



华南理工大学
South China University of Technology

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基于雨水管理的广州滨水工业遗存园区
公共空间设计研究——以紫坭糖厂为例

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Research on Public Space Design of Guangzhou's Waterfront Industrial Heritage Park Based on Stormwater Management: A Case Study of Zini Sugar Factory

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摘 要

在城市由增量扩张转向存量更新的发展语境下，滨水工业遗存园区的公共空间设计正处于文化遗产保护与生态功能重塑的双重叙事交汇点。相较于一般城市更新项目，此类场地因临江傍河而更具生态敏感性，同时亦面临工业时期遗留的大面积硬质化地表、合流制排水系统溢流污染及空间碎片化等历史欠账。然而，当前主流设计实践多侧重于工业美学的视觉转译与空间功能的业态置换，对于雨水径流的系统性管控及水生态韧性的构建仍存在显著缺位。面对极端气候频发与水源保护升级的现实压力，如何将雨水管理与工业遗存更新融合，使其成为激活滨水公共空间生态与人文价值的显性驱动力，已成为亟待回应的设计命题。

本研究以雨水管理为核心视角，引入水敏性城市设计与海绵城市理念作为理论工具，旨在探索雨水基础设施与工业遗产公共空间一体化设计的融合路径。研究针对广州滨水工业遗存的特殊水文地理条件与遗产保护限制，进行了兼顾水文效能、工业美学遗产保护与滨水公共活力的可持续设计方法实践。具体而言，研究遵循了“场地水文诊断—遗产价值评估—设计策略生成—绩效量化反馈”的技术路线：首先，通过对广州既有滨水工业遗存更新项目的实地调研与类型化分析，识别其在水生态功能上的共性缺失与空间设计痛点；进而，以紫坭糖厂为实证对象，揭示该场地的工业遗存价值与水文过程间的耦合矛盾。在具体设计中，研究涵盖了从建筑单体到场地整体的多层级雨水管理策略，强调通过雨水花园、生态滤池、蓄水模块等低影响开发设施，将原本被忽视的径流过程转化为具有工业记忆展示与公共游憩价值的景观叙事载体。通过上述路径，旨在为城市滨水区域中工业遗存的生态化转型提供设计实践案例。

研究遵循“理论研究—现状诊断—基地解析—设计实践”的逻辑展开。首先，通过文献综述系统梳理雨水管理理念演进与工业遗存更新理论，学习两者结合的理论框架。其次，通过对广州滨水工业遗存的实地调研与类型化分析，归纳其在空间建筑特征、水文生态问题及更新实践困境中的共性挑战，提炼引入系统性雨水管理策略的必要性与设计原则，并确立引入设计分析表与雨水管理绩效计算。在此基础上，选取广州紫坭糖厂作为实证案例，通过区域背景、历史沿革与水管理现状的解析，诊断其工业遗存价值与水文过程的耦合矛盾，明确水源保护、社区割裂与遗存创新利用三大核心问题。最后，借助设计实践方法，提出以雨水管理为切入点的公共空间更新方案，重点从总体布局梳理、水的形态重构以及建筑、道路、绿化与水的要素组合三个维度展开空间策略，并依据预先设定的绩效计算体系，从规划、场地、建筑三个层级对方案的径流控制与水质净化效能进行量化评估与调整反馈。

研究结果表明：1) 雨水管理策略与工业遗存保护并非不可调和的矛盾，通过低影响开发设施的分散化、微创化植入，可在不破坏历史肌理的前提下，系统应对场地径流调

控与面源污染防治的生态挑战。2) 紫坭糖厂设计实践验证了雨水管理作为空间叙事媒介的潜力：方案通过“源头—过程—末端”全流程体系的实践，将原有的硬质排水界面转化为雨水花园、生态滤池与蓄水模块等兼具生态功能与工业记忆展示的景观节点，有效提升了场地的雨洪调控能力与空间复合利用价值。3) 以“水的形态重构”为线索，雨水管理策略深度介入建筑界面、道路竖向与绿化配置，实现了水文过程可视化、遗产记忆活态化与公共生活日常化的三位一体协同。研究证实，以雨水为导向的设计路径能够为滨水工业遗存园区注入兼具生态韧性与文化厚度的公共活力。

关键词：雨水管理；滨水工业遗存；公共空间设计；绿色基础设施；水敏性城市设计

ABSTRACT

Against the backdrop of Chinese urban development transitioning from incremental expansion to stock-based regeneration, the design of public spaces in waterfront post-industrial heritage parks sits at the intersection of two compelling narratives: cultural heritage conservation and ecological performance reclamation. Compared with conventional urban renewal projects, these waterfront sites exhibit heightened ecological sensitivity due to their adjacency to rivers and streams, while simultaneously confronting a legacy of environmental deficits inherited from their industrial past—namely extensive impervious surface coverage, combined sewer overflow pollution, and spatial fragmentation. Nevertheless, prevailing design practices tend to prioritize the visual translation of industrial aesthetics and the functional reprogramming of spatial uses, often neglecting the systematic management of stormwater runoff and the cultivation of water-related ecological resilience. In the face of mounting pressures from increasingly frequent extreme weather events and exacerbated non-point source pollution, the question of how to liberate stormwater management from concealed engineering pipe networks and transform it into a visible catalyst for activating both the ecological and cultural values of waterfront public space has emerged as a pressing design proposition.

Adopting stormwater management as its central analytical lens, this study draws upon the theoretical apparatus of Water Sensitive Urban Design (WSUD) and the Sponge City concept to investigate an integrated design pathway that synthesizes stormwater infrastructure with the public realm of industrial heritage sites. Focusing on the specific hydrogeographic conditions and heritage conservation constraints characteristic of Guangzhou's waterfront industrial remnants, the research proposes a sustainable design framework that reconciles hydrological efficacy, the preservation of industrial aesthetic integrity, and the enhancement of waterfront public vitality. Methodologically, the study establishes a technical trajectory comprising "site hydrological diagnosis—heritage value assessment—design strategy generation—quantitative performance feedback." First, through field investigations and typological analyses of completed waterfront industrial heritage regeneration projects in Guangzhou, the study identifies common deficiencies in hydro-ecological functionality and recurring spatial design challenges. Subsequently, taking the Zini Sugar Factory as an in-depth empirical case study, a SWOT analysis is deployed to pinpoint precisely the coupled contradictions between the site's industrial heritage significance and its ongoing hydrological processes. In terms of concrete design intervention, the research explores a multi-scalar stormwater management strategy spanning from individual building envelopes to the overall site fabric. It emphasizes the deployment of Low Impact Development (LID) facilities—such as rain gardens, bioretention swales, and subsurface storage modules—to recast previously overlooked runoff processes as landscape narrative vectors that embody both the commemoration of industrial memory and the provision of public recreational amenity. Through this approach, the study seeks to furnish actionable design guidance for the ecological transformation of industrial heritage within high-density urban waterfront zones.

The research proceeds in accordance with the logical sequence of "theoretical framework construction—current condition diagnosis—site analysis—design verification." It commences with a systematic literature review tracing the evolution of stormwater management paradigms alongside theories of industrial heritage regeneration, thereby establishing a synthesized theoretical foundation for their integration. Following this, fieldwork and typological analysis of Guangzhou's waterfront industrial remnants are conducted to delineate shared challenges pertaining to spatial-architectural characteristics, hydro-ecological predicaments, and obstacles encountered in renewal practice. This phase crystallizes the imperative and design principles for introducing systematic WSUD strategies and establishes a research operational framework inclusive of a design evaluation matrix and a stormwater management performance calculation protocol. Building upon this foundation, the Zini Sugar Factory in Guangzhou is selected as the empirical case. Through an examination of its regional context, historical evolution, and current water management status, a SWOT analysis is employed to precisely diagnose the coupled conflicts between industrial heritage value and hydrological dynamics, thereby clarifying three core issues: water source protection, community severance, and the adaptive reuse of heritage assets. Ultimately, leveraging design praxis, the study advances a public space renewal scheme predicated on stormwater management as the key entry point. The spatial strategy unfolds across three dimensions: the reorganization of the master plan, the reconfiguration of water morphology, and the choreography of integrated components involving architecture, circulation networks, planting, and water features. In accordance with a predetermined performance calculation framework, the runoff control and water quality treatment efficacy of the proposed scheme are quantitatively evaluated and iteratively refined across three scalar tiers: the regional plan, the site scale, and the individual building.

The research findings reveal that: 1) Stormwater management strategies and industrial heritage conservation are not inherently irreconcilable. Through the decentralized and minimally invasive implantation of Low Impact Development facilities, the ecological challenges of runoff regulation and non-point source pollution control can be systematically addressed without compromising the integrity of the historical fabric. 2) The design practice at Zini Sugar Factory substantiates the potential of stormwater management as a medium for spatial narrative. By establishing a comprehensive "source—conveyance—end-of-pipe" treatment train, the scheme transforms formerly impervious drainage interfaces into landscape nodes—such as rain gardens, bioretention filters, and retention modules—that concurrently perform ecological functions and articulate industrial memory, thereby significantly enhancing the site's stormwater regulation capacity and the compound value of its spatial utilization. 3) Guided by the motif of "water morphology reconfiguration," stormwater management strategies deeply intervene in the design of building interfaces, road grading, and planting configurations, thereby effectuating a tripartite synthesis encompassing the visualization of hydrological processes, the vitalization of heritage memory, and the normalization of everyday public life. The study substantiates that a stormwater-driven design approach can infuse waterfront post-industrial heritage parks with a form of public vitality that embodies both ecological resilience and cultural profundity.

Keywords: Stormwater Management; Waterfront Industrial Heritage; Public Space Design; Green Infrastructure; Water Sensitive Urban Design

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Chapter 1: Introduction

1.1 Research Background and Genesis

1.1.1 Revaluation of Waterfront Industrial Heritage in the Context of Urban Stock-Based Regeneration

Since the beginning of the 21st century, urban development in China has been undergoing a significant transition from "incremental expansion" to "stock-based optimization." Amidst industrial restructuring and the upgrading of urban functions, a substantial number of industrial compounds situated along urban waterfronts have progressively ceased production activities, thereby emerging as latent urban spatial resources awaiting regeneration. Guangzhou, as one of the cradles of modern industry in China, features a concentration of historically significant industrial remnants distributed along both banks of the Pearl River. These range from shipyards dating back to the late Qing Dynasty, sugar refineries established during the Republican era, to iron and steel plants and chemical factories constructed after the founding of the People's Republic of China. Such industrial heritage sites not only bear witness to the city's trajectory of industrialization but also embody the collective memory and regional cultural identity of several generations.

