

MINISTRY OF EDUCATION
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**MANAGEMENT OF URBAN SURFACE DRAINAGE
IN THE ĐỒNG HỚI URBAN AREA, QUẢNG TRỊ PROVINCE,
BASED ON THE SPONGE CITY MODEL**

SUMMARY OF DOCTORAL THESIS
SPECIALITY: URBAN AND CONSTRUCTION
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INTRODUCTION

*** Rationale and Significance of the Research**

Urban flooding has become increasingly severe due to rapid urbanization, climate change, and the growing frequency of extreme weather events. In Viet Nam, particularly in coastal cities, urban inundation occurs frequently as a result of heavy rainfall, tidal surges, overloaded drainage systems, and the expansion of impervious surfaces, while climate projections have not been fully integrated into planning, drainage infrastructure remains fragmented, and management practices are highly decentralized. The Đồng Hới urban area (now part of Quảng Trị Province) represents a typical case of high vulnerability to natural hazards, characterized by low-lying topography in the downstream areas of the Nhật Lệ and Dinh rivers, and recurrent flooding during periods of intense rainfall combined with tidal effects. Pilot projects such as the Environmental Sanitation Project, the Coastal Cities Sustainable Environment Project, and the VN-SIPA program have been implemented only on a localized basis and have not yet established an integrated, catchment-based management framework.

In this context, the Sponge City (SPC) model is regarded as an appropriate approach, as it integrates green–grey infrastructure and non-structural measures to regulate surface runoff and enhance urban adaptive capacity. However, in Viet Nam, the implementation of the SPC concept remains at an experimental stage and lacks a comprehensive and coherent management framework.

Pursuant to Law No. 72/2025/QH15 on the Organization of Local Government and Resolution No. 202/2025/QH15 on the rearrangement of provincial-level administrative units, Quảng Bình and Quảng Trị provinces were merged into a single administrative unit named Quảng Trị Province as of 1 July 2025. Accordingly, the original dissertation title, “*Management of Urban Surface Drainage in Đồng Hới City, Quảng Bình Province toward the Sponge City Model,*” has

been revised to “*Management of Urban Surface Drainage in the Đồng Hới Urban Area, Quảng Trị Province, Based on the Sponge City Model*” to ensure consistency with the updated administrative context. The research topic is therefore of high urgency and significance, contributing to the mitigation of urban flooding in the Đồng Hới urban area and supporting the development of a climate-resilient and sustainable urban system under increasing climate and disaster-related pressures.

*** Research Purpose**

The objective of this research is to propose management solutions for urban surface drainage in the Đồng Hới urban area, Quảng Trị Province, based on the Sponge City model, with the aim of mitigating urban flooding, enhancing adaptive capacity to the impacts of climate change, protecting the urban environment, and ensuring sustainable urban development.

*** Research Objectives**

- To clarify the urban surface drainage management approach under the Sponge City (SPC) model through a review of relevant studies and international and domestic experiences.

- To analyze and assess the current situation in order to identify existing problems and limitations in urban surface drainage management in the Đồng Hới urban area, Quảng Trị Province.

- To establish a scientific basis for urban surface drainage management under the Sponge City (SPC) model.

- To develop a system of criteria and indicators for evaluating the effectiveness of urban surface drainage management in accordance with the Sponge City (SPC) model.

- To propose urban surface drainage management solutions for the Đồng Hới urban area under the Sponge City (SPC) model, tailored to the specific conditions of a coastal urban area.

*** Research Object and Scope**

- Research Object: Urban surface drainage management.

- Research scope:

+ Spatial scope: The Đồng Hới urban area, including Đồng Hới Ward, Đồng Thuận Ward, and Đồng Sơn Ward, which constitutes the political and administrative center of Quảng Trị Province (with an area of 155.87 km² and a population of 155,113).

+ Temporal scope: Up to 2030, with a vision toward 2045, in accordance with approved plans issued by competent authorities.

* **Research Methods**

The dissertation employs the following research methods: survey and data collection; analysis and synthesis; inheritance and expert consultation; forecasting; SWOT analysis; map overlay analysis; and mathematical modeling.

* **Scientific Significance of the Research**

- Theoretical significance: Contributing to the systematization of the theoretical basis of the Sponge City model and urban surface drainage management; clarifying the relationship between land-use planning, spatial organization, and drainage infrastructure in management under the SPC model; proposing a new approach for interdisciplinary research on urban infrastructure and climate change adaptation.

- Practical significance: Contributing to the mitigation of urban flooding through the Sponge City approach suitable for the conditions of a coastal city in Central Viet Nam; the results can be applied to management, planning, investment, and training in the field of urban technical infrastructure; meanwhile, pilot outcomes confirm the feasibility of the proposed solutions in the dissertation.

* **New Contributions of the Dissertation**

- Proposing the incorporation of Sponge City-based drainage content into urban planning and the organization of plan implementation.

- Proposing a set of criteria and indicators for evaluating urban surface drainage management under the Sponge City model.

- Proposing a group of general solutions for urban drainage management organization and community participation in accordance with the Sponge City model.

