REDUCING FLOOD RISK THROUGH DESIGN SCENARIOS FOR HEAVY RAIN, TIDES, AND URBANIZATION IN CAI RANG DISTRICT, CAN THO CITY: PROPOSED SOLUTIONS

Nguyen Van Hong[(1)], Nguyen Thao Hien[(1)], Le Xuan Hoa[(1)], Chau Thanh Hai[(1)], Nguyen Vu Luan[(2)]

[(1)]*Sub-Institute of Hydrology Meteorology and Climate Change*

[(2)]*Center for environmental consultancy and Technique*

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Abstract: *Urbanization often comes with flooding problems. The objective and subjective reasons why this situation persists and becomes increasingly serious are climate change and the concretization process. Currently, many studies have proposed solutions to forecast and warn of rain and tide causing urban flooding or methods to reduce flooding with sustainable green buildings. However, these solutions are all built on the old urban foundation, so flooding continues and the effectiveness of flood reduction is not high. In this article, the authors research the new urban area of Nam Can Tho, Cai Rang district, Can Tho City. This area is in the process of planning for infrastructure construction, so initial solutions have been proposed. Preventing flood risks caused by uncontrolled and unsynchronized urbanization is extremely necessary.*

Keywords: *Urban flooding, design scenario, SWMM, LID, Can Tho.*

1. Research Overview

The research area is located in Hung Thanh ward, Cai Rang district, Can Tho City, adjacent to Can Tho River in the Northwest; adjacent to Can Tho Bridge (National Highway 1A) in the Southeast; adjacent to Tran Hoang Na Street in the Northeast and adjacent to Cai Nai canal in the Southwest. The total area of this planning area is 365,740 m^2. In Figure 1, it can be seen that the area has the Cai Nai Canal flowing through it, which is a small branch of the Can Tho River and a secondary river of the main Hau River. Therefore, the hydrological regime of the area is strongly affected by tide, the upstream flow of the Mekong River. The hydrological regime is divided into two distinct seasons: Flood season from July to December and dry season from January to June. In the flood season, tide are also a factor that raises the water level in the river system and prevents flood discharge [1] (note: The green area is the research area).

Corresponding author: Nguyen Van Hong

E-mail: nguyenvanhong79@gmail.com

This is a new urban area of Can Tho City. Currently, the area is still in the process of planning and investing in infrastructure development, there is a lot of vacant land (Figure 2). This is a favorable condition for developing a smart city, avoiding repeating the old urban structure, lack of green space, lack of water storage facilities, etc.

In urban water management, the Storm Water Management Model (SWMM) model has been familiar in previous research works and it is highly appreciated when applied in practice. [2] research on flooding in Hanoi's Capital, with rapid urbanization, in addition to the positive trend of changing the face of the country, also entails the impact of obstructed and ineffective urban drainage; moreover, climate change has also become a major challenge today; the study applied the SWMM model to simulate the flood drainage system on May 24-25, 2003 and October 31-November 2, 2008 on To Lich River as a basis for making strategic regulations, quick response to floods and urban management, this is a useful method to refer to support future decision making. [3] presents the results of the study on the application of the EPA SWMM model with the Hydrodynamic wave method in the hydrological and hydraulic analysis of the drainage network of the new urban area of Le Minh Xuan, Ho Chi Minh City; the author has tested the hydrological and hydraulic model suitable for the hydrometeorological conditions, topographical, geomorphological and morphological characteristics of the area; from there, the most suitable model is selected as the basis for building the sewer network aperture; the results of the analysis and evaluation of the drainage network planning will solve the problem of flooding and high tides; from the research results, it is necessary to change the thinking and calculation methods in the process of urban drainage planning in new urban areas to avoid repeating the scenario that is happening in current urban areas. Through the above analysis, the author recommends using the EPA SWMM model for simulation because this model describes most of the properties of the basin to create flow on the basin surface; for the hydraulic model of the drainage network, the Hydrodynamic wave model should be used for simulation, because this model uses the finite difference method to solve and gives relatively accurate results compared to the actual regime of the network; the EPA SWMM hydrological model can simulate the flow and groundwater seepage in the basin, so it is possible to study the application of the model to select the type of permeable material and the water seepage model on roads, sidewalks, and parking lots to slow down the flow in the basin and replenish part of the groundwater for the city.

