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Research on the effect of rainfall flood regulation and control of wetland park based on SWMM model—a case study of wetland park in Yuanjia village, Qishan county, Shaanxi province

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Abstract. Taking the wetland park of Yuan Village in Qishan County of Shaanxi Province as the research object, this paper makes a reasonable generalization of the study area, and establishes two models of low impact development (LID) and traditional development in the park. Meantime, rainwater in the surrounding built up area is introduced to into the park for digestion. SWMM model is used to simulate the variation of the total runoff, peak flow and peak time of two development models in Wetland Park under one-hour rainfall at different recurrence periods.The runoff control effect in each single LID facility in the one-hour rainfall once during five years in the built-up area is simulated. The simulation results show that the SWMM model can not only quantify the runoff reduction effect of different LID facilities, but also provide theoretical basis and data support for the urban rainfall flood problem. LID facilities have effects on runoff reduction and peak delay. However, the combined LID facility has obvious advantages for the peak time delay and peak flow control. A single LID facility is more efficient in a single runoff volume control. The order of runoff reduction by various LID facilities is as follows: Rain garden>combined LID facility> vegetative swale> bio-retention cell > permeable pavement. The order of peak time delay effect by the LID facilities is as follows: combined LID facility> Rain garden> vegetative swale> bio-retention cell > permeable pavement. The order of peak flow reduction efficiency by various LID facilities is: combined LID facility> Rain garden> bio-retention cell > vegetative swale> permeable pavement.

1. Introduction

In 1971, EPA first proposed SWMM (Storm Water Management Model)—an urban storm water management model [1]. After multiple updates, the optimized LID facility processing module is added to the current SWMM 5.0 [2]. The LID module using SWMM model can effectively simulate and evaluate the rainfall runoff, peak time and water quality under different rainfall events, so as to provide accurate data support for layout and optimization of LID facilities in sponge city construction [3]. The existing domestic research mainly focuses on the runoff of residential areas, roads and other municipal infrastructures [4]. Most of the research on Wetland Park remains at the design level of qualitative analysis [5]. As a regional ecological cavernous region, wet parks have significant ecological value in undertaking regional rainwater consumption and regional ecological environment [6]. Therefore, it is particular important to introduce quantitative analysis [7].

2. Materials and methods

2.1. General description of the research area

Yuanjiacun Wetland Park is located in the territory of Yongshan Town, Qishan County. The region belongs to a temperate continental semi-humid climate [8]. Drought and wind in spring, high temperature and rain in summer, cold and drought in winter are the main climatic characteristics in this area. The distribution of regional annual precipitation is uneven. Precipitation in June, July and August accounts for 80% of the annual rainfall, and is mainly rainstorms [9]. The average annual precipitation is 632.8 mm. The maximum annual precipitation is 992.3 mm, and the minimum precipitation is 377.6 mm. The drought index is 1.33. The research area consists of two parts: the built-up area and the wetland park, as shown in Figure 1. The area of the wetland park, which is designed to undertake and absorb the rainwater runoff of 86.32hm^2 of the surrounding built-up area, is 10.13hm^2. The runoff is absorbed and purified after introduced to the wetland through a pipeline, and then discharged to the rainwater pipe network.

Figure 1. Plane graph of the research area.

Based on the topographical features and layout of the site survey pipeline, the research area is divided into 41 sub catchment areas and 1 water outlet end. The division results are shown in Figure 2.

2.2. Modeling of the research area

According to the storm water management idea of reduction at source-transmission in midway-regulation and storage at end, the low impact development of the research area layouts LID facilities combined with the site characteristics, selecting the vegetative swale, permeable pavement, rain garden, bio-retention cell and constructed wetlands. The storm water drainage path is as shown in Figure 3.

