainwater storage each year, mainly distributed in the northern part of the city. The green space beside a lake or river is the first in time sequence to receive the water from the water body when the rainy season comes, combined with the original riverbed and lakebed, a new catchment basin is formed to jointly receive the surface water or upstream water in the periphery of the small basin unit.And the green land at the lowest topography of the small basin unit, after the initial interception and infiltration of rainwater to the surface, small depressions are formed, and the runoff in the small depressions overflows to form the lowest point of water accumulation.

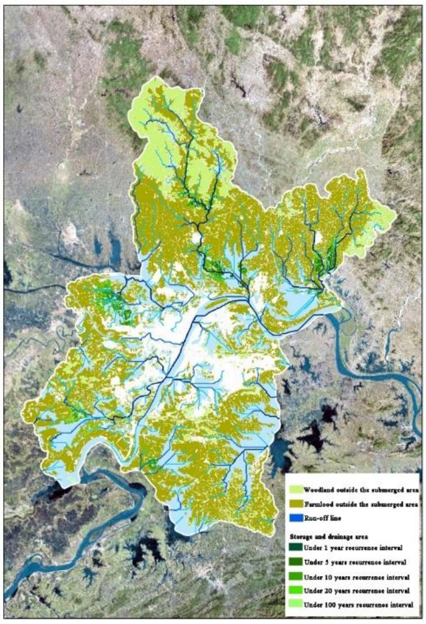

Figure 8. Function of green space system in Wuhan.

There are more storage and drainage areas under higher recurrence intervals in the south of the city. which shows that the storage and drainage area in the south of Wuhan increases obviously with the increase of rainfall intensity. In a longer frequency period, its land-use function can be normal, in a lower frequency period of the high risk of waterlogging. The green land in lower grades of storage and drainage area corresponds to the low frequency and middle-risk stormwater catchment space, which belongs to the major drainage system of surface space in response to rainfall and flood process under extreme weather. The green space outside the storage and drainage area has the function of infiltration and interception in terms of rainwater storage. Its elevation is higher than the catchment space in the small watershed, and it has the function of runoff production when the soil water content reaches saturation in the plain city, the green space located on the runoff line and buffer zone has the function of diversion.

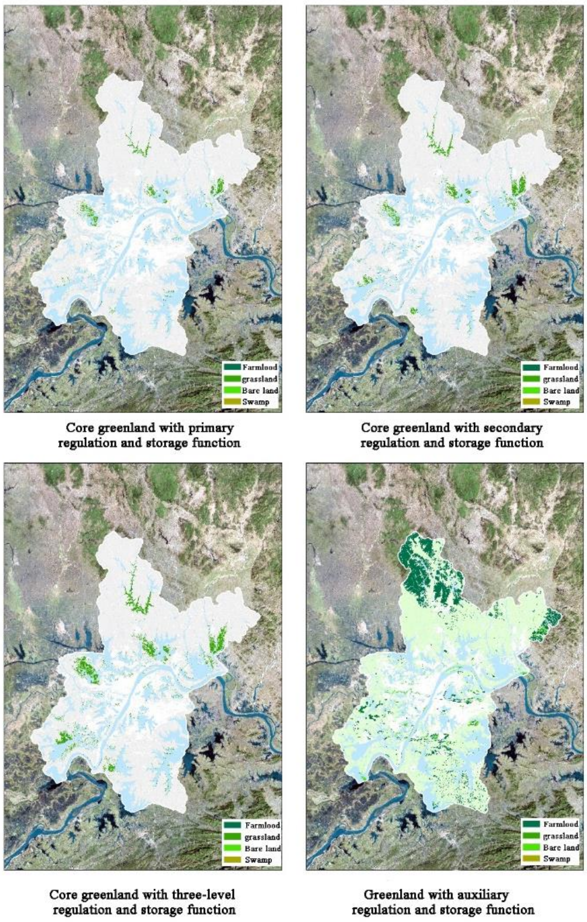

Figure 9. space structure of storage and drainage functional area.

As the main component of green space in the storage and drainage area (Figure 9 Table 4).On the one hand, the farmland is large, widely distributed, and relatively connected due to production needs, and it can store and collect rainwater, on the other hand, many lakes encroachments by farmland in the city, the soft space like lake have a high regulating and storing function, the land should be returned. Most of the forestland and grassland in the storage and drainage area of the built-up area is in a park containing lakes and ponds. During rainfall, the rainwater collected here is absorbed by vegetation and soil, the excess runoff is mainly discharged into lakes and ponds. As an important part of the urban hydrological cycle, it can also play the role of rainwater recycling while meeting the irrigation demand of the park green space.