*** Concepts and Terminology**

Key terms, including urban area, green infrastructure, grey infrastructure, existing urban areas, stormwater drainage system, surface drainage system, urban drainage planning, sustainable drainage systems, the Đồng Hới urban area, and urban surface drainage management under the Sponge City model, are compiled and defined in this dissertation to ensure consistency of interpretation throughout the study.

*** Structure of the Dissertation**

In addition to the Introduction, Conclusions, and Recommendations, the dissertation consists of three chapters: *Chapter 1*: Overview of urban surface drainage management under the Sponge City model. *Chapter 2*: Scientific basis for urban surface drainage management in the Đồng Hới urban area, Quảng Trị Province, under the Sponge City model. *Chapter 3*: Proposed solutions for urban surface drainage management in the Đồng Hới urban area, Quảng Trị Province, under the Sponge City model.

CONTENT

CHAPTER 1: OVERVIEW OF URBAN SURFACE DRAINAGE MANAGEMENT UNDER THE SPONGE CITY MODEL

1.1. Overview of Urban Surface Drainage Management under the Sponge City Model in Countries Worldwide and in Viet Nam

The dissertation presents an overview of the Sponge City approach, outlining its formation, development, and the rationale for selecting the Sponge City model for this study. It provides an overall assessment of urban surface drainage management under the Sponge City model in Viet Nam and selected countries worldwide, including the United States, the United Kingdom, the Netherlands, the Federal Republic of Germany, Singapore, and China.

1.2. Current Status of Urban Surface Drainage Management in the Đồng Hới Urban Area, Quảng Trị Province

An introduction to the Đồng Hới urban area, Quảng Trị Province. The research scope of the dissertation covers three newly established wards - Đồng Hới, Đồng Thuận, and Đồng Sơn (formerly Đồng Hới City), Quảng Trị Province, with a total area of 155.87 km² and a population of 155,113 people (Figure 1 and Figure 2).



Figure 1. Location of Quảng Trị Province after the administrative merger on the map of Viet Nam



Figure 2. The Đồng Hới Urban Area on the map of Quảng Trị Province

This section reviews the current status of the urban surface drainage system in the study area, covering catchment conditions, the drainage network, rainfall–storm events, and urban flooding, as well as drainage planning, investment projects, management practices, community participation, and operation and maintenance in the Đồng Hới urban area. It also assesses urban surface drainage management in the Đồng Hới urban area, Quảng Trị Province, using the SWOT method to identify key strengths, weaknesses, opportunities, and threats.

1.3. Scientific Studies Related to the Research Topic

* *Scientific research studies:* This section includes international

studies from countries such as China, Egypt, Bangladesh, the United States, Singapore, and Indonesia, as well as domestic studies, including scientific articles by Vietnamese experts.

* ***Related doctoral dissertations:*** This section analyzes and reviews doctoral dissertations directly related to urban surface drainage management, including: Urban drainage management for provincial capital cities in the Mekong Delta toward sustainable development (Huỳnh Trọng Nhân); Research on proposed solutions for managing the urban drainage network of central Hải Phòng City (Phạm Văn Vượng); Models and management solutions for detention ponds to regulate stormwater and mitigate urban flooding in central Hà Nội (Chu Mạnh Hà); Management of drainage and wastewater planning in Class III cities in the Central Coastal Region of Viet Nam (Vũ Tuấn Vinh); Management of drainage planning to mitigate flooding in urban areas of the Northern Coastal Region in response to climate change (Ngô Huy Thanh); and Models and management solutions for urban drainage systems in provincial capital cities of the Red River Delta up to 2020 (Nguyễn Thị Kim Sơn).

1.4. Key Issues to Be Addressed in the Dissertation

The key issues to be addressed in this dissertation include: The key issues addressed in this dissertation include: (1) clarifying the theoretical basis, international experience, and practical application of urban surface drainage management under the Sponge City model and identifying gaps relative to traditional approaches; (2) identifying key problems in surface drainage management in the Đồng Hới urban area as a basis for solutions; (3) establishing an integrated and multidisciplinary management framework for Sponge Cities and its linkages with SUDS, land-use planning, and urban spatial organization; (4) developing criteria and indicators to evaluate Sponge City management effectiveness; and (5) proposing feasible management solutions adapted to the conditions of coastal cities in Central Viet Nam, including the Đồng Hới urban are.

CHAPTER 2: SCIENTIFIC BASIS FOR URBAN SURFACE DRAINAGE MANAGEMENT IN THE ĐỒNG HỚI URBAN AREA, QUẢNG TRỊ PROVINCE, UNDER THE SPONGE CITY MODEL.

2.1. Theoretical Basis for Urban Surface Drainage Management under the Sponge City Model

* *Role of urban surface drainage management in urban development:* Clarifying the role of urban surface drainage management in sustainable urban development under climate change impacts, from the perspectives of institutions, management tools, and technical solutions;

* *Content of drainage management under the Sponge City model:* Identifying SPC management content based on current regulations; supplementing risk assessment frameworks, priority project selection, coordination mechanisms, enhanced community participation, data systems, evaluation criteria, and review–adjustment mechanisms.