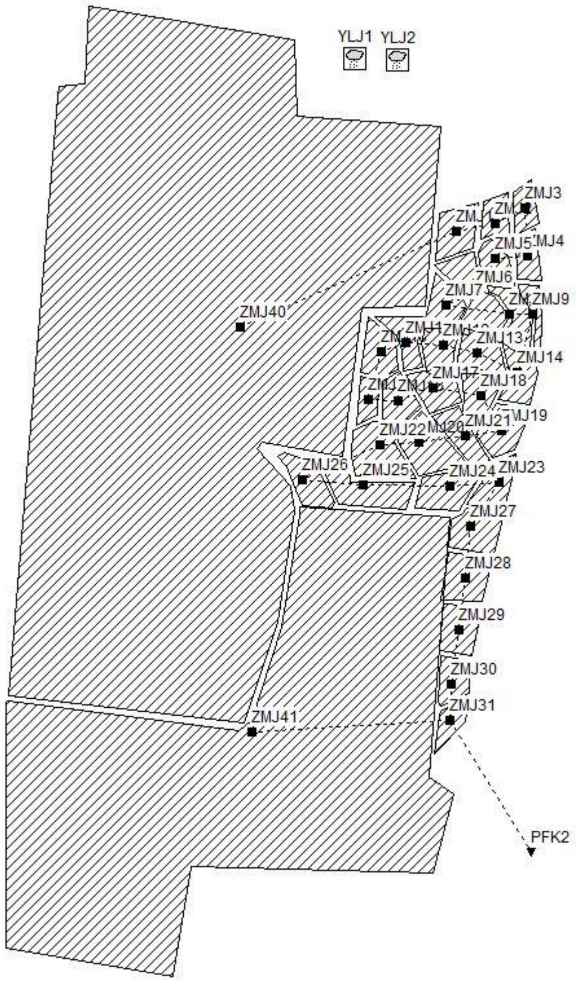

Figure 2. Generalization map of the research area . YLJ1 and YLJ2 represent the rain gauges with the recurrence interval of five years and ten years. ZMJ1~ZMJ41 represent sub catchment areas 1~41. PFK2 represents the discharge outlet.

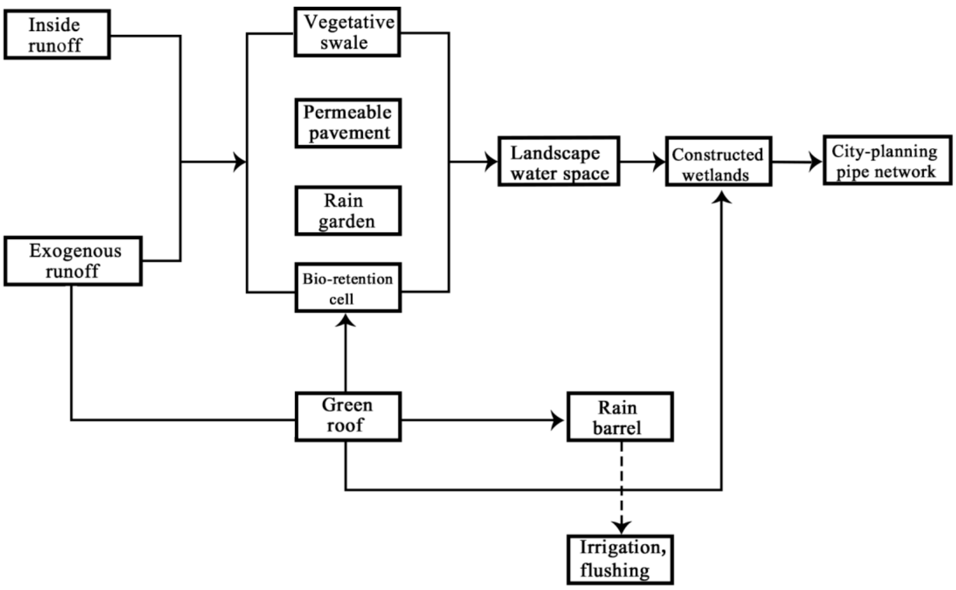

Figure 3. Storm water drainage path of low impact development.