Table 4. Analysis of green space structure in function area of rainfall-flood regulation and storage.

Recurrence interval (year)	Wood land (M2)	Grassland (M2)	Farmland (M2)	Bare land (M2)	Total area
1	4958750	115898400	851325	64550	121773025
20	9205700	272836450	2147250	107350	284296750
100	12663875	334992325	2564025	152425	350372650

3.3. Analysis of water system structure and storage and drainage capacity in Wuhan

The distribution of drainage system and land use structure in the storage and drainage area of the Wuhan River were analyzed under different heavy rainfall recurrence periods (Figure 10 Figure 11, Table 5). The water system within the scope of storage and discharge can be divided into two types: one is the river and canal and the lake reservoir, which are the final destination of all surface runoff as the natural depressions on the surface. The other is that the wet surface such as swamp, wetland, beach, etc. is used as the storage and drainage area, which plays the role of retaining runoff and purifying water quality. As the Yangtze River receives the upstream water and the catchment of the surrounding areas, the water level in flood season will be higher than the surrounding construction land and has artificial dam construction, so it can not be used as a runoff channel.

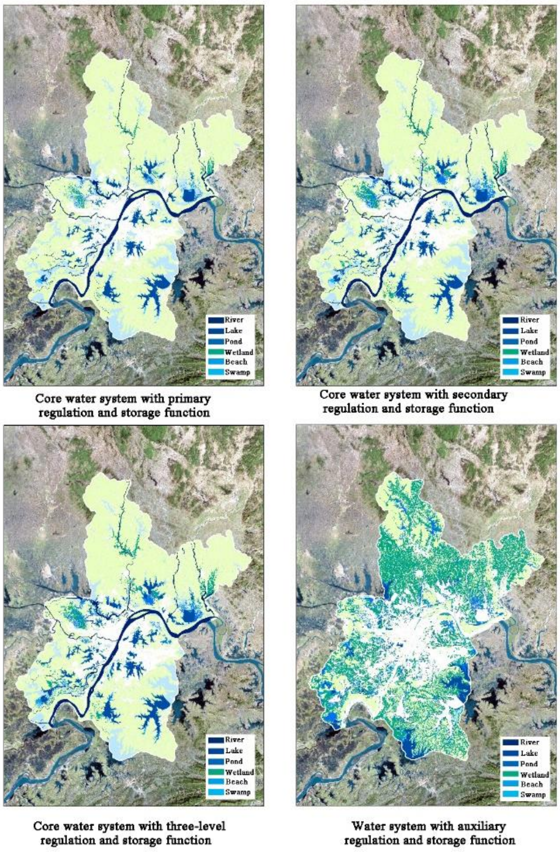

Figure 10. and storage function of water system in Wuhan.

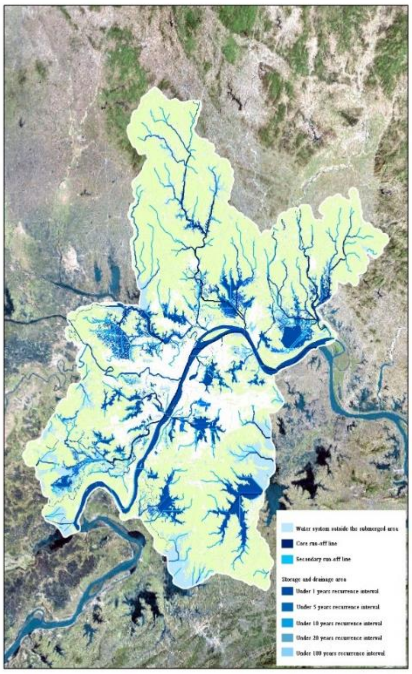

Figure 11. system structure of storage and drainage functional area.

Table 5. Analysis of water system structure in function area of rainfall-flood regulation and storage.