The following studies also provide evidence that the SWMM and LID duo is a useful tool for sustainable urban development and a more advanced, modern, smart city. This tool helps managers and investors save costs and time in choosing solutions suitable for the nature of project planning, ensuring efficiency during construction. [4], [5] and [6] stated that urban expansion leads to an increase in waterless areas and increases the speed of surface movement, especially in urban areas and large cities; to reduce damage caused by flooding and control runoff, these areas have developed a reasonable LID combination solution in urban stormwater management using SWMM software. To achieve more optimal efficiency of LID, studies [4], [7], [8] and [9] have proposed many types of design scenarios for risks caused by urbanization and climate change. [7] used EPA-SWMM software for the drainage model of the Binh Chanh area, using 2 scenarios applying SUDS solution: (1) scenario of increasing temporary storage capacity for reuse of rainwater (Rainwater harvesting); (2) scenario of reducing peak flow of water (Green roof, rain garden, and permeable pavement). [8] has combined GIS tools to assess the urban flooding situation in the Ninh Kieu district Metro residential area, Can Tho province in many urbanization scenarios. In particular, [4] has stimulated additional 2, 5, and 10-year recurrence cycles in two rainfall events in the city; thereby evaluating highly effective methods to reduce peak flow volume and drainage in the stormwater drainage system. And [9] the use of LID in BMP scenarios resulted in a 75% reduction in total urban surface runoff, a 22% to 46% reduction in peak flows, and up to 32% pollutant removal in cost-effective and environmentally friendly ways.

Inheriting the effectiveness of the SWMM and LID models in reducing urban flooding risks from the above domestic and foreign research results. This article will use this modeling tool to simulate the possibilities that may occur due to the urbanization process in the new urban area of Can Tho under the impact of heavy rain and tide. From there, propose green and sustainable solutions for future planning. The factors that help the author decide are the effectiveness in increasing infiltration capacity, extending the water concentration time, and reducing urban surface runoff.

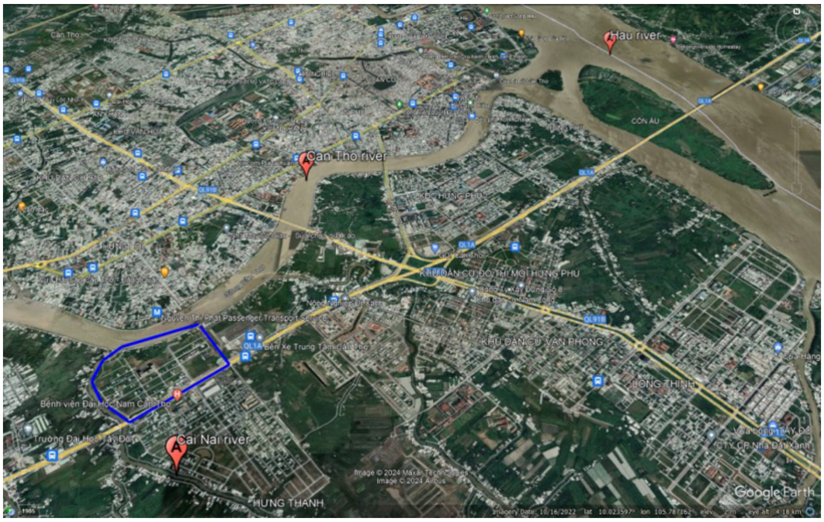


Figure 1. Geographical location of the research area Hung Thanh ward, Cai Rang district, Can Tho City