The traditional development rainwater runoff is common green space-pavement-water - pipe network, as shown in Figure 4. In order to build a contrast model and meet the function of the wetland park, the proportion of hard pavement and green space in the wetland park is the same as that of low impact development model.

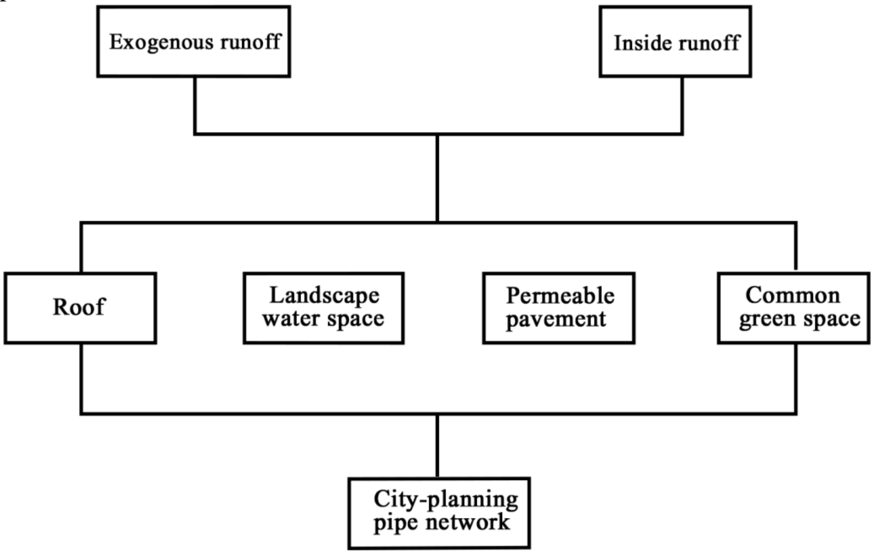

Figure 4. Storm water drainage path of traditional development.

2.3. Module parameter setting

The module parameters are set according to the characteristics of soil precipitation in the research area and principle of the model. Precipitation infiltration selects Horton model. According to the soil characteristics in the area, the maximum infiltration rate is 73.6mm/h, and the minimum infiltration rate is 5.2mm/h. The surface runoff is simulated by nonlinear reservoir model, and the wave equation is adopted for pipeline transportation. The Manning coefficients of ordinary green space, impervious pavement and storm water pipelines are 0.6, 0.011 and 0.013, respectively.

The rainfall is designed with the recurrence interval of five years and ten years, the rainfall duration is 1h, and the simulation time is 6h. The research area is in low impact development model and traditional development model. According to *Practical Hydrologic Handbook of Baoji*, rainstorm intensity formula is suggested to calculate the precipitation in the recurrence interval of five years and ten years. According to the design requirements, the precipitation in the recurrence interval of five years is chosen to simulate whether the design goal has been achieved. The rainfall pattern in the design is Chicago rain pattern. The the rainfall duration is 1 h, and relative position of rain peak is 0.4.

3. Results and discussion

Table 1 reflects the analog parameters using the LID of facilities.The exogenous rainfall is as shown in Figures 5 and 6. The runoff at the end of the outlet is compared under the two patterns as shown in Figures 9 and 10. By comparing Figures 5 and 6, it can be found that the runoff reduction of low impact development mode is about 25% lower than the traditional development model in the exogenous sub catchment area ZMJ40 and ZMJ41 with the recurrence interval of five years. The comparison between Figures 7 and 8 indicates that the runoff reduction of low impact development mode is about 20% lower than the traditional development model in the exogenous sub catchment area ZMJ40 and ZMJ41 with the recurrence interval of ten years. The peak flow rate is obviously reduced, and the peak time is obviously delayed. By comparing Figures 9 and 10, it can be found that with the increase of the recurrence period and the rainfall intensity, the runoff reduction rate in low impact development facilities are on the decline, and the time of arrival of the flood peak is shortened. The effect of low impact development facilities decreases as the rainfall recurrence period increases.