Concomitantly, the development of urban waterfront zones has garnered increasing attention, given their dual role as both ecologically sensitive corridors and focal points of public vitality. The pronounced spatial convergence between industrial remnants and waterfront areas renders the regeneration of waterfront industrial heritage a critical subject within the domain of urban design. These sites simultaneously possess industrial historical significance and waterfront ecological value. Consequently, their renewal design must not only respond to the imperatives of heritage conservation but also address the safety challenges inherent to riparian environments, all while fulfilling the aspirations of urban residents for high-quality public space.

1.1.2 The Absence and Limitations of "Water" Considerations in Contemporary Waterfront Industrial Heritage Regeneration

Guangzhou is characterized by a subtropical maritime monsoon climate, with an average annual precipitation of approximately 1800 mm. Over 80% of this rainfall occurs during the flood season, which is marked by frequent torrential downpours compounded by the backwater effects of typhoons and astronomical high tides. Consequently, the city faces pronounced risks of both urban waterlogging and waterfront inundation. Simultaneously, Guangzhou possesses a highly developed and densely reticulated river network. A significant

proportion of its industrial heritage sites were established along the Pearl River and its tributaries, giving rise to a spatial pattern predicated on riparian proximity. Nevertheless, within the ongoing process of stock-based regeneration, "water"—as a dynamic ecological agent and a latent landscape resource intrinsic to the site—has persistently been relegated to a condition of neglect or reductive simplification. This phenomenon manifests across four interrelated dimensions.

First, drainage paradigms exhibit a marked inertia toward conventional engineering solutions. Traditional industrial compounds predominantly employed combined sewer systems or direct stormwater discharge mechanisms, guided by the principle of "rapid conveyance and expedited drainage." Prevailing regeneration practices largely perpetuate this trajectory by resorting to grey infrastructure interventions such as the upsizing of subterranean pipe networks and the enlargement of conduit diameters. Stormwater thus continues to be construed as "wastewater" requiring swift evacuation. For a city like Guangzhou, which experiences high-intensity, short-duration storm events, a drainage strategy reliant exclusively on piped conveyance proves inherently susceptible to site-level inundation under exceedance rainfall conditions. Moreover, it severs the natural hydrological connectivity between precipitation and surficial ecological processes.

Second, heritage conservation imperatives impose constraints on the implementation of stormwater facilities. The constituent elements of industrial heritage—including mill buildings, machinery plinths, and ground paving systems—are subject to stringent regulations governing character preservation and structural integrity. Conventional Sponge City measures, such as sunken green belts, the excavation required for underground detention tanks, and topographic regrading, often prove impracticable due to their potential to disturb historical strata or disrupt the legibility of the industrial fabric. The inherent tension between conservation mandates and ecological exigencies situates stormwater management strategies within a paradox of "theoretical applicability yet practical infeasibility" on heritage grounds.

Third, a tendency toward the semiotic reduction of aquatic landscape value is prevalent. While a number of renewal projects have incorporated water features to enhance the ambience of the waterfront, such interventions frequently remain confined to the realm of visual ornamentation—exemplified by geometric reflecting pools or the fragmentary retention of wharf structures. The ecological processes associated with water and the site's capacity for stormwater retention and detention are systematically decoupled. The water body is thereby reduced to a static decorative element divorced from the broader ecosystem. Under Guangzhou's humid and warm climatic conditions, enclosed water features are particularly

susceptible to eutrophication and the proliferation of mosquitoes and other pests, paradoxically imposing an increased maintenance burden.

Fourth, the waterfront interface is characterized by functional monotony and ecological fragmentation. During the industrial era, the shoreline was predominantly encumbered by hard-engineered facilities such as docks, wharves, and loading platforms. Although regeneration efforts have sought to transform these areas into waterfront promenades, the land-water interface typically remains afflicted by issues including abrupt grade transitions, monospecific vegetation cover, and a conspicuous absence of ecological buffering capacity. Surface runoff from the site frequently discharges directly into adjacent riverine systems without prior interception or treatment, thereby exacerbating the pollutant loading of receiving waters and simultaneously precluding opportunities for the creation of a composite waterfront space that integrates purification functions with recreational amenity.

1.1.3 The Emergence and Application Potential of Stormwater Management

Under the compounding pressures of global climate change and accelerated urbanization, the conventional drainage paradigm predicated upon "grey infrastructure" dominance has proven increasingly inadequate in addressing the escalating complexity of urban water environmental challenges. It is within this context that the philosophy of Water Sensitive Urban Design (WSUD) has emerged as a salient response. Originating in Australia, WSUD seeks to holistically integrate the management of the urban water cycle into the processes of urban planning and design. By emulating natural hydrological regimes and deploying ecological, decentralized technical measures—including rain gardens, bioretention swales, and permeable pavements—it endeavors to achieve a multiplicity of objectives at the source, encompassing runoff pollution control, peak flow attenuation, water resource reclamation, and ecological enhancement. The foundational insight proffered by WSUD is that stormwater management constitutes not merely a matter of engineering technique, but fundamentally a challenge of spatial design. It advocates for the landscape-oriented and aesthetic articulation of water infrastructure, thereby rendering the processes of stormwater conveyance and purification both legible and experiential.

The introduction of WSUD principles into the domain of waterfront industrial heritage regeneration holds considerable promise. It not only offers a systematic means of ameliorating a site's hydro-environmental deficiencies and bolstering its ecological resilience but, more profoundly, enables the transformation of stormwater management facilities into distinctive elements of public space. Such an approach has the potential to infuse industrial heritage sites

with both ecological integrity and aesthetic value, serving as a verdant nexus that connects the past, the present, and the future. For the Zini Sugar Factory in Guangzhou—a paradigmatic site situated within the pluvial Lingnan region and endowed with a rich legacy of industrial hydraulic structures—a stormwater management design informed by the precepts of WSUD represents a critical pathway for confronting urban water challenges and unlocking the latent potential of the site.

1.1.4 Topic Origin and Problem Formulation

This study seeks to address a central research question: How can the principles of stormwater management be deployed as an integral and integrative methodology within the regeneration practice of waterfront industrial heritage sites in Guangzhou? The aim is to systematically resolve the multifaceted challenges these sites confront—encompassing hydro-ecological degradation, the imperatives of historical conservation, and the imperative for community revitalization—and thereby to delineate a sustainable development pathway characterized by ecological primacy, cultural continuity, and communal inclusivity. Through empirical design research centered on the Zini Sugar Factory, this study endeavors to furnish a concretized response to the aforementioned question and to offer both theoretical reference and strategic guidance for the regeneration of analogous post-industrial waterfront sites within the Guangzhou context.

1.2 Object of Study

1.2.1 Stormwater Management

As employed in this study, the term "stormwater management" does not denote the conventional urban drainage practice aimed solely at the expedited removal of runoff. Rather, it refers to a comprehensive and systematic strategy for stormwater control and utilization, predicated upon the values of sustainable development and ecological conservation.

From a historical perspective, international paradigms of stormwater management have undergone a fundamental transformation from an attitude of "fear and rejection toward acceptance and beneficial use." During the early phase (from the early 19th century to the 1960s), urban efforts were primarily directed toward the rapid conveyance of stormwater and wastewater away from the city via engineered channels and pipes, with the core objectives being "flood drainage and storage" and "point source pollution control" [1]. However, with the acceleration of urbanization, the adverse consequences of the conventional "rapid conveyance" model—including increased surface runoff, exacerbated non-point source

pollution, and the squandering of water resources—became increasingly manifest. Beginning in the 1980s, Western nations, notably Germany and the United States, began to emphasize "source control" techniques, advocating for the decentralized treatment of runoff at its point of origin. By the 1990s, the incorporation of sustainability principles ultimately propelled stormwater management into the phase of "sustainable management."

Within academic research and professional practice, a range of representative sustainable stormwater management frameworks have been developed internationally. Based on their primary problem-solving orientation, these may be broadly categorized into two archetypes.

The BMP Framework Centered on "End-of-Pipe Treatment": The concept of Best Management Practices (BMPs) in the United States first appeared in the Clean Water Act of 1977, with an initial emphasis on the abatement and control of non-point source pollution [2]. BMPs advocate for the "on-site" and "decentralized" treatment of stormwater utilizing novel technologies. Nevertheless, practical experience has demonstrated that while terminal detention alone can regulate peak flows, it is often insufficient to restore the site's natural water retention capacity and hydrological functions that have been compromised by development [3].

The LID Framework Centered on "Source Control": To address the limitations of BMPs, the Low Impact Development (LID) approach was systematically developed in the early 1990s by Prince George's County, Maryland, USA. The core objective of LID is to "restore natural hydrological cycles." It emphasizes the preservation and strategic utilization of a site's inherent natural features, in conjunction with the deployment of distributed, small-scale technical facilities, to replicate, to the greatest extent feasible, the pre-development hydrological regime [3]. The LID philosophy posits that the site itself constitutes the most effective "facility" for stormwater control; consequently, site planning and design must be inextricably integrated with stormwater management from the outset.

Subsequently, other nations have developed standardized frameworks with varying emphases. These systems, while distinct, exhibit considerable mutual influence with the BMP and LID paradigms and collectively constitute the prevailing international framework for contemporary stormwater management [1].

Sustainable Urban Drainage System (SUDS) in the United Kingdom: this framework holistically addresses water quantity, water quality, and environmental amenity. It seeks to "metabolize" stormwater through a three-tiered approach encompassing source control, conveyance control, and regional control, with the overarching aim of balancing economic development with environmental protection.

Water Sensitive Urban Design (WSUD) in Australia: This approach conceptualizes the urban water cycle (encompassing stormwater, water supply, and wastewater) as an integrated whole and aligns its management with the urban design process. It encourages the enhanced reuse of runoff through storage and treatment devices and gives coordinated consideration to ecological health, stormwater management, and economic development.

The Sound Water Cycle System in Japan: Driven by national legislation (e.g., the Basic Act on the Water Cycle), this framework promotes the restoration and maintenance of a robust water cycle system at the watershed scale through measures such as infiltration and retention.

The contemporary connotation of "stormwater management" has thus far surpassed the traditional scope of drainage. It is no longer merely a technical instrument for mitigating urban waterlogging but constitutes a comprehensive management regime aimed at achieving multiple objectives, including peak flow attenuation and runoff volume reduction, pollution control, water resource reclamation, ecological restoration, and landscape enhancement [2]. Its fundamental principle lies in the integration of "source control" and "downstream control": the former governs the timing of runoff release prior to its entry into the pipe network, employing infiltration, retention, and detention to achieve peak shaving, volume reduction, and groundwater recharge; the latter entails the regulation of flow quantity and the provision of preliminary treatment within the mid- to lower reaches of the drainage system [1].

1.2.2 Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design (WSUD) originated in Australia and constitutes an interdisciplinary planning and design methodology aimed at achieving the sustainable management of the urban water environment. The concept was first articulated by Australian scholars in 1994 and has since garnered progressive international recognition and application [4]. Its fundamental premise lies in the organic integration of urban water cycle management—encompassing stormwater, wastewater, groundwater, and potable water supply systems—into the processes of urban planning and design, with the objective of fostering the harmonious co-development of the "water–environment–society" nexus [5].