Recurrence interval	Wetland (M2)	River (M2)	Lake (M2)	Pond (M2)	Beach (M2)	Swamp (M2)	Total area (M2)
1	87337774	38455506	384463351	80171548	19169711	5871123	615469014
20	200326665	65312468	455772718	156149383	34131886	10589740	922282862
100	243529144	70933405	483866008	173033794	46196979	12233676	1029793010

The lakes and ponds within the storage and drainage area during the 1-year recurrence interval have the most rainwater storage capacity, and it can store the most rainwater with the least amount of land. At the same time, the high rainwater collection capacity makes it have the potential to construct a natural ecological water supplement system. Therefore, it is necessary to ensure that the surrounding catchment path is smooth so that the surface runoff is discharged into the lake. In the heavy rain recurrence period, most lakes and ponds are in the storage and drainage area. Compared with forest, grass, and dry land, lakes, lakes, and ponds are in general saturated with dynamic equilibrium, so their infiltration function is weaker during the rainfall period. Compared with the relatively scattered wetland beach, the lake has an obvious basin, it can store more rainwater under the condition of the same area, so we can deal with the urban waterlogging by strengthening the control of land use of lakes and its surroundings, and dispatching before flood season. The water system in the 100-year recurrence interval has a relatively low return frequency. And as the key area to mitigate urban waterlogging under the condition of high-intensity rainfall, it should have the function of emergency waterlogging prevention and the possibility of flexible land function replacement. For the few lakes outside the storage and drainage area, due to topographic and elevation factors, the runoff producing space in the small watershed unit is relatively small, and it is difficult to form obvious runoff channels to collect rainwater. Therefore, it can not play an obvious regulation function in a larger range under the natural condition, but it can be used as a strong row terminal.

4. Discussion

The urban ecological planning emphasizes the establishment of urban ecological functional zoning and takes the flood disaster as one of the ecological sensitivity evaluation factors. Most of the planning entity space is urban green space and water system, The urban ecological planning emphasized improving urban water environment and optimizing the allocation of water resources through water ecological restoration and construction of ecological landscape. Therefore, this study analyzes the functional zoning of Green Space and water system as two kinds of material carriers in urban space, according to the different grade distribution of the simulated storage and drainage area, the rainstorm intensity, waterlogging point, and the construction situation of the Wuhan area, the study area was divided into four types: the storage and drainage core area, the self-drainage strengthening area, the construction control area, and the local optimization area, and put forward the corresponding plan application suggestion and the control strategy to each kind of area.

4.1. How to formulate the control strategy for the storage and drainage of the green space system and water system?

First, soft spaces such as green spaces can better intercept, retain and purify rainwater, and play a key role in flood prevention and storage when the rainy season comes, in other times as open space, education space to provide a variety of ecological services for the city. The storage and drainage area include the urban green space of simulation storage and drainage areas. Planning in storage and drainage core areas should protect the existing green space which plays a key role, prohibit urban and village town construction and industrial layout. And the runoff inflow points of green space in storage and drainage areas should be added to cope with more surface runoff when rainfall intensity exceeds expectations in a more flexible way under extreme rainfall. The construction control area includes construction land within the simulated catchment area. In the construction control area, the construction intensity should be reasonably controlled in combination with LID facilities to make it have hydrological functions following the regulation and storage process without changing the land use, and the path of runoff should not be blocked. The self-discharge enhanced area includes most of the green space in the city. It is the largest infiltration area in the city and since the terrain elevation is opposite to the runoff producing area, self drainage should be strengthened to block rainwater and reduce runoff. The region mainly includes arable land, forestland, and grassland, which forms the basis of the whole ecological resources of the city. And the local optimum area includes the waterlogging point. The waterlogging formed by different storm intensities in the built-up area of the city, including the urban stormwater pipe network due to overflow load standards., The catchment path and turning point are designed through the newly added street green space, sunken green belt, and rainwater garden, and the rainwater runoff is directed to the catchment or self-discharge area by grey-green facilities (Figure 12).

Figure 12. zoning of green space optimization in Wuhan.