Table 1. LID facility parameters.

Rain garden		Bio-retention cell		Vegetative swale
Surface	Soil	Water storage	Drain	Surface
Storage depth 500mm	Thickness 300mm	Thickness 2000mm	Drainage coefficient 0	Storage depth 300mm
Vegetational cover 0.15	Porosity 0.463	Void ratio 0.75	Drainage index0	Vegetational cover 0.2
Coefficient of surface roughness 0.4	Water-yielding capacity 0.232	Penetrance 500mm/h	Culvert deviation height 0	Coefficient of surface roughness 0.3
Surface gradient 0.3	withering point 0.225	Blockage factor 0		Surface gradient 0.3
	Hydraulic conductivity 4.6mm/h			Depression slope 4
	Gradient of hydraulic conductivity 10			
	Suction head 90mm			

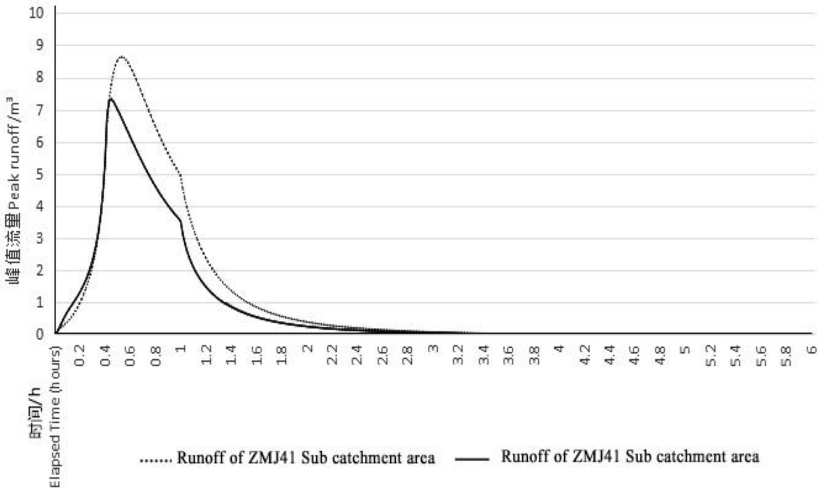

Figure 5. Exogenous runoff curves in 1 hour rainfallonce in five years under the traditional development mode.

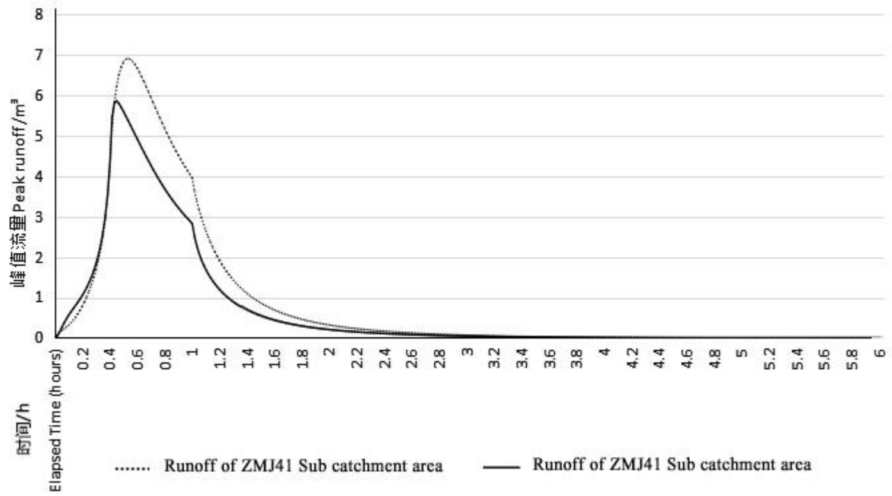

Figure 6. Exogenous runoff curves in 1 hour rainfall once in five years under the low impact development mode.