WSUD emphasizes multidisciplinary collaboration, synthesizing insights from urban planning, landscape architecture, water resource management, environmental engineering, and sociology [6]. Its objectives extend beyond stormwater regulation, water quality remediation, and water resource reclamation to encompass the restoration of urban hydrological equilibrium, the enhancement of ecological resilience, and the augmentation of the aesthetic and cultural value of the built environment. Within this framework, WSUD

employs a systematic and hierarchically structured design approach to effectuate comprehensive water management—from source to end-of-pipe—across multiple spatial scales, including the region, the city, the precinct, and the individual site [7].

1.2.3 The Water Sensitive City

In 2009, the National Water Commission of Australia further advanced the concept of the "Water Sensitive City" (WSC), extending the WSUD philosophy to the macro-strategic scale of urban policy. Brown et al. proposed a transitional framework for urban water management, positing that a Water Sensitive City should exhibit the following defining characteristics: a deep integration of infrastructure with the urban landscape to yield multiple ecological and social benefits; the deployment of adaptive, hybridized solutions to enhance systemic resilience; and broad-based community participation in the co-governance of water resources and the environment [8]. Thus, WSUD transcends a mere technical toolkit; it constitutes a holistic strategy for steering cities toward a trajectory of enhanced sustainability, resilience, and livability.

1.2.4 Sponge City Design

Sponge City Design denotes the comprehensive body of systematic planning and engineering design methodologies deployed to realize the objectives of "Sponge City" construction. Its essence lies in the strategic integration of nature-based solutions with engineered interventions. By leveraging a repertoire of technical measures—encompassing infiltration, retention, storage, purification, utilization, and drainage—it seeks to construct an urban water system endowed with the resilience and adaptive capacity of a sponge. Under conditions of high-intensity urbanization, this approach facilitates the natural accumulation, natural infiltration, and natural purification of rainwater, thereby effectively mitigating flood and waterlogging hazards, alleviating water scarcity, and controlling non-point source pollution [9].

This design paradigm transcends the conventional, singular approach to stormwater management predicated upon "rapid conveyance" and "end-of-pipe control." It pivots toward a Low Impact Development (LID) framework guided by the principles of "source abatement, process control, and systemic governance." It emphasizes the utilization of urban spatial elements—including buildings, roadways, and green spaces—as fundamental carriers. Through the deployment of a diversified array of ecological facilities (e.g., bioretention cells, permeable pavements, and green roofs), it establishes a distributed system for stormwater regulation and utilization, thereby achieving the integrated objectives of aquatic ecology,

water security, water environment, and water resources stewardship.

1.2.5 Water Sensitive Urban Design and Sponge City Design

Water Sensitive Urban Design (WSUD) and Sponge City Design both constitute significant conceptual and methodological responses to the challenges confronting the urban water environment. While the two paradigms exhibit considerable commonality in their overarching objectives and technical repertoire, they are also distinguished by notable divergences attributable to differing geographical provenances and developmental stages.

Shared Commonalities: Both approaches advocate for a fundamental departure from the conventional stormwater management paradigm predicated upon "end-of-pipe treatment" and "rapid conveyance." They jointly endorse the principles of Low Impact Development (LID), emphasizing the source control of stormwater runoff and the deployment of ecological, decentralized facilities to promote on-site infiltration, detention, retention, purification, and beneficial reuse of rainwater [9]. Their ultimate aims converge upon the mitigation of urban waterlogging, the amelioration of water environmental quality, the restoration of urban hydrological cycles, and the enhancement of urban ecological resilience and sustainability.

Key Distinctions: The differences between the two frameworks manifest primarily in the following dimensions:

1. **Conceptual Breadth and Genesis:** WSUD, originating in Australia, embodies a broader conceptual ambit. It extends beyond the purview of stormwater regulation to encompass the systematic integration of water supply, wastewater treatment, and groundwater management within the urban design process. It foregrounds the management of the entire urban water cycle as a fundamental instrument for shaping urban space and augmenting landscape aesthetics and community value, with the ultimate goal of achieving a harmonious "water–environment–society" nexus [6]. Sponge City, conversely, represents a localized articulation of these international principles within the Chinese context. In its initial phase of introduction, it exhibited a more concentrated focus on resolving the core issue of stormwater management—namely, the realization of "natural accumulation, natural infiltration, and natural purification." Consequently, it is characterized by a more explicit policy orientation and a stronger emphasis on quantifiable performance targets, such as the volume capture ratio of annual rainfall runoff.

2. **Dimensions of Systemic Integration:** from its inception, WSUD has emphasized deep transdisciplinary integration. It mandates collaborative synergy among urban planners, landscape architects, environmental engineers, and social scientists from the earliest stages of

design, thereby enabling the seamless incorporation of water infrastructure into the urban fabric and the provision of multiple ecosystem services and social functions [7]. While Sponge City design in practice advocates for multi-agency coordination, its initial technical framework has been largely steered by the water resources and municipal engineering sectors, with a predominant focus on achieving stormwater control targets through a combination of "grey and green" engineered facilities. The deeper synthesis with urban spatial quality and socio-cultural dimensions remains an area of ongoing development and refinement.

3. Developmental Trajectory and Maturity: WSUD has evolved into a more mature theoretical framework, complete with articulated models of urban developmental progression. Notably, it has advanced a six-stage transition framework charting the evolution from the "Water Supply City" to the "Water Sensitive City," encompassing multidimensional shifts across technological, social, institutional, and cultural spheres, thereby reflecting a broader and more long-term perspective [4]. In contrast, Sponge City, as a state-mandated construction initiative vigorously promoted at the national level in China, demonstrates robust engineering practicability and formidable policy implementation capacity, aimed at rapidly and efficiently addressing the pressing water security challenges confronting contemporary Chinese cities.

In summary, Water Sensitive Urban Design furnishes a more expansive and integrative theoretical and practical framework, whereas Sponge City may be regarded as its contextualized application and practical innovation within the specific milieu of China. The two paradigms share a common origin in their core principles, yet exhibit distinct differences and complementary potential in terms of scope of implementation, depth of integration, and stage of developmental maturity.

1.2.6 Industrial Heritage

Industrial heritage refers to a distinct category of built environment characterized by specific historical and spatial attributes, engendered by the transition of cities from the industrial era to the post-industrial epoch. Such sites are frequently situated in strategic urban locations—including central urban areas, waterfront zones, or pivotal transportation nodes—and are accordingly regarded as spatial resources possessing considerable potential for redevelopment and adaptive reuse [10][11]. Concurrently, these sites are often marked by a degree of spatial and social disarticulation or severance from the surrounding urban fabric [12]. Their internal composition typically includes a substantial corpus of buildings, structures, landscape installations, and site textures that collectively embody and convey industrial

memory, thereby constituting the material repository of industrial cultural heritage. Consequently, industrial heritage transcends a mere spatial typology; it represents a complex urban system that synthesizes historical stratification, spatial characteristics, economic potential, and collective social memory.

1.2.7 Public Space

Within the scope of this study, Urban Public Space refers to spatial venues in a city that are open to the public and accommodate diverse social activities. It is not only an integral part of the urban morphological fabric but also an important container and medium of urban social life. Guo Enzhang points out that urban public space is "the cream of the urban environment" and its essence is "a social activity place that takes human beings as the main body and promotes the occurrence of social life events" [29]. This definition emphasises the organic unity of the three elements—"human being, activity, and place"—in public space, and rejects the one-sided understanding that regards public space merely as an architectural accessory or a vehicle for formal composition.

From the perspectives of function and composition, urban public space encompasses natural landscape environments, urban public green spaces, squares, streets, garden spaces, and other types, characterised by basic attributes such as openness, accessibility, diversity, and cultural richness [30]. Under different classification systems, public space can be categorised according to natural vs. artificial attributes, functional types, land-use properties, and urban structural hierarchy. For example, according to functional types, it can be divided into four major categories: residential, working, transportation, and recreational. Among these, recreational public space includes waterfront spaces, open sites in industrial heritage redevelopment parks, pedestrian systems, and rest nodes, which are highly relevant to the type of public space examined in this study—the Zini Sugar Refinery [30].

It is worth noting that there is an essential difference between the design of urban public space and landscape design. Landscape design focuses on the ecological and aesthetic construction of a site, emphasising the organisation of natural elements such as greenery configuration, vegetation selection, and water treatment, with the goal of creating an outdoor environment that is visually appealing and ecologically valuable. In contrast, urban public space design centres on human behaviour and social activities, paying attention to the sociality, accessibility, comfort, and cultural expression of space. As Guo Enzhang notes, public space should meet comprehensive quality evaluation criteria such as "sociality, comfort, accessibility, safety, pleasure, harmony, diversity, cultural richness, and ecological soundness",

among which "sociality" is its fundamental attribute [29]. Therefore, public space design is not merely an accumulation of landscape elements, but rather a spatial response to human behaviour, social interaction, and cultural identity.

In summary, the "public space" discussed in this thesis specifically refers to the ground-level and near-ground-level spaces within the Zini Sugar Refinery campus that are open to the public and available for diverse uses, including the waterfront belt, open spaces between heritage buildings, the pedestrian system, and marginal areas with potential for social activities. Its design research will take rainwater management as the technical thread and human behaviour and experience as the core objectives, emphasising the dual functions of public space in ecological regulation and social service.

1.3 Scope of Study

1.3.1 The Strategic Position and Waterfront Environment of Guangzhou

As a national central city, the core engine of the Guangdong-Hong Kong-Macao Greater Bay Area, and a pivotal node of the Belt and Road Initiative, Guangzhou possesses a strategic significance of profound and multidimensional import. From a geographical perspective, Guangzhou occupies the geometric center of the Pearl River Delta. Leveraging the Pearl River as a golden waterway, it has historically served as China's "Southern Gateway" to the world. In the contemporary era, it constitutes a critical juncture within the Bay Area's "A-shaped" spatial framework, fulfilling a gateway function that radiates inland influence while simultaneously articulating global connectivity. From a developmental trajectory perspective, Guangzhou embodies both a millennia-old commercial capital and a modern hub of trade and commerce. In recent years, guided by the spatial strategy of "One River, Two Banks, Three Belts," the city has consistently bolstered its functions in international commerce, integrated transportation, technological and cultural innovation, and regional service provision, advancing steadfastly toward the status of a leading global city.