Figure 2. Current status of land use in Can Tho's new urban area

2. Research methods and data used

2.1. Research methods

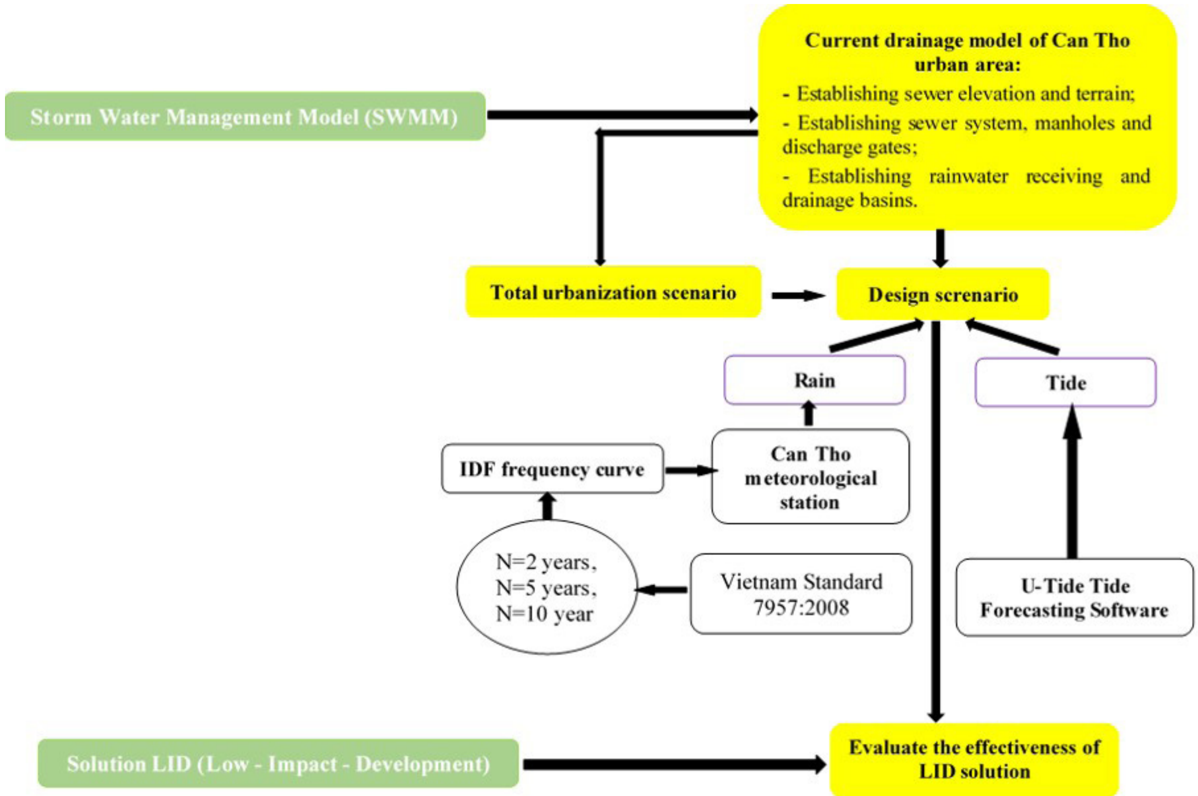


Figure 3. Research method diagram

2.1.1. Establishing drainage model of the study area

The SWMM (Storm Water Management Model) model was developed by the US Environmental Protection Agency in 1971 and was improved to Ver 5.1 in 2015. EPA-SWMM is a computer program used to simulate hydrological, hydraulic, and water quality systems for closed/open sewer networks in drainage basins (urban or rural) [10]. The SWMM model simulates actual rainfall data based on period rainfall, water level factors (tidal process lines at the discharge gate location), and other input data such as technical infrastructure systems, roughness and permeability parameters, etc. to predict flood values for the basin (Figure 3). According to the actual cross-section data at Cai Nai Canal with coordinates 10°00.089'; 105°45.810', the current bank foundation (rightbank) is determined with an elevation of 2.41 m (Figure 4).

From the above data, the study interpolates the values of base elevation, manhole depth, and sewer bottom elevation for the SWMM urban drainage model (Figure 5), serving the calculation of hydrological flow on the basin surface and hydraulic flow in the drainage system.

The urban stormwater drainage system is a combination of manholes and circular sewers with different diameters, designed to flow directly into Cai Nai Canal at 03 outlets CX3, CX4, and CX5. The water collection system is arranged along the bottom of the sidewalk and then leads to the river and canal. Using precast reinforced concrete sewer pipes with diameters D400, D600, D800, D1000. For sewers that take on the role of bearing the load, they will be designed with D=600, 800, and 1,000. The sewer line D=1,000 is the main load-bearing sewer line that directly connects the branch sewer system to the 02 main outlets (Figure 6).