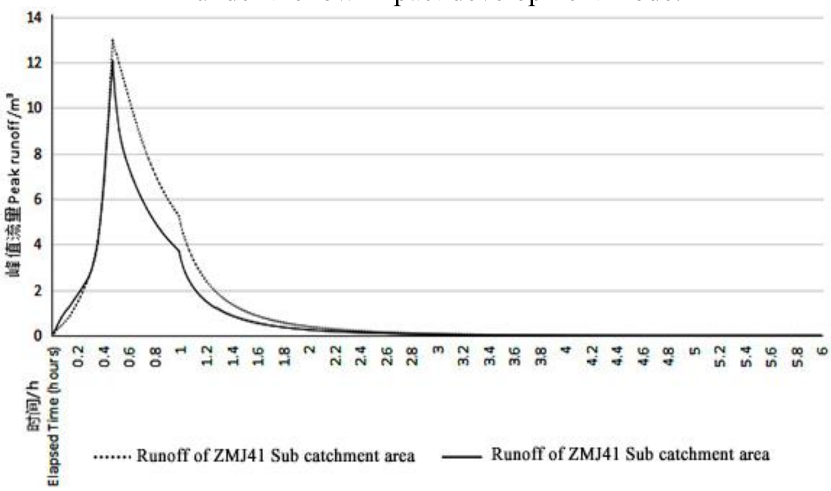

Figure 7. Exogenous runoff curves in 1 hour rainfall once in tern years under the traditional development mode.

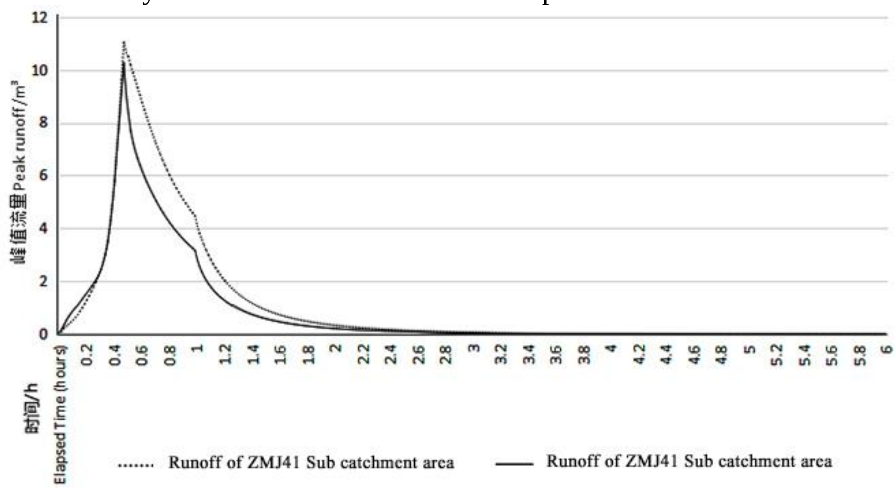

Figure 8. Exogenous runoff curves in 1 hour rainfall once in ten years under the low impact development mode.

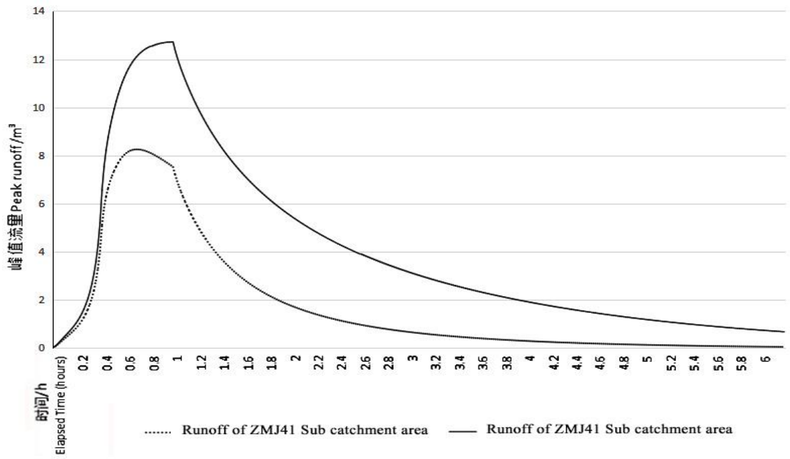

Figure 9. Runoff curves at the rainwater outlet in 1 hour rainfall once in five years.