Within this overarching strategic framework, Guangzhou's waterfront environment constitutes the foundational substrate for its spatial structure, ecological matrix, and cultural identity. The municipal territory is interlaced with the hydrological network of the Pearl River system—encompassing the West River, North River, East River, and their numerous tributaries and distributary channels (chong)—giving rise to the city's distinctive "Cloudy Mountains and Pearl River Waters" (yun shan zhu shui) urban morphology. This intricate water network not only serves as a vital ecological corridor and the bedrock of blue-green infrastructure, delivering critical ecosystem services such as stormwater retention and

detention, wildlife habitat provision, and microclimatic regulation, but also constitutes both the arterial vessel of the city's historical development and the skeletal framework of its spatial organization. From historic commercial wharves and early modern industrial shorelines to the contemporary public waterfronts of today, the spatial evolution of the Pearl River's banks and its tributaries provides a profound cartography of Guangzhou's transformation from a traditional port settlement into a modern, cosmopolitan metropolis.

Presently, the "water-city nexus" in Guangzhou is undergoing a profound paradigm shift. Under the new imperatives of high-quality development and ecological civilization construction, the value of waterfront space has transcended singular transport, economic, or aesthetic functions. Instead, it is increasingly recognized for its integral role as a composite "living infrastructure." This reconceptualization demands that the planning and regeneration of waterfront environments holistically address their contributions to multiple strategic objectives: enhancing urban ecological resilience (e.g., mitigating flood and waterlogging hazards, improving water quality), perpetuating historical and cultural lineage (e.g., conserving riverside industrial heritage, sustaining the memory of wharves and docks), catalyzing social vitality (e.g., providing high-quality public space, fostering waterfront social interaction), and driving innovative economic activity (e.g., attracting creative industries, developing waterfront cultural tourism). The question of how to systematically restore and revitalize this invaluable blue-green asset—enabling it to accommodate hybridized functions, express distinctive regional character, and foster a harmonious relationship between people and water in this new era—has thus emerged as a critical proposition central to enhancing Guangzhou's comprehensive urban competitiveness and long-term sustainable development capacity.

1.3.2 Climate and Water Resource Characteristics

Guangzhou is situated within the southern subtropical monsoon climatic zone. Its climatic and hydrological characteristics collectively constitute core determinants of the city's natural ecological endowment, exerting a profound influence on its urban spatial morphology, ecological security framework, and pathways toward sustainable development.

Climatic Characteristics: the climate of Guangzhou is distinguished by pronounced monsoonal influence, the concurrence of high temperatures and abundant precipitation, and marked spatial and temporal heterogeneity in rainfall distribution. The city experiences a mean annual temperature of approximately 21.9°C, ample thermal resources, and an extended frost-free period. Average annual precipitation approximates 1,800 millimeters; however, its

seasonal distribution is highly concentrated, with the wet season (April through September) accounting for roughly 80% of the annual total. This precipitation frequently manifests as short-duration, high-intensity rainstorms, which readily induce urban waterlogging. Conversely, the dry season (October through March of the following year) is characterized by comparatively meager rainfall, rendering the region susceptible to seasonal drought. During the summer months, Guangzhou is recurrently impacted by typhoons and severe convective weather phenomena. These climatic stressors are compounded by the urban heat island effect engendered by extensive impervious surface coverage, thereby amplifying both the risks of extreme precipitation events and elevated temperatures. Collectively, these conditions pose formidable challenges to the urban stormwater management regime and the capacity for thermal environmental regulation.

Water Resource Characteristics: the water resources of Guangzhou exhibit a composite profile defined by "abundant aggregate availability, pronounced spatiotemporal disparity, and salient water quality pressures." This profile manifests across several specific dimensions:

Dominance of Transboundary Inflow and Limited Endogenous Resources: Guangzhou occupies the lower reaches of the Pearl River basin, a region characterized by a dense hydrological network. While the substantial transboundary flows originating from the West River, North River, and East River constitute the primary source of municipal water supply, the city's endogenous, locally generated water resources are comparatively constrained. Consequently, per capita local water availability falls below the national average, rendering Guangzhou subject to the concurrent pressures of both resource-scarcity and engineering-induced water deficits.

Dense River Network and Pronounced Water Environmental Loading: the Pearl River's front and rear channels, in concert with a multitude of urban and peri-urban creeks (chong), form an intricate hydrological matrix that has historically fulfilled a multiplicity of functions encompassing water supply, navigation, and drainage. Yet, the trajectory of rapid urbanization has precipitated a suite of environmental degradations within segments of this water network, including water quality impairment, fragmentation of ecological corridors, and diminished flood conveyance capacity. The ambient water quality and the provisioning of ecosystem services have consequently been compromised to varying degrees.

Persistent Growth in Water Demand and Challenges in Stormwater and Wastewater Management: concomitant with population growth and economic development, the aggregate demand for water across productive, domestic, and ecological sectors exhibits a sustained upward trend, imposing structural strain upon the equilibrium of water supply and demand.

Simultaneously, urban expansion has resulted in increased surface runoff volumes and amplified non-point source pollutant loading. Notably, pollution attributable to the first flush of stormwater runoff has emerged as a critical constraint impeding the attainment of water quality objectives within urban streams and the broader health of the watershed ecosystem.

The confluence of Guangzhou's distinctive hydroclimatic profile—characterized by "flood-season pluvial inundation and dry-season water scarcity"—with its dense yet ecologically sensitive river network constitutes the complex contextual backdrop against which urban water system governance and waterfront spatial regeneration must be undertaken. Within this empirical context, the integration of systematic stormwater management, aquatic ecological restoration, and sustainable water resource utilization into the purview of urban design—and into waterfront renewal strategies in particular—assumes critical importance for enhancing urban climate adaptability, safeguarding water security, and fostering a harmonious relationship between human communities and hydrological systems.

1.3.3 Industrial Spatial Distribution and Developmental Characteristics

Guangzhou possesses a long and distinguished history of industrial development and has served as a significant crucible of modern Chinese industry since the late Qing Dynasty and the Republican era. The city's dense hydrological network of the Pearl River system provided an inexpensive and highly efficient conduit for the transportation of raw materials and the shipment of finished goods, thereby incentivizing a substantial concentration of industrial enterprises—including shipyards, paper mills, textile factories, and sugar refineries—to establish their operations along the riverine frontage. This historical process engendered the formation of extensive waterfront industrial zones arrayed along the Pearl River's front and rear channels and the banks of its principal tributaries [14]. This developmental trajectory has bequeathed to Guangzhou a rich repository of industrial heritage resources, particularly waterfront industrial remnants, which now constitute vital vessels of collective urban memory and spatial identity.

These waterfront industrial heritage sites are broadly characterized by the following salient attributes:

(1) **Pronounced Locational Value:** The majority are situated within what are now core waterfront zones along the city's primary developmental axes, thereby possessing immense latent potential for land value realization and urban regeneration, accompanied by substantial pressures for redevelopment.

(2) **Significant Ecological Remediation Burden:** historical patterns of extensive and often

environmentally indifferent industrial production have resulted in varying degrees of contamination to adjacent soils, sediments, and the water columns of neighboring creeks (chong) and the Pearl River itself. Consequently, any process of site renewal is inextricably entangled with the complex imperatives of water environmental governance and ecosystem restoration.

(3) Intimate Coupling with the Urban Water System: the inherent characteristics of the site—including its topographic grading, internal drainage pathways, legacy flood control and stormwater infrastructure, and the nature of its connections to the municipal macroscale stormwater and wastewater networks—constitute core technical considerations that cannot be circumvented in the regeneration and adaptive reuse of these sites.

1.3.4 Rationale for Defining the Regional Research Scope

This study explicitly defines the regional research scope as Guangzhou City, particularly its waterfront industrial heritage sites within the municipal territory, and ultimately focuses on Zini Sugar Refinery along the Shawan Waterway in Panyu District as an empirical case study. This delineation is based on a threefold consideration: the typicality of the research object, the focus of the research problem, and practical feasibility.

First, in terms of the typicality and representativeness of the research object and problem, Guangzhou serves as a quintessential microcosm and a high-density sample repository of waterfront industrial heritage regeneration issues within the Greater Bay Area and even China. As a significant cradle of modern Chinese industry and a treaty port, Guangzhou, relying on its dense Pearl River water system, historically developed a waterfront industrial corridor densely distributed along the front and rear channels of the Pearl River and major tributaries. This corridor has accumulated a rich variety of industrial heritage, spanning shipbuilding, papermaking, textiles, sugar refining, and other sectors. These heritage sites currently face the core challenge of transitioning from "productive waterfronts" to "living, ecological, and vital waterfronts". Their regeneration process must systematically address multiple complex issues, including historical pollution remediation, enhancement of pluvial resilience, reshaping of public space, and cultural continuity. Therefore, taking Guangzhou as the research scope ensures that the coupling issue of "stormwater management" and "public space design" explored in this study has a solid empirical foundation and broad practical significance.

Second, based on the requirements of operational feasibility and precision for research depth, narrowing the research scope from the macro level of the "Guangdong–Hong Kong–Macao Greater Bay Area" to the specific "Guangzhou City" is a necessary pathway to

move from theoretical framework construction to refined design strategy implementation. Cities within the Greater Bay Area differ in their development stages, policy environments, and water system characteristics; an overly broad geographical scope would risk generic research conclusions. Focusing on Guangzhou facilitates an in-depth analysis of the common constraints and design logics for the regeneration of waterfront industrial heritage under a unified policy context (e.g., stock renewal under the "manufacturing-based city" strategy, and "sponge city" construction requirements) and a shared natural base (south subtropical monsoon climate, high-density river network). This helps formulate a coherent and rigorously testable design methodology.

Third, regarding the suitability and demonstrative value of the case study, Zini Sugar Refinery represents an "ideal type" that embodies and concretizes the above research issues. Located on the banks of the Shawan Waterway, it is a microcosm of Guangzhou's waterfront industrial spatial configuration. As a defunct large-scale state-owned factory, it possesses significant heritage value, a complex built environment, and potential hydrological and ecological legacies from past industrial activities. Its ongoing revitalization and regeneration demands are closely tied to the surrounding communities' expectations for high-quality public space. Selecting Zini Sugar Refinery enables a systematic design response and validation of macro-regional issues (such as pluvial flood management and industrial heritage revitalization in Guangzhou's waterfronts) within a clearly bounded and elementally complete site, thereby endowing the research outcomes with both theoretical depth and practical reference value.

In summary, establishing the research scope as "Guangzhou City – Waterfront Industrial Heritage Sites – Zini Sugar Refinery" – a multi-scalar and progressively focused framework – aims to ensure that this study is grounded in a real, typical, and urgent urban regeneration context. This guarantees that the research findings achieve both academic rigor and practical specificity, while offering regional exemplary value.

1.4 Research Objectives and Significance

1.4.1 Research Objectives

Against the macro-background of China's vigorous promotion of sponge city construction, urban stormwater management is undergoing a strategic shift from the "rapid drainage" model to an integrated model encompassing "infiltration, retention, storage, treatment, reuse, and discharge". Concurrently, with the advent of the post-industrial era, numerous urban waterfront industrial heritage sites are facing opportunities for functional replacement and spatial transformation. Such sites typically feature strong waterfront connectivity, ample open

space, and relatively low land costs, providing advantageous conditions for the implementation of stormwater management technologies. However, current research on stormwater management design in the context of industrial heritage regeneration remains insufficient, lacking systematic design strategies and methodological guidance.