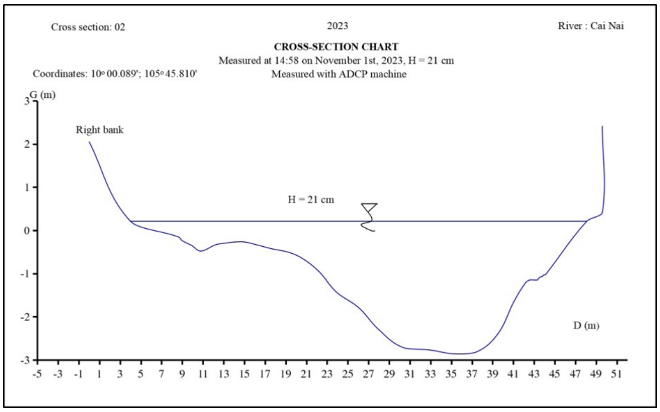


Figure 4. Cross-section diagram of Rach Cai Nai

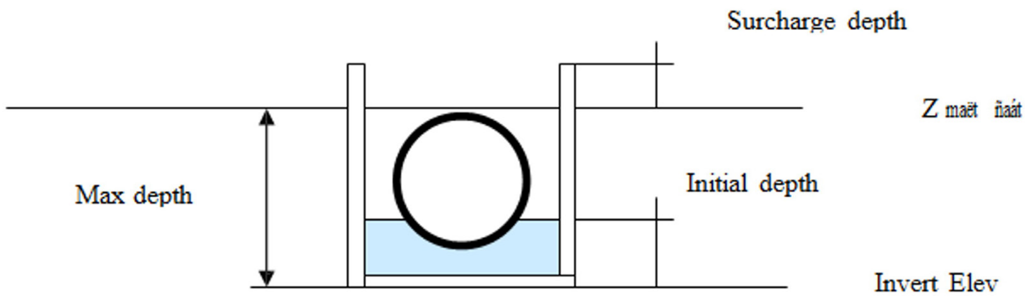


Figure 5. Details of parameters to be declared for urban drainage system

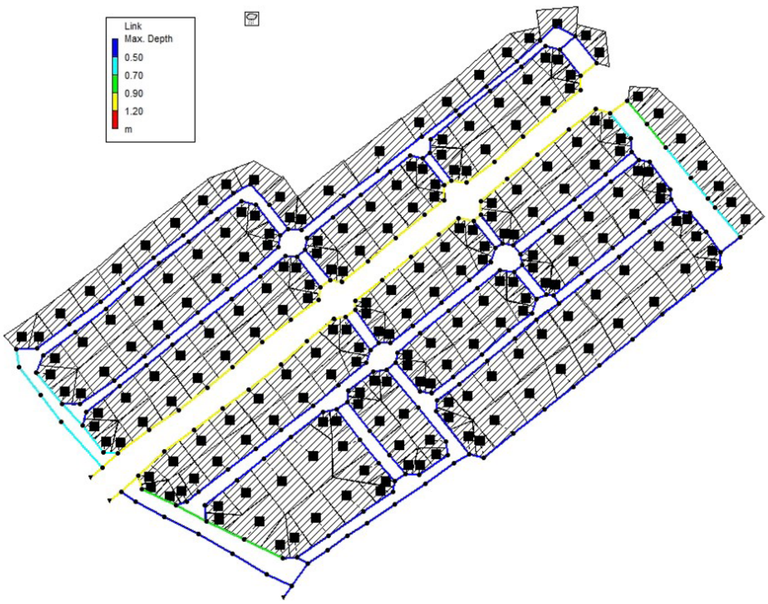


Figure 6. Sewer lines, manholes, outlets, receiving basins and stormwater drainage in the SWMM model of the research area Hung Thanh ward

In the model setup, there are a total of 195 basins, each basin is linked to a corresponding water intake. The basins in the SWMM drainage model are subdivided according to the planned urban planning. The percentage of impervious area (% Imprev) is based on the standard TCVN 7957:2008 [11] (Table 1).