* *Benefits of applying the Sponge City model:* Synthesizing and systematizing the benefits of SPC in flood reduction, water quality improvement, enhanced natural infiltration and storage, improved microclimate, ecology, landscape, urban spatial value, and socio-economic efficiency;

* *Relationship between land-use planning, architectural–landscape space, and sustainable drainage with the Sponge City model:* Clarifying the linkages among land-use planning, spatial organization, SUDS, and SPC; affirming SUDS as the technical foundation and SPC as an integrated management model at the catchment–urban scale.

* *Factors affecting urban surface drainage management under the SPC model:* Identifying and analyzing the impacts of natural conditions, climate change, urbanization, planning, external irrigation

and drainage systems, data and technology, institutions and policies, organizational structures, and staff capacity.

** Roles of stakeholders in urban surface drainage management under the SPC model:* Defining the roles of central ministries, local governments at all levels, operating entities, and communities; emphasizing multi-sectoral and multi-stakeholder coordination mechanisms in Sponge City–based management.

2.2. Legal Basis Directly Related to Urban Surface Drainage Management

** Central-level legal documents related to urban surface drainage:* The dissertation systematizes key laws (the Law on Urban and Rural Planning, the Law on Water Resources, the Law on Environmental Protection, the Law on Irrigation, and the Law on Disaster Prevention and Control), clarifying regulations on stormwater retention and drainage, water resource protection, restrictions on infilling lakes and ponds, prevention of river and stream culverting, and the integration of climate change adaptation and infrastructure safety into urban drainage management.

- Government Decrees:

Clarifying the roles of Consolidated Document No. 13/VBHN-BXD and Decrees No. 80/2014, 05/2025, 145/2025, 178/2025, 53/2024, and 140/2025 in specifying the contents of planning, construction, and operation of drainage systems; delineating the authority of different levels of government; protecting lakes, ponds, and wetlands; and integrating drainage and technical infrastructure into urban planning toward sustainability.

- Ministerial Circulars:

Synthesizing and analyzing Circulars No. 04/2015, 13/2018, 15/2021, 01/2021, 15/2023, 10/2025, and 16/2025, thereby identifying technical requirements, service pricing, sludge management, planning, and data standardization (GIS and drainage information layers), while emphasizing elements aligned with the Sponge City

principles of “retain – infiltrate – regulate – slow discharge.

- *Other documents, standards, and policies:*

Reviewing resolutions and decisions on sustainable development, climate change adaptation, and urban drainage orientation (No. 136/NQ-CP, 589/QĐ-TTg, 681/QĐ-TTg, 1055/QĐ-TTg, etc.) and TCVN 7957:2023, highlighting the compatibility between objectives of stormwater reuse, flow regulation, and increased on-site infiltration and storage with the principles of the Sponge City model.

* ***Local legal documents related to urban surface drainage:*** The dissertation reviews legal documents issued by Quảng Bình Province (now applicable to the Đồng Hới urban area after the administrative merger), clarifying the roles of Decision No. 42/2016/QĐ-UBND on drainage and wastewater management, Decision No. 901/QĐ-UBND on wastewater treatment tariffs, and the Adjusted Master Plan of Đồng Hới City toward 2045 (including the delineation of 13 catchments, hydrological calculations, detention ponds, and water storage spaces) as important legal and technical bases for urban surface drainage management and for integrating SPC principles at the local level.

* ***General remarks on the legal framework:*** The existing system of laws, decrees, circulars, and standards has established a foundational legal framework for integrating the Sponge City model into urban drainage management; at the same time, it confirms that the planning, organizational, technical, and data-related proposals in the dissertation are firmly grounded in the current legal framework.

2.3. Experience in Urban Drainage Management under the Sponge City Model

* ***International experience:*** The dissertation synthesizes experience from China (Wuhan, Nanjing) and Germany (Berlin, Hamburg), clarifying the integration of SPC into planning, infrastructure investment, and management; comparing centralized (central government–led) and decentralized (locally driven) models; and extracting technical indicators (on-site rainfall retention targets,

infiltration rates, stormwater retention ratios, etc.) as a basis for developing SPC evaluation criteria and indicators.

* ***Domestic experience:*** This includes the document “Guidelines for Applying Sustainable Urban Stormwater Drainage Design” issued by the Ministry of Construction in cooperation with GIZ, principle-based tables for selecting solutions by scale and region, and frameworks for stakeholder role allocation; synthesizing pilot projects and programs (SUDS/SPC in the Mekong Delta, VN-SIPA Đồng Hới, Ecopark, etc.) to demonstrate feasibility and multi-objective effectiveness, and to derive practical management indicators and lessons to support the proposed SPC model in the dissertation.