On this basis, this study takes Zini Sugar Refinery in Guangzhou as a specific case and aims to achieve the following research objectives:

(1) To delineate the core connotations and applicable conditions of international stormwater management concepts, thereby providing theoretical support for the stormwater management design of waterfront industrial heritage sites. Through tracing and comparing mainstream concepts such as BMPs/LID (United States), WSUD (Australia), and SUDS (United Kingdom), this study clarifies their technical principles and scope of application under the two fundamental frameworks of "source control" and "downstream control", establishing a theoretical foundation for subsequent design strategies.

(2) To analyse the existing conditions and stormwater management potential of the Zini Sugar Refinery site, identifying the opportunities and constraints for implementing stormwater management within the context of industrial heritage regeneration. Through systematic site investigation of geographic location, hydrological characteristics, spatial configuration, built heritage, and landscape resources, this study evaluates the feasibility and advantages of the site in terms of runoff control, rainwater resource utilisation, and ecological restoration.

(3) To propose a public space design strategy for stormwater management applicable to waterfront industrial heritage sites in Guangzhou, and to validate this strategy through the Zini Sugar Refinery case study. Drawing on the "source control" principle emphasised by the LID concept—namely, maximising the simulation of natural hydrological functions by fully preserving and utilising the site's natural characteristics and integrating decentralised, small-scale technical facilities—this study explores pathways for organically integrating stormwater management facilities with public space design and industrial landscape regeneration.

(4) To construct a generalisable design paradigm for stormwater management in Guangzhou's waterfront industrial heritage sites, providing references for the planning and design of similar projects. Through an in-depth analysis of the Zini Sugar Refinery case, this study synthesises transferable design principles and technical models, offering insights for the regeneration of Guangzhou's waterfront industrial heritage and the practical implementation of sponge city construction.

1.4.2 Theoretical Significance

The theoretical significance of this study is primarily reflected in the following three aspects:

(1) It enriches the interdisciplinary dialogue between urban stormwater management and industrial heritage regeneration. Existing research tends to treat stormwater management as a purely hydrological engineering or environmental engineering technical issue, with relatively little exploration of its integration with spatial morphology, landscape experience, and place identity from an urban design perspective. On the other hand, studies on industrial heritage regeneration, while focusing on historical value preservation, functional replacement, and spatial regeneration, pay limited attention to the restoration and utilisation of site hydrological functions. This study introduces stormwater management concepts into the design of waterfront industrial heritage sites, attempting to establish a theoretical bridge between the two domains, thereby offering new approaches for the ecological transformation of urban design.

(2) It expands the applied research of international stormwater management concepts within a specific site typology in Guangzhou, China. The formulation and refinement of concepts such as BMPs/LID (United States), WSUD (Australia), and SUDS (United Kingdom) have all been grounded in their respective national natural conditions, social contexts, and governance systems. Given the differences in geographical environment, urban development models, and planning governance systems between China and Western countries, the introduction of foreign concepts requires local adaptation. This study takes Zini Sugar Refinery in Guangzhou as a case study to explore the applicability and transformation of these concepts within the context of Guangzhou's waterfront industrial heritage, thereby contributing to the enrichment of China's localised theoretical system for sponge city construction.

(3) It deepens the understanding of the application mechanisms of the "source control" concept at the site scale. The core of modern stormwater management lies in the organic integration of "source control" and "downstream control", wherein source control emphasises on-site treatment of stormwater before it enters the drainage system. The LID framework further asserts that the site itself is the most important and effective "facility" for controlling stormwater runoff, and that site planning and design must be highly integrated with stormwater management from the outset. Focusing on public space as a carrier, this study explores how hydrological function restoration can be achieved through site design, thereby deepening the theoretical understanding of the application mechanisms of the "source control"

concept at the micro-scale.

At the theoretical level, this study serves both as an extension and supplement to existing stormwater management research and as an enrichment and expansion of industrial heritage regeneration theory. It holds positive theoretical value for advancing China's sponge city construction towards greater refinement, regional specificity, and diversity.

1.4.3 Practical Value

This study offers practical value in the following respects:

(1) Providing direct design basis and implementation blueprint for the regeneration of Zini Sugar Refinery: the design proposals, technical strategies, and phased implementation pathways proposed in this study can serve as a scientific foundation and clear guidance for government decision-making, developer investment, and the subsequent detailed work of planning and design institutes. This will facilitate the high-quality implementation of the project and help avoid arbitrary development and homogenised construction.

(2) Offering a demonstrative model for waterfront regeneration in Guangzhou: Guangzhou possesses numerous similar waterfront industrial heritage sites. The "Zini Model" explored in this study—which seeks to achieve a balance among multiple objectives such as water source protection, heritage preservation, community development, and industrial innovation—can provide technical references, transferable approaches, and confidence for comparable projects. It thus holds significant demonstrative and radiating value.

(3) Providing methodological insights for the modernisation of urban governance: the interdisciplinary collaboration, water-system synergy, and multi-stakeholder co-governance approach to planning and design advocated in this study responds to the demands of contemporary urban governance modernisation. It offers actionable methodological insights for overcoming common challenges in urban regeneration, such as institutional silos and insufficient community participation, thereby contributing to the overall effectiveness of refined urban management and integrated governance.

1.5 Research Methods

This study takes Zini Sugar Refinery in Guangzhou as a case study object, focusing on the core issue of "public space design for waterfront industrial heritage sites based on stormwater management". A combination of multiple research methods is employed to ensure the scientific rigor, systematicity, and practical guidance value of the research. The specific research methods are as follows:

(1) Literature Review Method

Extensive collection and synthesis of academic literature, policy documents, technical guidelines, and practical case studies from both domestic and international sources in the fields of stormwater management, sponge cities, industrial heritage regeneration, and waterfront public space design. The study focuses on tracing and examining the origins and development of mainstream stormwater management concepts such as BMPs/LID (United States), WSUD (Australia), and SUDS (United Kingdom), clarifying their core principles, technical measures, scope of application, and implementation guarantee mechanisms. Concurrently, the policy background and technical guidelines of China's sponge city construction, as well as relevant research outcomes in the field of industrial heritage regeneration, are systematically reviewed. Through the literature review, a solid theoretical foundation is established for this study, and the position of the research question within the academic landscape is clarified.

(2) Case Study Method

Selection and in-depth analysis of representative domestic and international exemplary cases that integrate waterfront industrial heritage regeneration with stormwater management design. The case selection takes into account geographical distribution, scale, regeneration models, and technical characteristics, with a particular focus on how these cases integrate stormwater management facilities into site design, address the relationship between industrial heritage preservation and ecological function restoration, and achieve synergies between public space quality enhancement and environmental benefits. Through comparative analysis and synthesis of experiences from these cases, a reference framework is established to inform the design strategies for Zini Sugar Refinery, and generally applicable design principles are distilled.

(3) Field Investigation Method

Systematic field investigation is conducted with Zini Sugar Refinery in Guangzhou as the research object. The investigation encompasses the following: site condition surveys, documenting fundamental information such as topography, hydrological characteristics, distribution of built heritage, open space patterns, paving and greening conditions, and existing drainage facilities; spatial usage observations, understanding current patterns of site use, pedestrian activity rhythms, and public perceptions of and needs for the spatial environment; and photographic documentation, providing detailed primary data for subsequent design research.

(4) Multi-Disciplinary Comprehensive Analysis Method

Stormwater-management-oriented design of waterfront industrial heritage sites involves

multiple disciplinary fields, including urban planning, landscape architecture, hydraulic engineering, environmental science, and heritage conservation. This study adopts a multi-disciplinary comprehensive analysis perspective, integrating the technical logic of stormwater management (e.g., runoff coefficient calculation, facility sizing determination, water quality treatment requirements) with the aesthetic logic of spatial design (e.g., place-making, landscape experience, contextual continuity), coordinating the restoration goals of ecological functions with the value preservation of industrial heritage, and connecting site-scale technical measures with regional-scale hydrological cycles, in order to formulate integrated design solutions.

(5) Design Research Method

The design research method is a research approach specific to the fields of urban design and architecture, emphasising the advancement of knowledge production and theoretical construction through design practice itself. Based on preliminary investigation and analysis, this study undertakes exploratory design using Zini Sugar Refinery as the site. The process is as follows: first, based on site conditions and stormwater management objectives, an overall design concept and spatial structure are proposed; second, various stormwater management facilities—such as bioretention swales, constructed wetlands, permeable paving, green roofs, and rainwater harvesting systems—are integrated into the public space system, while coordinating their relationships with industrial heritage preservation, traffic organisation, and functional activities; third, through design development and graphic representation, the feasibility and effectiveness of the design strategies are tested; finally, principles and methods with generalisable value are distilled from the design outcomes, forming a two-way feedback loop between theory and practice.

The five research methods described above are mutually reinforcing and complementary: the literature review provides a theoretical foundation for subsequent work; the case study expands the reference horizon for design; field investigation solidifies the primary evidence base for the research; multi-disciplinary comprehensive analysis ensures the integrity and coherence of the study; and the design research method translates theoretical understanding into spatial proposals while achieving a reverse contribution to knowledge. Through the integrated application of this methodological framework, this study strives to achieve a synthesis of theoretical depth and practical validity.