Table 1. *Impermeability parameters according to basin surface*

Drainage surface properties	Waterproof parameters
Roof, concrete surface	0.75
Lawn, garden, park	0.32

2.2.2. Data used in design scenario calculations

Constructing IDF rainfall frequency curve in calculating design rainfall

The IDF curve represents the relationship between rainfall intensity (I) - duration (D) - frequency (F). This is an important characteristic used to determine rainfall intensity by frequency to calculate design rainfall for drainage works and urban planning. The relationship between these three variables is often represented in the form of a graph, in which rainfall duration is placed on the horizontal axis, intensity is placed on the vertical axis and the curves correspond to rainfall frequency (Figure 7), [12-14].

Can Tho is a type I urban area according to urban drainage standards (Viet Nam Standard 7957:2008). To calculate and design the drainage system, it is necessary to take rains with a recurrence period of 2 years, 5 years, and 10 years, corresponding to P = 50%, 20%, and 10%. Take the current rainfall for the 90-minute on April 2, 2023, to build a design rainfall scenario (Figure 8).

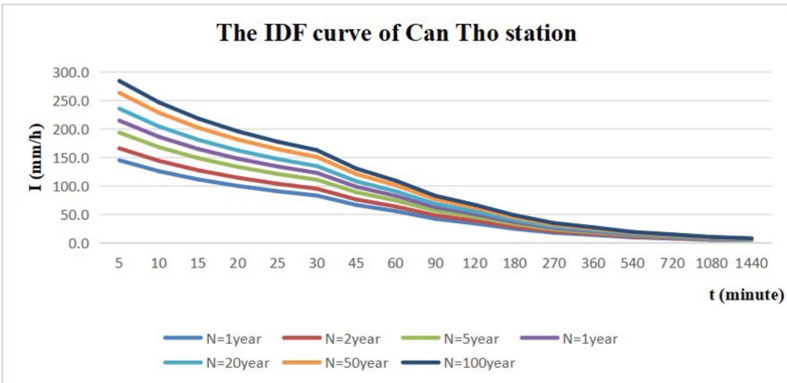


Figure 7. IDF rainfall frequency curve by period at Can Tho station

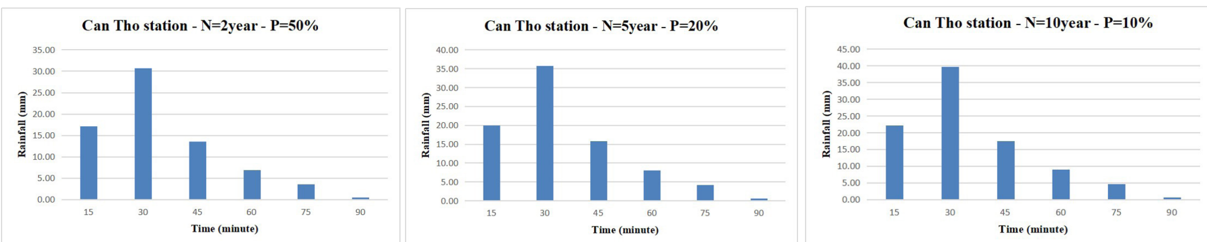


Figure 8. Rainfall scenario P=50%, 20% and 10%

U-tide tide forecasting software in water level calculation application

The U-Tide software uses harmonic constants as input to forecast tide levels for any period. The data in the forecast analysis ensures a long and stable period. Here, the study uses actual hourly observation data series from 2014 to 2023 to check the forecast error.

The Southern region from Ba Ria-Vung Tau to near Ca Mau cape has an irregular semi-diurnal tide regime, so Vung Tau marine station was chosen to analyze the wave constants of the Southern coastal area before forecasting the tide. Table 2 evaluates the amplitude error and phase error with some main wave constants at Vung Tau station, the results show that the amplitude error is quite low, only about 0.011 m and the phase error is 2.8957 degrees. Thus, the forecast level at this station has high accuracy, these wave parameters can be used to forecast future tide levels.