CHAPTER 3: PROPOSED SOLUTIONS FOR URBAN SURFACE DRAINAGE MANAGEMENT IN THE ĐỒNG HỚI URBAN AREA, QUẢNG TRỊ PROVINCE, UNDER THE SPONGE CITY MODEL

3.1. Perspectives, Objectives, and Principles of Urban Surface Drainage Management under the Sponge City Model

* ***Management perspectives:*** The dissertation proposes six perspectives: (1) Complying with the legal framework while incorporating SPC elements; (2) Integrating SPC into urban planning and drainage planning; (3) Ensuring SPC contributes to both flood reduction and enhanced climate change adaptation and environmental protection; (4) Establishing a streamlined organizational structure with clear decentralization and avoiding overlaps; (5) Strengthening the application of information technology, AI, and big data in monitoring and forecasting; (6) Enhancing community and stakeholder participation.

* ***Management objectives:*** Based on these perspectives, the dissertation defines five objectives: (1) Reducing urban flooding and climate change impacts on drainage infrastructure; (2) Integrating structural, non-structural, and nature-based solutions from the

planning stage; (3) Prioritizing digital transformation in SPC management; (4) Ensuring efficient use of resources and mobilizing public–private investment; (5) Promoting the role of ecosystems in infiltration, storage, regulation, and surface water quality improvement.

* ***Management principles:*** The dissertation supplements six SPC management principles, including: (1) Managing stormwater as a resource and controlling it at the source, linked to water quality protection; (2) Integrating SUDS/LID from the planning stage; (3) Institutionalizing community participation; (4) Ensuring multi-sectoral coordination with clear allocation of responsibilities; (5) Prioritizing the application of science, technology, and digital transformation; (6) Ensuring overall effectiveness and evaluability through the SPC criteria system.

3.2. Proposed Technical Management Solutions for Urban Surface Drainage under the Sponge City Model

* ***Proposed criteria and indicators for evaluating drainage management under the Sponge City model:***

The dissertation develops an evaluation criteria system based on relevant principles and requirements, structured into four groups with 15 indicators, of which nine indicators are inherited from international and domestic experience and six indicators are newly proposed to suit the conditions of Viet Nam and the Đồng Hới urban area (Table 1). The proposed indicators enable a comprehensive assessment covering planning, technical infrastructure, operation and maintenance, and organizational management, while being linked to data availability and the potential application of digital transformation in the future. In addition, the dissertation proposes an expected scoring scale (from 0 to 5★) as a flexible evaluation tool, allowing the identification of SPC implementation levels by phase and comparison among cities with different conditions.

Table 1. Proposed Criteria and Indicators for Evaluating Urban Surface Drainage Management in the Đồng Hới Urban Area under the Sponge City Model

Criteria Group	No .	Indicator	Unit
Urban Planning and Drainage Planning	1	Integration of land-use planning, architectural–landscape spatial organization, and drainage planning	Yes/No
	2	Application of green infrastructure solutions combined with grey infrastructure in urban planning	Yes/No
Drainage Technical Infrastructure	3	Stormwater collection and runoff control rate (runoff volume control rate)	%
	4	Percentage of impervious surfaces	%
	5	Water reuse rate	%
	6	Removal rate of suspended solids (TSS)	%
	7	Urban heat island mitigation effect	°C
Operation and Maintenance Management	8	Data digitalization and application of GIS and AI in drainage management	Yes/No
	9	Drainage operation procedures under the Sponge City (SPC) model	Yes/No
	10	Management of drainage system information and databases using GIS	Yes/No
	11	Monitoring of discharge flow and effluent water quality at outfalls using automatic monitoring equipment	Yes/No
Organizational and Institutional Management	12	Supplementation of management functions and responsibilities for SPC-based drainage management among relevant agencies	Yes/No
	13	Availability of guidance, training, and capacity-building programs for SPC-based drainage management	Yes/No
	14	Existence of community monitoring groups and mobilization of resources for	Yes/No

Criteria Group	No .	Indicator	Unit
		operation and maintenance of drainage infrastructure	
	15	Availability of guidance and communication activities promoting the advantages of applying the SPC model in urban drainage management	Yes/ No

**** Proposed selection of sustainable drainage solutions under the Sponge City model:***

The selection of technical solutions is guided by (1) the established SPC criteria–indicator system, (2) objectives of runoff control and flood reduction, water quality improvement, ecosystem restoration, and climate change adaptation, and (3) local natural and technical conditions, land availability, and operational capacity. On this basis, the dissertation proposes a set of solution selection principles linked to an application matrix across three spatial scales (household, neighborhood, citywide) and three terrain slope ranges, thereby identifying eight priority solution groups for the Đồng Hới urban area. The solution system is arranged along a roadmap from pilot implementation to scaling up, linked to maintenance requirements, assignment of responsibilities, and effectiveness evaluation using the proposed criteria system.

**** Proposed incorporation of Sponge City–based surface drainage content into urban planning:***

SPC content is integrated into urban planning through two approaches: (1) newly prepared or comprehensively revised planning documents, and (2) already approved plans; and is specified at three planning levels, including master planning, zoning planning, and detailed planning. The dissertation proposes three solution groups to ensure coherence and feasibility: (1) integrating SPC indicators and components into spatial organization, drainage corridors, and technical infrastructure systems; (2) utilizing mechanisms for partial

adjustments, renovation projects, and local technical guidelines for approved plans; and (3) establishing a set of SPC technical indicators and flexible appraisal mechanisms to enable lower-level plans to proactively integrate SPC while remaining consistent with higher-level plans (Figure 3).