1.6 Technical Roadmap

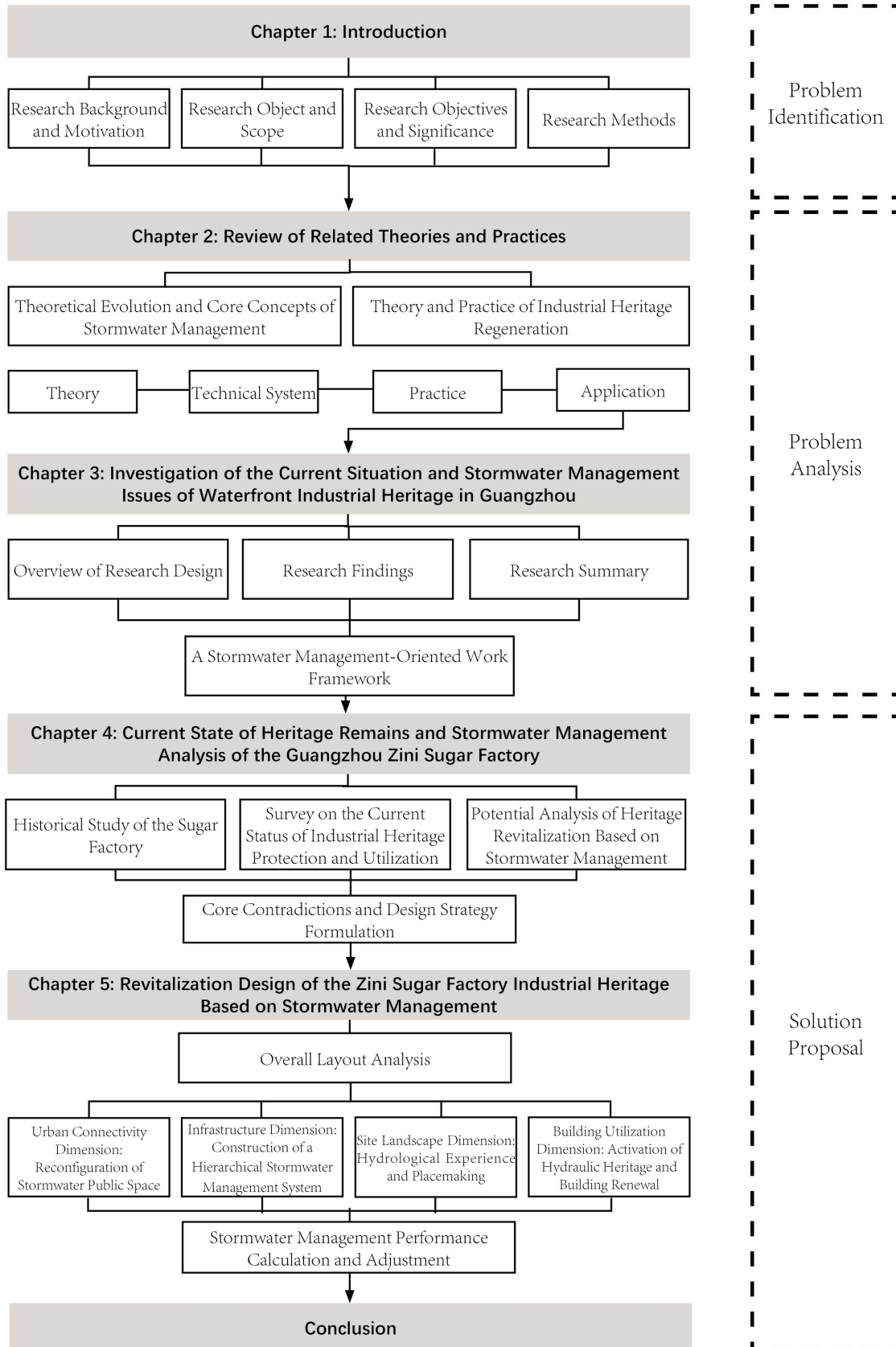


Figure1 - 1 Roadmap

1.7 Chapter Summary

This chapter systematically elaborates on the research background, objects, scope, objectives, significance, and methods, laying the foundation for the entire study.

In terms of research background, within the context of urban stock renewal, the value of waterfront industrial heritage has become increasingly prominent. However, current renewal practices generally lack systematic consideration of the “water” element, particularly the insufficient application of stormwater management strategies. Based on this, the core research question is proposed: how to effectively integrate stormwater management strategies into the public space design of waterfront industrial heritage sites in Guangzhou.

Regarding conceptual definition, this chapter clarifies the connotations and interrelationships of core terms such as “stormwater management,” “water-sensitive urban design,” and “sponge city design,” adopting “water-sensitive urban design” as the main theoretical framework, while also defining the boundaries of the research subjects—“industrial heritage” and “public space.”

The research scope focuses on Guangzhou, analysing its typical waterfront environment, subtropical monsoon climate, and distribution characteristics of high-density industrial heritage, with the Zini Sugar Factory as a specific case for in-depth study.

The research objectives include identifying existing problems, formulating design strategies, and proposing specific methods. The theoretical significance lies in introducing stormwater management into the discourse of industrial heritage renewal, filling a gap in interdisciplinary research. The practical value is to provide actionable design references for similar projects in Guangzhou and South China.

Research methods encompass literature review, case study analysis, field investigation, and spatial diagrammatic analysis, with a technical roadmap clarifying the research logic and overall framework.

In summary, this chapter demonstrates the necessity and feasibility of the research, offering a theoretical basis and pathway guidance for the subsequent construction of design strategies.

Chapter 2: Review of Related Theories and Practices

2.1 Theory and Practice of Industrial Heritage Regeneration

2.1.1 The Connotation and Evolution of Value Perception in Industrial Heritage Regeneration

Industrial heritage regeneration is not merely a matter of physical spatial transformation; rather, it is a complex process involving revaluation, functional reconstitution, and cultural remaking. Its connotation has continuously deepened alongside socio-economic development and the evolution of heritage conservation concepts. At its core, this process has shifted from the static preservation of "objects" to the dynamic transmission and reuse of "values," ultimately aiming to achieve an organic integration of industrial remains with contemporary urban life. Accompanying this shift is a profound evolution in society's perception of the value of industrial heritage.

1. The Connotation of Industrial Heritage Regeneration: From "Preservation" to "Activation"

The connotation of industrial heritage regeneration has long surpassed the initial "museum-style" static preservation. The International Committee for the Conservation of the Industrial Heritage (TICCIH), in the Nizhny Tagil Charter for the Industrial Heritage (2003), explicitly states that the preservation of industrial heritage primarily relies on its utilisation; continuous reuse is conducive to its protection, and old buildings should be granted new, appropriate functions. This established the core concept of "activating regeneration."

The connotation of industrial heritage regeneration primarily comprises three levels. The first is the regeneration of physical space. Through adaptive retrofitting, structural reinforcement, and ecologically oriented technological modifications of existing buildings and structures, their core historical characteristics are retained while meeting new functional and safety standards. This constitutes the physical foundation of regeneration. The second is the insertion of functions and industries. Based on the intrinsic characteristics of the heritage and regional development needs, new functions such as cultural and creative industries, technological innovation, exhibitions, commerce, and housing are introduced, facilitating a transformation from "production space" to "living space" or "consumption space," thereby stimulating economic vitality [34]. The third is the continuation of history and culture. The regeneration process serves as a means of interpreting and transmitting industrial history, collective memory, and local cultural identity. Through spatial narrative, artistic intervention, and event programming, industrial culture becomes a new regional identifier, strengthening

social cohesion [35].

Therefore, the essence of industrial heritage regeneration is a value-oriented process of creative transformation. Through spatial intervention and value reconstruction, it aims to reintegrate heritage sites that have lost their original functions into the urban economic, social, cultural, and environmental systems, thereby achieving sustainable development.

2. The perception of the value of industrial heritage has undergone a notable evolution from singular to pluralistic, and from neglect to recognition. This process is also referred to as the "heritagisation process" [35].

Phase 1: Neglect and Demolition (Early to Mid-20th Century)

In the early and middle stages of industrialisation, old industrial buildings were regarded as symbols of "obsolescence" and "backwardness." Their value was understood only in terms of the recovery of material resources or the redevelopment potential of the land. Under the urban regeneration model of "demolish and rebuild," a large number of industrial remains were demolished, and their potential historical and cultural value was completely ignored.

Phase 2: Discovery of Historical and Aesthetic Value (Mid to Late 20th Century)

With the advent of the post-industrial society and the rise of "Industrial Archaeology" (Michael Rix, 1955) [36], people began to re-evaluate the history of the industrial age. Industrial remains, as tangible testimonies of technological history, social history, and architectural history, gradually saw their historical value, technological value, and unique machine aesthetics and structural aesthetics [37] discovered and recognised. Conservation movements began with iconic individual structures such as bridges and canals, aiming to "preserve the past for the future." At this stage, the perception of value remained somewhat elitist and oriented towards historical commemoration.

Phase 3: Expansion of Economic and Social Value (Late 20th to Early 21st Century)

Against the backdrop of increasing scarcity of urban land resources, the economic value and redevelopment potential of industrial remains—characterised by large open spaces and low rents—became prominent. The success of the LOFT model demonstrated the considerable commercial potential of transforming such sites into creative industry parks and commercial spaces. Simultaneously, their role as carriers of collective memory in fostering community identity and promoting social cohesion [40] was widely recognised. Regeneration practices shifted from point-specific conservation to a combination of "bottom-up" and "top-down" approaches, leading to the development of industrial parks and districts, as exemplified by the IBA (Internationale Bauausstellung) plan in the Ruhr region of Germany.

Phase 4: Deepening of Ecological and Holistic Value (Since the 21st Century)

The deepening of the concept of sustainable development has brought heightened attention to the ecological value of industrial remains as "stock space" (i.e., avoiding resource consumption and environmental pollution caused by large-scale demolition and new construction). Furthermore, value perception has expanded from individual buildings to the overall environment, encompassing industrial landscapes, spatial textures, ecological systems, and associated intangible culture [33]. Waterfront industrial remains, possessing the triple attributes of industrial heritage, waterfront space, and potential public space, have seen their regeneration increasingly integrated with ecological restoration and the construction of urban public space systems [38]. Value perception has thus become increasingly pluralistic and integrated.

2.1.2 Theoretical Trends and Practice Models of Industrial Heritage Regeneration

The theory and practice of international industrial heritage regeneration have developed over an extended period, giving rise to a series of influential intellectual trends and diverse mature practice models. These have provided significant references for the global dissemination and application of such regeneration. The developmental trajectory reveals an evolutionary trend: from individual building conservation to comprehensive regional revitalisation, from singular cultural functions to the integration of diverse functions, and from a focus on physical space to an emphasis on ecological and social sustainability.

1. The Evolution of Theoretical Trends

(1) Industrial Archaeology and Value Reassessment

The intellectual movement for industrial heritage conservation originated in the United Kingdom in the 1950s. Michael Rix introduced the concept of "Industrial Archaeology" in 1955, calling for the recording and preservation of machinery and monuments from the Industrial Revolution [41]. The core of this movement lies in employing scientific methods to survey, document, and evaluate the value of industrial remains as a prerequisite for all conservation and regeneration actions. It has promoted society's rediscovery and recognition of the historical and technological value of industrial heritage, thereby laying the theoretical foundation for subsequent conservation movements.

(2) The Maturation of the "Adaptive Reuse" Concept

The Burra Charter (1979) explicitly articulated the concept of "adaptive reuse," defined as "changing the use of a place to accommodate a new function." It emphasises that the key is to find appropriate uses for heritage sites such that their cultural significance is maximally

preserved and interpreted [42]. This concept transcends mere physical preservation, emphasising a balance between conserving heritage values and introducing new functions, and has become the core principle guiding industrial heritage regeneration.

(3) Integration of "Ecological Renewal" and "Sustainable Development" Concepts

With the widespread adoption of sustainable development concepts, industrial heritage regeneration has come to be regarded as a green approach to reducing resource consumption and extending building lifecycles. Ecological restoration, brownfield remediation, and green building technologies have been widely applied in regeneration practices. For example, the Emscher Park in the Ruhr region of Germany transformed the industrial landscape into a continuous, large-scale ecological park, achieving comprehensive environmental, economic, and social benefits [42].