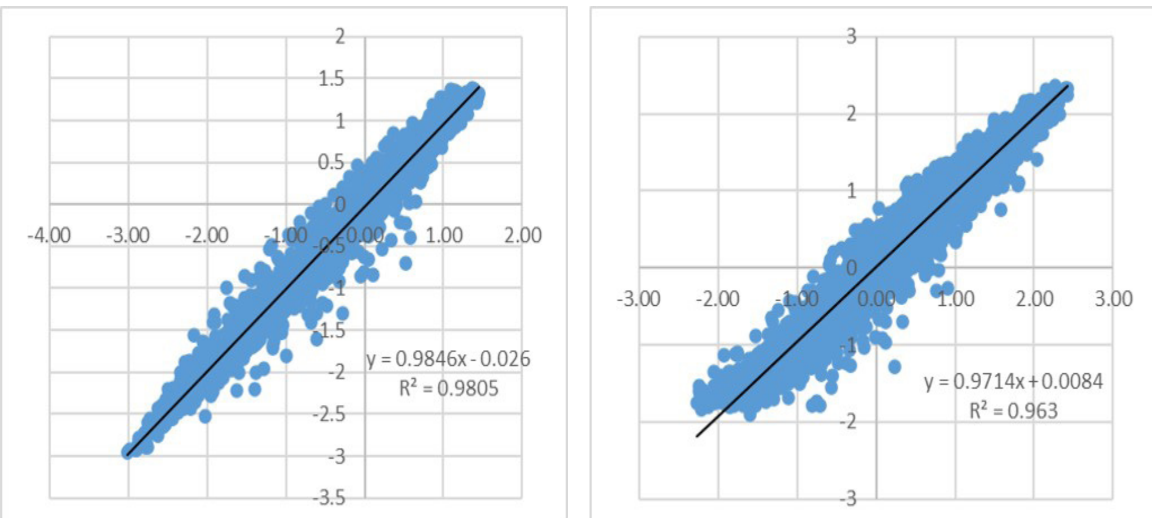
To ensure accuracy after checking the error in the wave constant forecast, water level data continued to be used to evaluate the correlation between the calculation and the actual measurement at Vung Tau and Tran De stations before putting the data into the simulation forecast. The correlation value gave quite good results (Figure 9).

To create scenarios of heavy rain - tides suitable for planning and developing new urban areas, the author proposes to build according to future scenarios, including the expected planning time frame (2030) and the mid-century point of 2050, specifically as follows:

- Scenario 1: 100% urbanization with %Imprev (0.75) - P50% rainfall - forecast tide 2030;
- Scenario 2: 100% urbanization with %Imprev (0.75) - P20% rainfall - forecast tide 2030;
- Scenario 3: 100% urbanization with %Imprev (0.75) - P10% rainfall - forecast tide 2030;
- Scenario 4: 100% urbanization with %Imprev (0.75) - P50% rainfall - forecast tide 2050;
- Scenario 5: 100% urbanization with %Imprev (0.75) - P20% rainfall - forecast tide 2050;
- Scenario 6: 100% urbanization with %Imprev (0.75) - P10% rainfall - forecast tide 2050.

Table 2. Evaluation of amplitude and phase errors at Vung Tau station with main constants

No	Wave constant	Amplitude (m)	Amplitude error (m)	Phase (degree)	Phase error
1	M2	0.783	0.00119	39.6	0.0717
2	K1	0.598	0.000848	313	0.0665
3	O1	0.447	0.000928	263	0.0905
4	S2	0.305	0.00111	81.5	0,215
5	SA	0.212	0.00456	355	1.16
6	P1	0.191	0.000775	309	0.226
7	N2	0.165	0.000877	15.5	0.345
8	K2	0.0948	0.00108	95.0	0.721
Total			0.01137		2.8957



a) Vung Tau station *b) Tran De station*

Figure 9. Water level inspection at stations

3. Results and solutions

3.1. Map of flooding scenarios due to heavy rain, tides and urbanization

Below are 06 maps of flooding scenarios due to heavy rain and tides forecasted to combine the urbanization process in 2 years (2030 and 2050). The inundation depth is interpolated from the result of SWMM model of Hung Thanh urban area established above and DEM (Digital Elevation Model) with a resolution of 15 m x 15 m throught ArcGIS.

The flood level is classified according to standard 338/BXD-KTQH on the urban drainage framework program: light flood (0.1-0.15 m); moderate flood (0.15-0.3 m), severe flood (>0.3 m) (Figure 10).