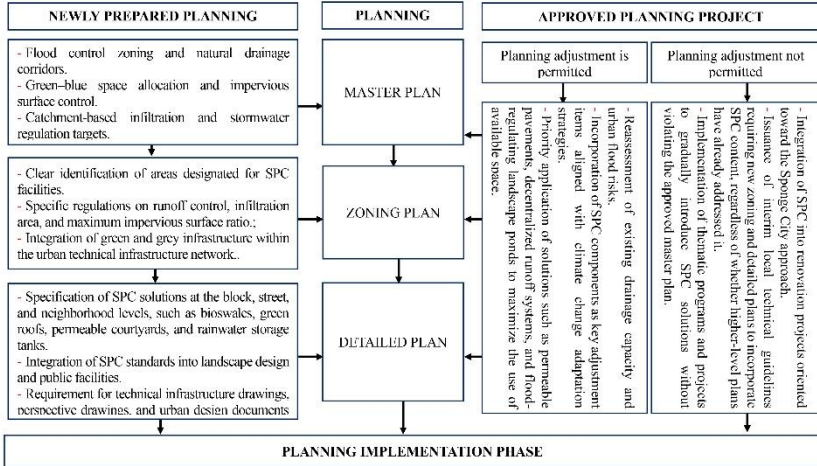


Figure 3. Proposed Procedure for Integrating Sponge City-Based Urban Surface Drainage Content into Urban Planning

3.3. Proposed Organizational Management Solutions for Urban Surface Drainage in the Đồng Hới Urban Area under the Sponge City Model

* *State management organization solutions:* State management solutions for urban surface drainage under the Sponge City model in the Đồng Hới urban area are implemented through institutional consolidation, integration of SPC tasks into existing agencies, and clear delineation of responsibilities, specifically:

- *Division of Economic Infrastructure & Urban Development:* Addition of one SPC officer, with key tasks including: (1) Monitoring, compiling, and synthesizing SPC criteria within the area; (2) Coordinating small-scale SPC projects and linking data with the Department of Construction and the Environmental Services & Urban

Development Company; (3) Managing ward-level SPC databases using basic GIS and updating asset conditions; (4) Providing baseline information for appraisal of provincial-level SPC plans and projects; (5) Coordinating with the Public Utility Services Management Unit in maintenance and compliance inspection of SPC construction; and (6) Organizing communication activities and receiving public feedback on drainage conditions to strengthen community participation in management.

- *Department of Construction*: Supplementation of specialized tasks including (1) Appraisal of planning documents (master plans, zoning plans, detailed plans) and drainage projects integrating the SPC model; (2) Issuance of local technical guidelines, SPC criteria, and evaluation indicators consistent with national codes and standards; (3) Management of provincial-level GIS/BIM databases and linkage with national databases; (4) Leading inter-sectoral coordination to integrate SPC into provincial planning and urban development programs; (5) Proposing policy mechanisms and lists of lakes, ponds, and wetlands to be protected to maintain natural water storage spaces; and (6) Monitoring and supervising SPC implementation across the province, with periodic reporting to the Provincial People’s Committee.

- *Environmental Services and Urban Development Joint Stock Company*: (1) Operating drainage systems combining conventional infrastructure and SPC-based facilities (detention ponds, bioswales, green roofs, etc.); (2) Applying GIS, IoT, and rainfall–flood–flow sensors for monitoring, early warning, and operation; (3) Participating in technical appraisal and providing data for hydraulic and hydrological modeling (SWMM, MIKE Urban, SewerGEMS, etc.); (4) Proposing a list of priority projects for rehabilitation and expansion of SPC-based drainage infrastructure; and (5) Periodically reporting operational performance to management authorities.

- *Public Utility Services Management Unit*: ((1) Maintaining rain gardens, infiltration trenches, bioretention ponds, and other SPC facilities in public spaces; (2) Organizing communication activities to

raise community awareness of the SPC model and urban behavior guidelines associated with sustainable drainage; (3) Receiving and handling public feedback through smart city platforms; and (4) Coordinating with the Environmental Services & Urban Development Company in landscape and technical maintenance to ensure continuous and effective operation of SPC facilities.

*** *Supplementing and refining policy mechanisms:*** (1) Revising Decision No. 42/2016/QĐ-UBND to incorporate SPC management requirements; (2) integrating climate change adaptation objectives into relevant regulations; (3) promoting socialization of small-scale SPC facilities (e.g., rain gardens, green roofs, permeable parking areas); (4) providing standard design support, permit fee incentives, and piloting community-based maintenance contracts; (5) mandating SPC integration in planning and construction permitting; (6) establishing public service procurement for SPC operation and maintenance using environmental service funds; (7) applying the polluter-pays principle in drainage service charges to reduce runoff; and (8) clarifying responsibilities among the Department of Construction, the Department of Agriculture and Environment, local authorities, and operators.