(4) "Urban Catalyst" and "Placemaking" Theories

The "urban catalyst" theory, proposed by Wayne Atton and others, posits that the strategic introduction of new elements (e.g., cultural programmes) can stimulate and guide incremental development in surrounding areas [43]. Combined with the theory of "placemaking," this approach emphasises that industrial heritage regeneration should focus on creating attractive, sense-of-belonging, and vibrant public spaces, thereby activating regional vitality, rather than merely completing physical spatial transformation.

2. Main Practice Models

Table2 - 1 Main Practice Models of Industrial Heritage Regeneration

Table2 - 1 Main Practice Models of Industrial Heritage Regeneration			
Practice Models	Connotation	Typical Case Studies	Characteristics
Culture-Led Model	This model transforms industrial heritage into cultural facilities such as museums, art galleries, theatres, and cultural centres, aiming to enhance the regional cultural taste and shape	This project transformed a former coal mine into a design museum, visitor centre, and cultural event venue. It has been successfully inscribed as a UNESCO World Heritage Site and has become a global model for culture-driven industrial region	This model emphasises the public attributes and educational functions of heritage, but imposes high demands on operational management and sustained financial

Table2 - 1 Main Practice Models of Industrial Heritage Regeneration

Practice Models	Connotation	Typical Case Studies	Characteristics
	cultural landmarks.	transformation.	investment.
Function Replacement Model	This model is the most common. It replaces industrial buildings with office, commercial, residential, or mixed-use functions according to market demand and locational characteristics, thereby injecting new economic vitality.	United States: SoHo District in New York This project transformed abandoned cast-iron factory buildings (lofts) into artist studios, galleries, high-end brand stores, and residential units, creating a world-renowned art district and driving the gentrification of surrounding areas.	This model offers high flexibility and rapid economic returns; however, caution is required against excessive commercialisation, which may lead to the loss of historical ambience and the weakening of cultural driving forces [39].
Public Space-Led Model	This model focuses on transforming industrial heritage and its surrounding environment into public open spaces such as parks, plazas, and greenways that serve citizens, and is particularly suitable for waterfront industrial areas.	United States: The High Line Park in New York This project transformed an abandoned elevated railway into a linear sky garden. It has not only become an internationally renowned model of public space but has also significantly stimulated urban regeneration and property value appreciation in the surrounding areas.	This model has strong public welfare attributes, significantly improves the urban environment, and enhances the quality of life. However, it typically requires government leadership and substantial public financial investment.

Table2 - 1 Main Practice Models of Industrial Heritage Regeneration

Practice Models	Connotation	Typical Case Studies	Characteristics
Tourism and Leisure-Led Model	This model develops industrial heritage into destinations for heritage tourism, leisure, and entertainment, such as industrial heritage trails, themed hotels, and performing arts centres.	Germany: The "Industrial Heritage Trail" in the Ruhr District This project connects 19 industrial tourism attractions, 6 national museums, and 12 typical industrial towns through a regional tourist route, successfully transforming the entire industrial region into a vast, open-air theme park [42].	This model can effectively promote employment and consumption; however, it is necessary to avoid theming it into a theme park, which would lead to the loss of heritage authenticity.

International theoretical trends in industrial heritage regeneration have evolved from value reassessment, through functional reuse and ecological sustainability, to the contemporary emphasis on vitality creation and community participation. Correspondingly, practice models have also become increasingly diversified and integrated, with successful projects often combining multiple models.

These rich international experiences demonstrate that successful industrial heritage regeneration is by no means a mere case of "old wine in new bottles." Rather, it is grounded in a profound understanding of heritage values, guided by appropriate planning theories, and implemented through creative and integrated models. Ultimately, it achieves the multiple objectives of heritage conservation, economic development, environmental improvement, and social cohesion. This provides a valuable theoretical toolkit and practical frame of reference for the regeneration of waterfront industrial heritage in Guangzhou.

2.1.3 The Specificity and Challenges of Waterfront Industrial Heritage Regeneration

As a distinctive subcategory of industrial heritage, waterfront industrial heritage regeneration, while sharing common characteristics with general industrial heritage

regeneration, derives a unique set of values and complexities from its close integration with water bodies—a special natural and spatial element. Recognising these specificities and challenges is a prerequisite for successful regeneration practices.

1. Specificity of Waterfront Industrial Heritage Regeneration

Duality of Ecological Sensitivity and Ecological Value

Waterfront industrial heritage sites are often located in ecologically sensitive zones, where industrial pollution (brownfields) of soil and water may exist, resulting in a fragile ecological baseline. However, the specificity of their regeneration lies in the fact that they simultaneously hold significant potential for ecological restoration and the enhancement of ecosystem service functions. The regeneration process is not merely about pollution remediation; it also involves restoring the ecological corridors between the city and the water body through measures such as ecological restoration, sponge city infrastructure, and the transformation of waterfront ecological shorelines, thereby restoring biodiversity and significantly improving the microclimate and ecological environmental quality of the area [38]. This aligns closely with the core objectives of Water-Sensitive Urban Design (WSUD).

Scarcity of Spatial Location and Landscape Resources

The attribute of being "waterfront" implies access to the most 稀缺 (scarce) public landscape resources within the city. This specificity transforms regeneration from a simple internal spatial renovation into a process of "re-territorialisation" of the city's most valuable frontage spaces. Regeneration projects bear the public responsibility of converting previously enclosed productive waterfronts into open, shared living and ecological waterfronts. Their success directly affects the improvement of the urban public space system and the shaping of the city's image [44].

High Potential for Functional Mix and Vitality Activation

The inherent attractiveness of waterfront areas, combined with the large spaces typical of industrial heritage, provides an excellent vehicle for functional mix. Regeneration can integrate diverse functions such as culture, leisure, commerce, office, residential, and even ecological services, creating a triple value superposition effect of "heritage space + waterfront space + public space" [38]. This mixed-use nature makes it easier to transform such sites into urban destinations with 24-hour vitality. For example, the Guangzhou Pazhou Beer District (Party Pier) transformed a brewery into a riverside dining and entertainment complex, successfully activating the night-time economy.

Unique Carrier of Historical Layering and Cultural Memory

Waterfront industrial heritage bears witness to the historical layering of cities through

different periods—pre-industrial, industrial, and post-industrial. It serves as a composite carrier of wharf culture, shipping culture, industrial civilisation, and waterfront living memories. Its regeneration is not merely about preserving industrial buildings but also about continuing the entire waterfront industrial landscape and historical context. It possesses stronger narrative qualities, and its cultural value has greater depth and breadth.

2. Core Challenges in Waterfront Industrial Heritage Regeneration

(1) The Conflict between Water Source Protection and Development Intensity

Waterfront industrial heritage sites are often located adjacent to sensitive water bodies such as rivers and lakes. The shorelines in question frequently fall within water source protection zones or ecologically sensitive areas, subject to stringent environmental capacity and development intensity controls. However, as a significant type of urban stock development, industrial heritage regeneration objectively requires the introduction of a certain scale of commercial, cultural, or residential functions to ensure economic sustainability. This creates a deep tension between the rigid constraints of ecological protection and development demands. This tension manifests in three ways: first, the increase in impervious surfaces resulting from high-density development exacerbates surface runoff and non-point source pollution loads, threatening the water quality safety of receiving water bodies; second, large-scale new construction may disrupt the ecological continuity and visual corridors of the waterfront; third, underground space development (e.g., underground parking garages, commercial facilities) may disturb subsurface hydrological processes and riverbank stability. Achieving functional renewal and vitality regeneration under the bottom-line constraints of ecology is the primary challenge facing waterfront industrial heritage regeneration.

(2) The Conflict between Industrial Isolates and Community Fragmentation

Due to the requirements of industrial production regarding transport conditions and safety isolation, waterfront industrial plants historically formed relatively enclosed spatial units—bounded by walls, railway spurs, and dock operation areas—remaining fragmented from surrounding urban communities in terms of spatial connectivity and social interaction for extended periods. Following industrial withdrawal, this pattern of "industrial isolates" has not naturally dissolved. Instead, it persists due to complex property rights, delays in land-use conversion, and inadequate infrastructure connections. In regeneration practice, if the focus is only on internal spatial renovation and functional replacement within the plant area, while neglecting systematic integration with surrounding communities in terms of transport networks, public services, and ecological corridors, the regenerated park may easily become a new "enclave" detached from the urban fabric, failing to achieve the openness and social

value of public space.

(3) The Conflict between Heritage Preservation and Innovative Utilisation

Industrial heritage embodies the craftsmanship, architectural aesthetics, and collective memory of specific historical periods. Preservation requirements cover multiple aspects, including the building structures themselves, spatial textures, and the remnants of equipment and facilities. There exists a significant adaptive tension between this preservation imperative and the insertion of contemporary functions. On the one hand, heritage-listed factory buildings, warehouses, silos, and other structures face strict constraints on structural alterations, spatial partitioning, and equipment installation. The large-span column-free spaces, comfortable physical environments, and fire evacuation conditions required by modern commercial or cultural functions are often difficult to achieve. On the other hand, site elements formed during the industrial period—such as ground pavements, railway tracks, and pipe galleries—though historically valuable, exhibit hardened, engineered morphological characteristics that conflict with contemporary ecological design principles. Achieving creative functional transformation and adaptive spatial reuse while respecting the authenticity and integrity of the heritage is the core proposition that distinguishes industrial heritage regeneration from general urban design.

2.2 Theoretical Evolution and Core Concepts of Stormwater Management

2.2.1 Evolution of Mainstream International Stormwater Management Concepts

Looking at the historical evolution of international stormwater management, its core concepts have undergone a progression from "water quantity control" to "water quality management," and subsequently to "sustainable integrated management." This evolution reflects a fundamental shift in how humans perceive the value of stormwater—from being regarded in the early days as "waste to be discharged as quickly as possible," to later being seen as "a utilizable resource" and an integral component of the urban ecosystem.

In the late 1950s, the prevailing philosophy of urban stormwater management in the United States was primarily "conveyance and discharge." By the 1970s, it became increasingly evident that a drainage-oriented approach alone was insufficient to address the pollution of receiving water bodies and urban flooding caused by stormwater runoff. Around the same period, Germany also began to prioritize the control of stormwater runoff pollution, adhering to the principle of "zero runoff increase" for newly developed land. In the 1980s,

academic research confirmed that stormwater runoff was a major contributor to water pollution in the United States, prompting the U.S. Environmental Protection Agency (EPA) to implement the "National Urban Stormwater Program," which verified the severity of urban stormwater issues [1].