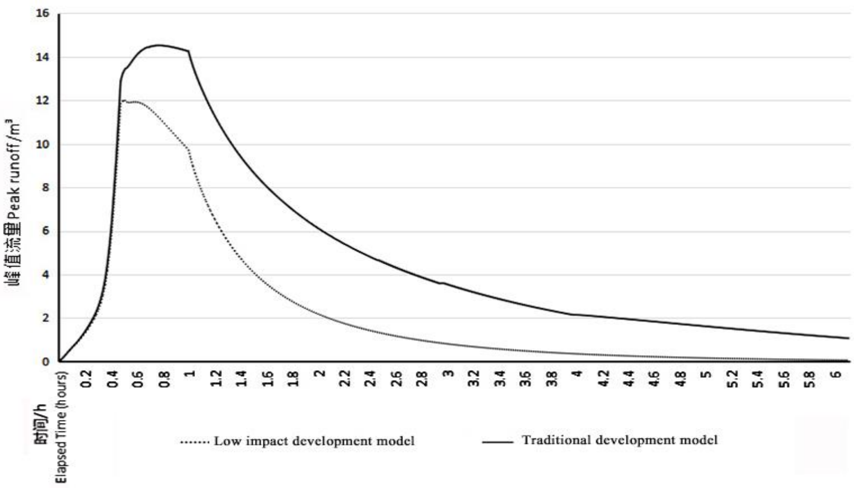

Figure 10. Runoff curves at the rainwater outlet in 1 hour rainfall once in ten years.

Table 2. Runoff simulation under the rainfall intensity with the recurrence interval of five years by different LID facilities.

Type of LID facilities	Area ratio	Total Runoff	Runoff reduction	Peak flow	Peak time
Without LID facility	-	64830	0	8.71	36
Rain garden	11%	46327	18530	6.07	51
vegetative swale	11%	49793	15037	6.70	46
permeable pavement	11%	59361	5469	7.44	38
bio-retention cell	11%	49904	14926	6.31	45
combined LID facility	11%	47855	16945	5.16	62

In the rainfall condition with the recurrence interval of five years, vegetative swale, permeable pavement, rain garden, bio-retention cell and single LID facility are selected in sub catchment area ZMJ40 to simulate the runoff change, and the simulation results are as shown in Table 2. Each LID has effect on runoff reduction and peak delay. The order of runoff reduction by LID facilities is: Rain garden>combined LID facility> vegetative swale> bio-retention cell > permeable pavement. The order of the peak time delay by the LID facility is: combined LID facility>rain garden> vegetative swale> bio-retention cell > permeable pavement. The order of peak flow reduction efficiency by various LID facilities is: combined LID facility> Rain garden> bio-retention cell > vegetative swale> permeable pavement. It can be concluded that the combined LID facility has obvious advantages in peak time delay and peak flow control. However, a single LID facility is more efficient in runoff volume control.

4. Conclusions

SWMM model can quantify the runoff reduction effect of different LID facilities, and provide theoretical basis and data support for solving the urban stormwater flood problem. LID facilities have effects on runoff reduction and peak delay. However, the combined LID facility has obvious advantages in peak time delay and peak flow control. In single runoff volume control, a single LID facility is more efficient. The order of runoff reduction by various LID facilities is: Rain garden>combined LID facility> vegetative swale> bio-retention cell > permeable pavement. The order of peak time delay effect by the LID facilities is: combined LID facility> Rain garden> vegetative swale> bio-retention cell > permeable pavement. The order of peak flow reduction efficiency by various LID facilities is: combined LID facility> Rain garden> bio-retention cell > vegetative swale> permeable pavement.

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