*** *Solutions for improving operation and maintenance management:*** Enhancing SPC-based urban surface drainage operation is implemented through three solution groups: (1) an operational organization model that combines conventional systems with SPC facilities and standardizes procedures through an SPC Operation Manual; (2) digital technology and data application, including GIS, IoT, rainfall–flood–flow sensors, simulation software (SWMM, MIKE Urban, SewerGEMS), and digitized design, operation, and maintenance records in line with Circular No. 16/2025/TT-BXD; and (3) smart city integration, linking SPC facilities with digital maps, cameras, and citizen feedback systems to support real-time operation and community-based monitoring.

3.4. Proposed Community Participation in Urban Surface Drainage Management under the Sponge City Model.

Measures to strengthen community involvement in urban surface drainage management under the Sponge City model focus on: (1) participation in consultation and solution selection at the planning stage; (2) participation in construction supervision, operation monitoring, and incident reporting via smart city platforms; (3) participation in maintaining small-scale green and infiltration facilities in residential areas; (4) participation in communication, awareness raising, and the development of community regulations to protect drainage systems; and (5) participation in catchment-based co-management of SPC infrastructure. These forms of participation are structured across three management stages, as shown in Figure 4.



Figure 4. Community participation across the stages of urban surface drainage management under the Sponge City model

3.5. Application of Research Results to the Bảo Ninh New Urban Area within the Đồng Hới Urban Area

*** Rationale for selecting the pilot area:** The Bảo Ninh New Urban Area is selected due to its complete detailed planning, ongoing infrastructure development, favorable coastal conditions, and relatively complete detention ponds and district-level culvert systems. The area is used to verify the feasibility of the Sponge City model through: (1) supplementing SUDS solutions; (2) applying SewerGEMS modeling with GIS data; and (3) refining management

coordination and strengthening community participation.

* ***An overview of the study area:*** The project applying the research results of the dissertation is the Báo Ninh Urban Area, with an area of 55.83 ha, located within the Đồng Hới urban area (Figure 5).



Figure 5. Location of the Báo Ninh New Urban Area on Google Earth

Natural conditions and current status: Flat, tide-influenced terrain with high groundwater levels and infrastructure under development according to the approved plan; a monsoon climate (average temperature 24.4°C, annual rainfall 1,300–4,000 mm); and typical coastal sandbar–estuary landforms characterized by sand dunes and natural freshwater ponds.

Overview of land use, spatial organization, and approved drainage planning: The planned area includes residential, public-service, green space–water body, transportation, and technical infrastructure land, arranged in a grid with main axes and green corridors. Stormwater runoff is collected into a central detention pond and discharged to the Nhật Lệ River, with a design runoff coefficient of $C = 0.95$.

* ***Analysis of site-specific characteristics for applying the SPC-based evaluation criteria system:*** Báo Ninh has distinctive natural conditions (highly permeable sand dunes, shallow groundwater table, and tidal influence), a newly planned grid-based layout with substantial green and water spaces, and a coordinated drainage system, which are favorable for integrating SPC solutions and quantitatively assessing infiltration, storage, and runoff reduction criteria. As the area is under development, operational procedures and community participation mechanisms can be established at an early stage, making it suitable for developing and applying the criteria system.

*** Proposed sustainable drainage solutions for the Bảo Ninh New Urban Area:** Proposed solutions include green roofs for high-rise buildings, permeable parking areas, roadside bioswales, enhanced detention pond functions, and green strips with sunken planting beds along sidewalks. Selected solutions are incorporated into SewerGEMS simulations to assess runoff reduction and drainage performance.

*** Application of SewerGEMS Connect Edition for hydraulic simulation of the drainage system**

- *Overview of SewerGEMS Connect Edition:* SewerGEMS Connect Edition is a hydraulic–hydrologic simulation software for stormwater, wastewater, and combined sewer systems, enabling analysis of drainage capacity, optimization of facility size and location, and integration of SWMM algorithms and GIS data.



Figure 6. Simulation Results of the Drainage Network before the Application of the SPC Model



Figure 7. Simulation Results of the Drainage Network after the Application of the SPC Model

- *Simulation process and results:* The Bảo Ninh New Urban Area (55.83 ha) is simulated under two scenarios: (1) the current design and (2) a SUDS-applied design. The process includes data preparation, GIS/CAD setup, network input, application of the Rational Method with the GVF-Rational solver, model execution, and result comparison. Figures 6 and 7 present simulation results, while

Appendices 3 and 4 show drainage network changes before and after SUDS application.

**** Application of GIS in Urban Surface Drainage Management under the Sponge City Model***

- *Development of the database system:* The database system consists of three data layer groups: (1) base data; (2) land-use, architectural–landscape space, and urban design data; and (3) ground elevation and urban surface drainage data. Map data are collected from approved planning documents, edited, standardized, and converted into ArcGIS format (ESRI standard) using the VN2000 coordinate system.