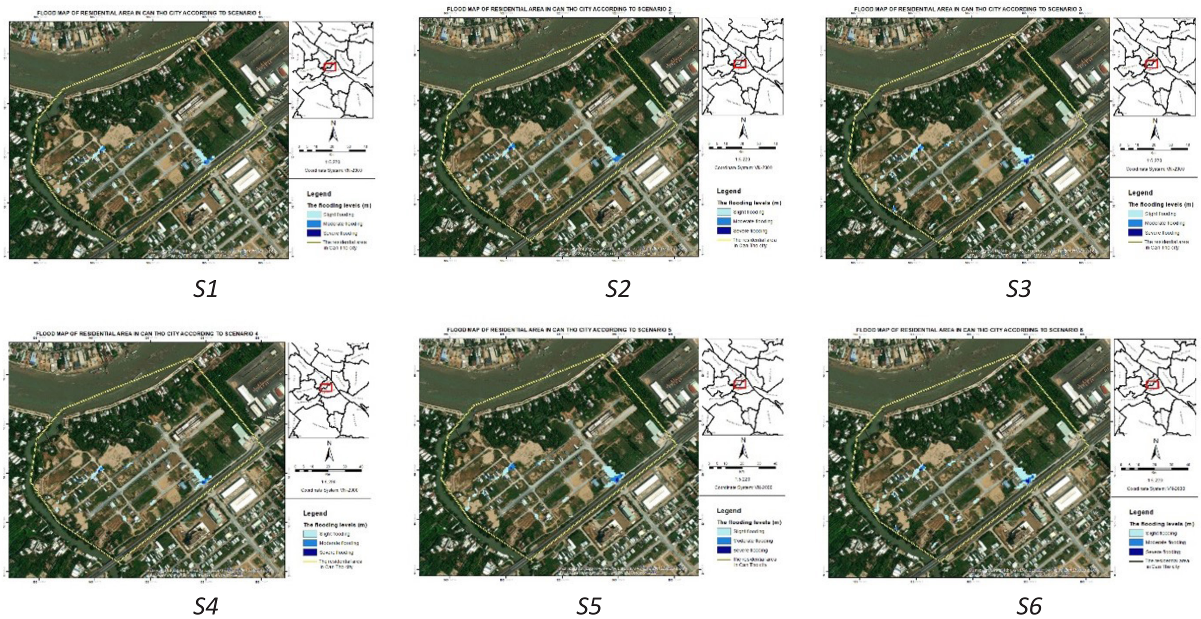


Figure 10. Flood map of Can Tho new urban area according to 6 design scenarios

3.2. Proposed LID solutions to minimize flood level

For construction projects that serve long-term needs, establishing calculation scenarios based on combination factors is extremely necessary. The combination design scenarios are built based on meteorological and hydrological factors, specifically the design rainfall according to the IDF curve and the water level according to the U-Tide forecasting software. To shorten the low-risk scenarios, the author chooses the scenario with the highest rainfall and tide, which is the riskiest of the 06 scenario groups. That is scenario number 6 with rainfall frequency P = 10% with the corresponding water level occurring in the middle of the century

The LID (Low - Impact - Development) solution is a suitable and effective solution for research, it supports the field of urban environmental management. Instead of building deep, straight drainage systems or underground sewer systems to quickly drain rainwater, the sustainable drainage system seeks to delay the drainage of rainwater and considers rainwater as a valuable resource by building urban architecture based on combining green ecological principles with existing drainage principles and technical solutions to reduce the load on the drainage system reasonably. The purpose of this solution is to limit urban flooding, replenish groundwater, minimize environmental pollution, and create green areas for the city. LID solutions [15-19] include Bio-Retention Cell, Green roofs, Permeable pavement, and Rain barrel.

Each LID solution is applied depending on the urban planning infrastructure designed to serve the types of works. For residential and villa projects, LID such as bio-retention systems, green roofs, and rainwater collection systems ensure both green space and water storage and reuse; for projects such as schools, permeable pavement solutions are more suitable when designed as a parking lot, part of a schoolyard, etc.