Second, the function of the water system in the storage and drainage area is to regulate runoff and store rainwater. As an important space for rainwater storage, urban lakes should control the water storage capacity, water quality, water quantity, and water body function area, determine the difference of the amount of rainwater that can be regulated and stored by each lake, develop the functional zoning, and formulate the rainwater treatment plan for different storage requirements. The storage and drainage core area includes the rivers, lakes, and ponds within the simulated storage and drainage area, which is the lowest point within the small watershed unit in the process of rainfall. As the terminal of surface runoff collection, the existing water body area should be retained, it is strictly forbidden to develop cities and build villages and towns, and at the same time, to slow down the slope of the shoreline and replace the hard shoreline with the soft shoreline. Based on the soil water retention capacity and infiltration capacity of different wetlands, the functions and corresponding planning measures of different wetlands in the urban hydrological process are determined. The construction control area includes the built-up area within the simulated storage and drainage area and a large number of original lakes and ponds occupied by the construction land. The land should be returned to the lake in this area, at the same time, the construction intensity should be controlled, the scientific vertical design should be made, and the construction standard should be raised reasonably. The self-discharge strengthening area includes other water space in the range of the city, which corresponds to the function of conflux in a certain range of hydrological process, but still exists the drainage system with lower elevation in a larger range, therefore, although it can not become the core storage space, it can still receive some rainwater and collect the runoff in smaller units. At the same time, the area can be used as the space for dispatching and forced drainage to collect the water from various ways to share the water pressure of other areas. The local optimum area is the area where the runoff route in the simulation storage and drainage area, which corresponds to the runoff process in the hydrological process. The Core run-off line takes on the main function of runoff, and the secondary run-off line can better penetrate the built land to collect surface runoff and rainwater. Some run-off lines passing through urban construction land are blocked by urban buildings and disturbed by underground pipe networks, which result in their not being able to run off normally. Therefore, the original drainage system of the edge stone ditch can be changed into the drainage system of the roadside open ditch in suitable construction areas. Some of the runoff lines in the natural plots can be connected with the catchment area by using space such as turf furrow (Figure 13).

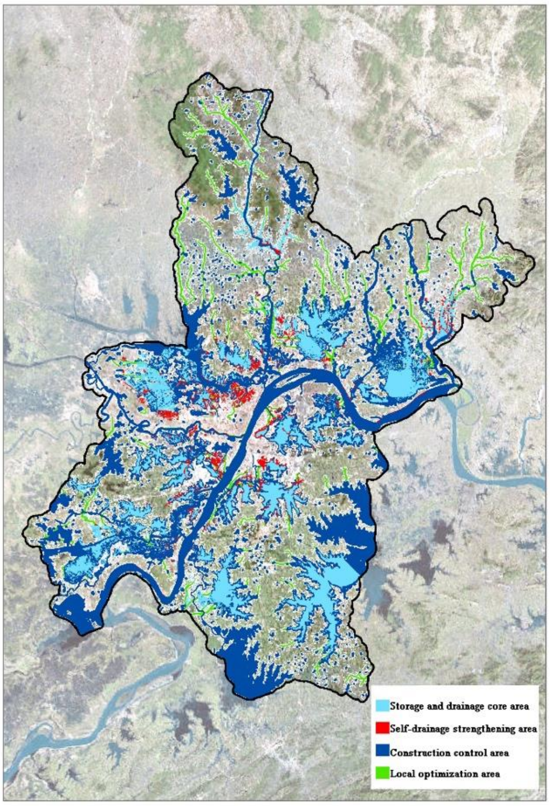

Figure 13. zoning of water system optimization in Wuhan.

4.2. How to reduce the risk of waterlogging of public facilities in the completed area of Wuhan?

The built-up areas within the storage and drainage areas face risks of waterlogging. Once a 100-year rainstorm comes, it will take a long time and be of great intensity, and the standards of the urban underground drainage network will be unable to cope with such a large amount of water, it often causes the paralysis of important infrastructures such as electric power system, transportation system, which needs the natural solution of a major drainage system and perfect flood prevention and emergency management system. The study selected several public buildings, including the government, places of interest, university campuses, bus stations, hospitals, parking lots, gas stations, train stations, etc. According to the layout of public buildings in the storage and drainage area, the waterlogging risk under different rainstorm intensity is analyzed and suggestions are put forward (Figure 14).

For the storage and drainage areas within the higher return period, the surrounding public service facilities which can not carry out the change of land use should be transformed combining with the surrounding green space system and the LID facilities. The function of stormwater drainage and runoff adjustment should be improved, and the planning of emergency flood prevention and disaster avoidance should be done well. The region not only has a strong capacity to store and discharge water but also can share the water pressure in the surrounding area. It can also make use of its landscape benefits and drainage advantages to build appropriate public service facilities matching the flood-resistant function, such as urban slow-walking trails, education demonstration bases, avoid the layout of gas stations, transportation hubs, and other important functions. The construction intensity of the public facilities should be controlled in the storage and drainage area of the lower recurrence interval firstly, and the surface runoff should be directed to the nearby green water system. At the same time, the internal topography and pipe network are inspected to ensure that the surface runoff route is not blocked by vertical design and pipe network dredging. For the public service facilities around the waterlogging point and catchment path, it is suggested to build green space or artificial storage facilities nearby. The overall storage and drainage capacity can be improved by control of designated units and the joint defense of several units to ensure water ecological safety.