- *Application of GIS in urban surface drainage management*
 - + Manhole information management: Key parameters to be managed include manhole name, ground elevation, main pipe invert elevation, and location coordinates (Figure 8).

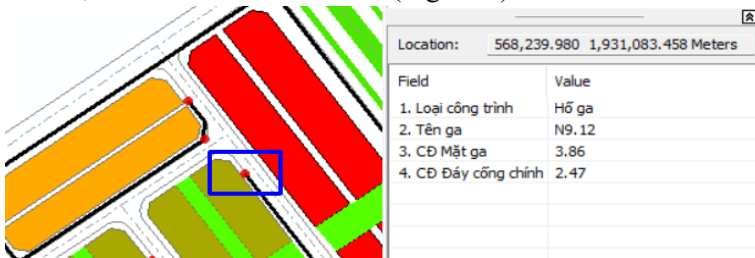


Figure 8. Stormwater Manhole Data

- + Drainage pipe information management: Storing information such as pipe length, slope, upstream and downstream manholes, and diameter to assess drainage performance and identify potential bottlenecks (Figure 9).

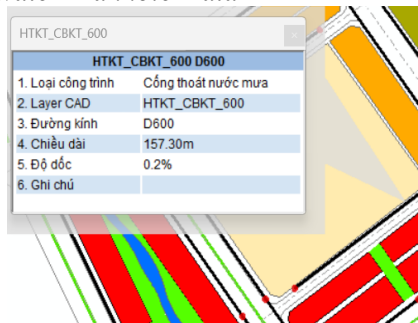


Figure 9. Drainage Pipe Management Data

+ Green space land information management: Green land parcels are assigned unique IDs (land tags), specific areas, and information on SUDS solutions that have been applied or are planned for implementation (Figure 10).

QH_CX	
1. Loại công trình	Cây xanh
2. Layer CAD	QH_CX
3. Tem đất	CX3
4. Diện tích	1656.09 m2
5. Giải pháp SPC	Dải / bãi lọc sinh học; Vườn thảm; Lưu vực thấm / lưu trữ nước; Mương lọc sinh học

Figure 10. Green Space Management Data

+ Villa, row housing, and commercial residential land: Managing land parcel IDs, area, number of buildings, building density, maximum building height, and applied SUDS solutions enables accurate determination of infiltration capacity and

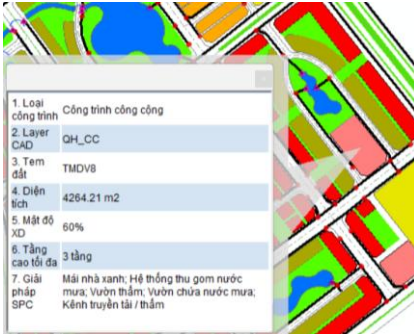
26 nhà	
1. Loại công trình	Nhà ở liền kề
2. Layer CAD	QH_OLK
3. Tem đất	LK2A
4. Diện tích	3387.02 m2
5. Số nhà	26 nhà
6. Mật độ XD	80%
7. Tầng cao tối đa	5 tầng
8. Giải pháp SPC	Mái nhà xanh; Thu nước mái và đường; Vườn thảm; Tường xanh / mảng tường đứng; Vườn chứa nước mưa

Figure 11. Data for Managing Row Housing

the volume of stormwater to be controlled at the source (Figure 11).

+ Social housing, mixed-use buildings, and public facilities: GIS clearly represents land parcel IDs, area, building density, maximum building height, and appropriate SUDS solutions to reduce loads on the drainage network (Figure 12).

+ Parking areas: Managing area, surface paving materials, and applied SUDS solutions such as permeable paving, bioretention filter layers, or underground storage tanks provides a basis for integrating sustainable drainage solutions into urban functional spaces (Figure 13).



1. Loại công trình	Công trình công cộng
2. Layer CAD	QH_CC
3. Tên đất	TMDV8
4. Diện tích	4264.21 m2
5. Mật độ XD	60%
6. Tầng cao tối đa	3 tầng
7. Giải pháp SPC	Mái nhà xanh; Hệ thống thu gom nước mưa; Vườn thấm; Vườn chứa nước mưa; Kênh truyền tải / thấm

Figure 12. Public Facilities Management Data



1. Loại công trình	Bãi đỗ xe
2. Layer CAD	HTKT_BDX
3. Diện tích	240 00 m2
4. Loại vật liệu	Gạch thấm
5. Giải pháp SPC	Bể chứa nước mưa; Vườn thấm; Lưu vực thấm / lưu trữ nước; Mương lọc sinh học

Figure 13. Parking Area Management Data

*** Operation organization, community participation, and**

implementation roadmap:

- *Operation organization:* Integrated operation of grey and green infrastructure; development of SPC operating procedures; task allocation with the Environmental Services & Urban Development Company responsible for operation, the Public Utility Services Unit responsible for maintenance of green facilities, and the community monitoring through smart city applications.