The results of applying the LID solutions to the mathematical model show that the effectiveness of supporting the reduction of runoff from rain on the surface is up to 80% (Table 3); increasing the self-permeability of the soil, shortening the time to create overflow in each basin and reducing the water level in each manhole (Figure 11).

Table 3. Peak flow reduction rate per basin

Solution	Q max	% decrease in peak Q	Solution	Q max	% decrease in peak Q
Current	0.4	0.25	**Current**	0.5	0.8
Bio-Retention Cell	0.3		**Rain barrel**	0.1	
Current	0.6	0.33	**Current**	0.7	0.43
Green roof	0.4		**Permeable pavement**	0.4	

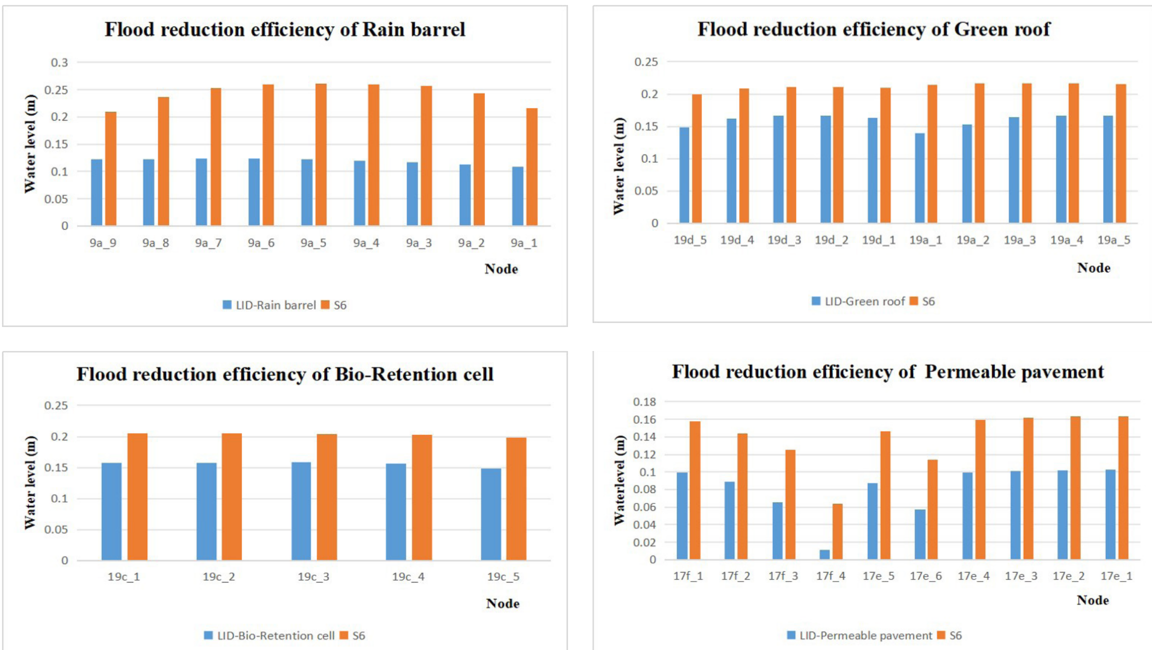


Figure 11. Flood reducton efficiency of LID solutions

The flood reduction ability of LID solutions is quite effective, the flood level has been significantly reduced compared to the current scenario. According to Table 3 and Figure 11, the rainwater harvesting system solution has the best performance among the 4 solutions, reducing 80% of the surface runoff and helping to reduce the water level in each manhole by about 0.14 m.

4. Conclusion

The design scenarios for the combination of rain, tide and urbanization are suitable for the nature of natural conditions and the current status of the new urban area. LID and SWMM in urban stormwater management are built assuming for the basins with flood risks to bring good efficiency, serving to reduce flooding for the project, especially since these solutions are highly sustainable and suitable for the urbanization process but still ensure flood prevention.

However, because the research area is still in the process of planning and investment, the LID solution designs before being applied in practice need to conduct surveys of the terrain, geology, soil, and infrastructure structure of the area for construction, ensuring the best flood reduction efficiency.

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Declaration: *The authors declare that this article is the author's research work, has not been published elsewhere, and is not copied from previous studies; there is no conflict of interest between the authors.*

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