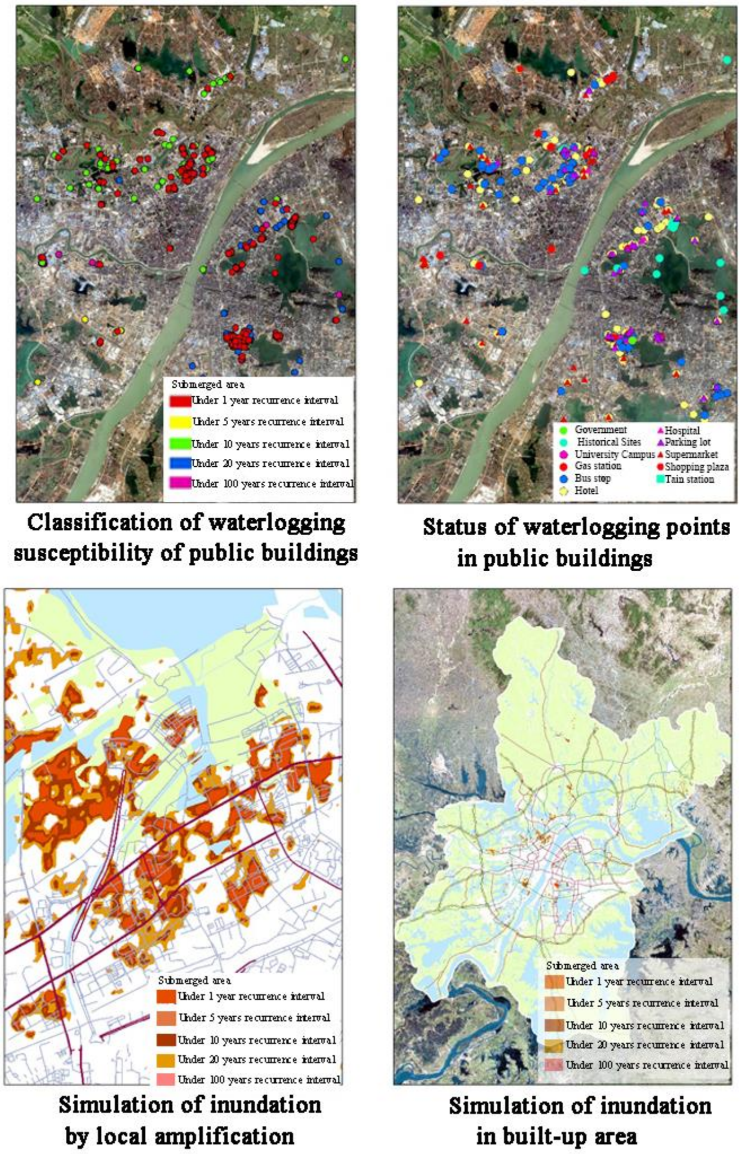

Figure 14. inundation of public facilities in built-up area of Wuhan.

5. Conclusion

The study takes advantage of lake resources in Wuhan, Based on the elevation terrain, basement cover, and gray infrastructure, the vertical organization, and layout of rainfall and flood process is carried out to control the water green spatial pattern matching the storage and drainage process. The planning should optimize the waterlogging retention system of the vertical water system, construct a low-land storage area, and optimize the connection through planting grass ditch, biological retention zone, and together form the major drainage system of Plain Lake City.

The study is based on the concept of NBS to optimize the layout of the large-scale drainage system, emphasizing to find an ideal balance between gray infrastructure and green infrastructure through the intervention of artificial technology, and to extend the urban construction land from two-dimensional layout to three-dimensional layout, It is a grey-green combination system to control the whole urban storm flood process under the three-dimensional heterogeneous space in macro. At the middle and micro level, it is necessary to solve the conflicts between buildings and surrounding land, road traffic, as well as the time dimension in the Near and long-term and the local area and the overall contradiction. The simulation of storm-flood processes in the solution process only serves as a tool and method for assisting planners to better understand nature. The real work is done by the storage and drainage space itself, which is in line with the rainfall-flood process, rather than by artificial technology. In future research, scholars should further refine the construction of major drainage system at different scales, and improve the major drainage system and planning and construction combined with the operational approach.

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Author Contributions: YAN ZHOU conceived and designed the experiments; XUEYUAN WANG performed the experiments, analyzed the data and wrote the paper; JIANING YU contributed reagents tools and wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

LUCC: land use/land cover change
ArcGIS: Arc Geographic Information System
RS: Remote Sensing
NBS: Nature-based solutions
LID：Low impact development

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