- *Community participation:* Establishment of SPC community monitoring groups; implementation of the “Green Neighborhood – Clean Drainage” initiative; strengthening communication and guidance on the maintenance of green and infiltration facilities.

- *Implementation roadmap:* 2025–2027: data completion and pilot implementation of SPC solutions; 2028–2032: expansion and refinement of coordination mechanisms; After 2032: standardization, scaling up, and integration into urban planning.

33.6. Discussion of Selected Research Results of the Dissertation

*** Discussion of technically related solutions**

The three technical pillars include: (i) the SPC criteria and indicator system; (ii) selection of locally appropriate sustainable drainage solutions; and (iii) integration of SPC into urban planning. The criteria system and the 0–5 star scoring scale enhance objectivity, while SPC

solutions are selected based on local conditions and integrated through a three-step procedure.

**** Discussion of state management solutions:***

This group of solutions focuses on clarifying responsibilities, refining policies, establishing SPC operation procedures, and strengthening community participation across three management stages. Streamlining the organizational structure and providing clear legal guidance are essential. Implementation largely depends on diversifying financial resources beyond the state budget.

**** Discussion of proposed solutions in the context of provincial merger, management model reform, and the effectiveness of a two-tier local government system:***

Although the dissertation was developed under a three-tier government model, the proposed SPC solutions remain applicable—and even more advantageous—under a two-tier system. The two-tier model helps to: (1) shorten procedures and accelerate incident response; (2) enhance the proactive role of communes/wards in supervision and operation; (3) improve inter-sectoral coordination through the consolidation of infrastructure and environmental functions; (4) use resources more efficiently; and (5) increase integration in SPC management.

**** Discussion of the scalability of research results to coastal cities under different development contexts:***

The urban surface drainage management solutions under the Sponge City model for the Đồng Hới urban area are developed using an integrated management approach that links natural conditions, urban space, technical infrastructure, and institutional frameworks. For coastal cities with similar conditions, the principles and solutions can be applied relatively directly. For coastal cities with different development contexts, the model should be flexibly adjusted in terms of implementation scale and roadmap to ensure feasibility and effective climate change adaptation.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The dissertation demonstrates that the SPC model is an integrated management approach well suited to the context of increasing flooding driven by climate change in coastal urban areas such as the Đồng Hới urban area. The study has: (1) clarified the theoretical foundation and management content of the SPC model; (2) assessed the current status of urban surface drainage management in the study area and identified key limitations; (3) clarified the linkages among SUDS, land-use planning, and urban spatial organization; (4) developed a system of criteria and indicators for evaluating the effectiveness of SPC management; and (5) proposed a feasible SPC management solution system with reference value for coastal cities with similar conditions.

Recommendations

1. At the central level: Complete the legal framework and incorporate SPC into codes and standards; integrate SPC across planning levels; pilot SPC in selected special-context cities.

2. At the local level: Review and update SPC in planning and investment programs; enhance staff capacity on SPC and digital technologies; establish flexible financial mechanisms (PPP, green finance).

3. For the community: strengthen communication and awareness raising; promote community participation in SPC operation, maintenance, and monitoring.

4. Future research directions: Expand validation of the criteria system across different urban types; analyze the socio-economic and environmental impacts of SPC; further refine and quantify the criteria system based on empirical data and simulations.

LIST OF THE AUTHOR'S PUBLISHED SCIENTIFIC WORKS RELATED TO THE DISSERTATION

Professional journal articles:

1. Nguyen Huu Phu (2025), *Proposal some solutions for surface drainage management in Dong Hoi urban area according to the Sponge City model*, Construction Planning Journal, No. 12.2025, ISBN 2734-9888.
2. Nguyen Huu Phu (2025), *Research and proposal of criteria and indicators for evaluating urban stormwater management towards the sponge City model*, Construction Planning Journal, No. 9.2025, ISBN 2734-9888.
3. Nguyen Huu Phu (2024), *Some theoretical and legal foundations for urban stormwater management towards a sponge city model*, Construction Planning Journal, No. 9.2024, ISBN 2734-9888.
4. Nguyen Huu Phu (2023), *Sustainable Urban Drainage solutions applying in Vietnam - situation and proposed*, Construction Planning Journal, No. 06.2023, ISBN 2734-9888.
5. Nguyen Huu Phu (2023), *Some lessons learned in applying sponge cities around the world*, Applied Science and Technology in Construction - ASTC 2023, ISBN 978-604-478-966-8, Ha Noi Publisher.

Textbooks for Teaching Purposes:

1. Vu Hoang Diep, Nguyen Thi Lan Anh, Chu Van Hoang, Dinh Thi Thu Hoai, Nguyen Huu Phu, Tran Quang Huy, Nguyen Thi Ngoc Uyen (2023), *Site Preparation for Construction (Part 1)*, ISBN 978-604-82-7661-4, Construction Publisher.

Institutional-Level Scientific Research Projects:

1. Chu Van Hoang, Nguyen Huu Phu (2025), *Research on the instructional content for the course Design Project: Site Preparation for Construction (Part 1) under the Urban Infrastructure Engineering specialization*, Hanoi Architectural University.