Since the 1990s, the concept of sustainable development has progressively permeated the field of stormwater management. With accelerating urbanization, the proportion of impervious surfaces in cities has gradually increased, and cities have evolved into "hard-shell cities" composed of reinforced concrete. As a result, stormwater resources are not effectively utilized, further exacerbating the deterioration of urban water cycle systems and ecosystems [2]. Against this backdrop, developed countries such as the United States, Australia, and the United Kingdom have developed distinctive stormwater management frameworks: Best Management Practices (BMPs) and Low Impact Development (LID) in the United States, Water Sensitive Urban Design (WSUD) in Australia, and Sustainable Urban Drainage Systems (SUDS) in the United Kingdom. While all rooted in the principle of "source control," these approaches each emphasize different aspects—ranging from natural environment protection, to urban water cycle restoration, to the balance between ecology and development—thereby providing diverse theoretical foundations for contemporary stormwater management.

2.2.2 The WSUD Concept in Australia

Water Sensitive Urban Design (WSUD) originated in Australia in the early 1990s as a novel urban water management paradigm developed in response to the country's prolonged drought, water scarcity, and severe challenges related to water quantity, water quality, and drainage within urban water systems (Wong, 2006) [12]. Australia experiences low average annual precipitation, and urban development has significantly interfered with the natural water cycle, prompting both the government and academia to seek systematic approaches that integrate water cycle management into urban spatial planning. In 1994, Whelan and colleagues explicitly introduced the concept of WSUD, the core of which lies in using interdisciplinary and integrated design to mitigate the negative impacts of urbanisation on natural hydrology and enhance the sustainable utilisation of water resources [14].

WSUD is defined as a design approach that integrates spatial design with the urban water cycle [16]. The connotation of WSUD extends beyond stormwater management technologies; it emphasises treating the urban water cycle (including water supply, wastewater, stormwater, and groundwater) as an integrated whole, and combining it with urban design, landscape

planning, and spatial governance to achieve synergies between water ecology, water environment, and urban development (CRC for Water Sensitive Cities, 2012). Its fundamental principle is to mimic natural hydrological processes through green infrastructure (e.g., rain gardens, constructed wetlands, permeable pavements), treating stormwater, runoff, and even wastewater as recoverable resources, thereby promoting a "closed-loop cycle" within the urban water system [3].

In terms of evolution, WSUD has progressed from technological exploration to systematic integration. In 1997, Australia enacted legislation to elevate the role of water in urban planning. The first International Conference on Water Sensitive Urban Design was held in 2002, marking international recognition of the concept. In 2004, WSUD was incorporated into national strategies. By 2006, relevant projects received the International Water Association (IWA) Grand Award, indicating a maturation of the technical framework [15]. In 2008, WSUD was introduced to China, where scholars such as Wang Jianguo and Liu Xiaoxia promoted its applied research in landscape architecture and planning [14]. Currently, WSUD has evolved from an early focus on stormwater runoff volume control into a comprehensive framework that integrates water resource utilisation, ecological protection, and urban spatial optimisation, forming a complete set of implementation pathways across macro-, meso-, and micro-scales [13].

1. Core Principles

The practice of WSUD follows six core principles [17], which guide the entire process from macro-scale planning to micro-scale design.

Increase Permeable Surfaces: this principle aims to reduce impervious hard surface areas at the source and increase opportunities for on-site stormwater infiltration, thereby reducing total surface runoff volume and peak flow, while also recharging groundwater. Specific measures include: replacing traditional impervious pavements with permeable pavements (e.g., pervious concrete, permeable pavers); incorporating grass pavers or tree-pit green spaces in parking lots and plazas; and promoting green roofs to retain and evaporate roof runoff.

Drain Stormwater Naturally: This emphasises respecting and utilising the natural drainage paths and topography of a site, avoiding over-reliance on conventional grey drainage pipe systems. Design should prioritise the use of natural gullies, depressions, vegetated swales, and water bodies to naturally collect, retain, and infiltrate stormwater runoff, thereby fully leveraging the site's natural drainage functions and creating stormwater management landscapes with flood retention and detention benefits.

Control Runoff at the Source: Stormwater should be treated and managed near the source

where runoff is generated (e.g., roofs, pavements, plazas). By rapidly directing runoff into facilities such as rain gardens and sunken green spaces, on-site retention, purification, and utilisation of stormwater can be achieved, preventing the accumulation of pollutants and mitigating the impact of peak flows on downstream drainage systems.

Interrupt Surface Runoff: This principle aims to interrupt the rapid flow of stormwater over continuous impervious surfaces and shorten runoff flow paths. Using facilities such as bioswales and vegetated buffer strips, runoff is intercepted during conveyance and directed into retention areas, promoting infiltration or evaporation, thereby effectively reducing soil erosion and improving water quality.

Reveal the Regulation Process: This principle makes visible, through landscape design, the stormwater management processes traditionally hidden underground (e.g., the flow, collection, and purification of stormwater). This not only enhances the scientific and aesthetic value of the landscape but also improves public understanding of and engagement with the water cycle. For example, open drainage channels, wetlands, and detention basins can be designed as prominent landscape elements.

Emphasise Element Integration: WSUD pursues the deep integration of stormwater management facilities with landscape, recreation, and ecological functions. Technical facilities (e.g., rain gardens, bioswales) should be combined with activity spaces, recreational paths, topography, vegetation, seating areas, and even artistic sculptures to achieve a unity of form and function, delivering multiple benefits encompassing ecological, environmental, social, and economic dimensions.

2. Technical Framework

WSUD has developed a technical framework comprising four major categories of technologies: retention technologies, infiltration-enhancing technologies, detention and storage technologies [17], and reuse technologies (see Table). These technologies can be flexibly selected and combined according to different application scenarios and objectives.

Table2 - 2 Introduction to WSUD Technologies

Table2 - 2 Introduction to WSUD Technologies		
Classification of Technologies	Technology Name	Technical Characteristics and Functions
Retention Technologies	Green Roof	By laying a planting layer on building rooftops, green roofs enable the absorption, storage, evaporation, and delayed discharge of stormwater, while also providing thermal insulation, energy savings, and

Table2 - 2 Introduction to WSUD Technologies

Classification of Technologies	Technology Name	Technical Characteristics and Functions
		environmental beautification.
	Canopy Interception	By utilising the canopies and branches of trees and shrubs to intercept rainfall and subsequently return it to the atmosphere through transpiration, this technique represents an important approach for simulating the hydrological processes of natural forests.
Infiltration-Enhancing Technologies	Permeable Pavement	By paving surfaces with porous materials (such as permeable asphalt, permeable bricks, and grass pavers), rainwater rapidly infiltrates, effectively recharging groundwater and reducing surface runoff. Research indicates that its runoff reduction capacity can reach 40%–90% [17].
	Green Parking Lot	By combining permeable pavements with bioswales and planting beds, green parking lots enable the collection, infiltration, and primary filtration of stormwater runoff while still fulfilling parking functions.
	Green Street	By installing bioswales, permeable tree pits, and similar facilities along both sides of the street, green streets enable the on-site retention and treatment of stormwater runoff. This approach represents a key water-sensitive retrofitting technique for urban road spaces.
Detention and Storage Technologies	Bioswale	A shallow, vegetated channel designed to collect, convey, and filter stormwater runoff. Studies have shown that it can achieve removal rates of 55%–95% for pollutants such as total suspended solids (TSS), total phosphorus (TP), and chemical oxygen demand (COD), while also effectively attenuating flood peaks.
	Rain Garden / Bioretention Basin	A sunken landscape facility planted with flood- and drought-tolerant vegetation,

Table2 - 2 Introduction to WSUD Technologies

Classification of Technologies	Technology Name	Technical Characteristics and Functions
		designed to store, infiltrate, purify, and detain runoff through a specialised layered structure (planting soil, sand layer, gravel layer). It is one of the most widely applied WSUD techniques.
	Stormwater Wetland	By simulating natural wetlands and utilising the "soil-plant-microorganism" ternary system, stormwater wetlands provide detention, storage, and advanced treatment of high-flow stormwater runoff or first-flush pollution, while offering significant ecological and landscape benefits.
	Multi-Functional Detention Basin	Typically located at the downstream end of a regional drainage system, multi-functional detention basins are designed to provide large-scale storage of peak stormwater flows and prevent urban flooding. After rainfall events, the stored stormwater can be purified and subsequently used for non-potable purposes such as landscape water replenishment and firefighting, thereby achieving resource utilisation.
	Rain Barrel	A small-scale facility used to collect rainwater from building rooftops. The harvested rainwater can be used for irrigation, car washing, and similar purposes, representing a simple and easily implementable rainwater utilisation technique.
Reuse Technologies	Ecological Recycling Treatment System	A composite agro-ecosystem that integrates aquaculture with hydroponics. Its core principle is that organic waste, such as fish excrement from the aquaculture water, is broken down by microorganisms into nutrients that can be absorbed by plants. The plants absorb these nutrients while purifying the water, after which the treated water is

Table2 - 2 Introduction to WSUD Technologies

Classification of Technologies	Technology Name	Technical Characteristics and Functions
		recirculated back to the aquaculture tanks. This system not only produces both aquatic and plant agricultural products but also serves as an efficient, water-conserving ecological water purification technology. It can be integrated into waterfront regeneration projects as an ecological education demonstration feature.

Both Water Sensitive Urban Design (WSUD) and Sponge City represent advanced concepts for addressing urban water environment challenges and achieving sustainable water management, with significant overlaps in core objectives and technical measures. However, due to differences in their origins and development pathways, certain distinctions exist in conceptual emphasis, system architecture, and implementation scales. A systematic analysis of their similarities and differences can facilitate integrated innovation in the context of urban regeneration practices in China.

2.2.3 The Sponge City Theory in China

Against the backdrop of the burgeoning development of international stormwater management concepts, China has been exploring integrated approaches to address its water-related challenges tailored to its national conditions since the early 21st century. In 2013, the Central Urbanization Work Conference explicitly proposed the construction of "sponge cities that naturally accumulate, naturally infiltrate, and naturally purify water," marking the elevation of sponge city development to a national strategy [27]. The introduction of the sponge city concept not only reflects the absorption and reference of advanced international experience but also represents a systematic response to China's complex water issues.

(1) Background

Present-day China is facing a complex interplay of multiple water-related challenges, including water scarcity, water quality pollution, flooding disasters, and the loss of aquatic habitats [27]. In the process of rapid urbanization, more than ten million people move into cities each year, and the newly constructed building stock accounts for half of the world's total. Consequently, the impervious surface area in Chinese cities has increased dramatically, transforming urban areas into "hard-shell cities" made of reinforced concrete [4][2]. A survey

of 351 cities across China in 2010 revealed that 213 cities had experienced varying degrees of waterlogging and inundation, among which 137 cities suffered from more than three flooding events [27].

At the same time, unscientific engineering interventions have led to a systemic degradation of water-related functions—practices such as narrowing rivers for land reclamation, indiscriminate encroachment on lake wetlands, and the channelization and hardening of river courses have resulted in a 15% reduction in the national lake area and a 28% reduction in terrestrial wetland area [27]. These water problems constitute a syndrome of systemic and comprehensive issues that urgently call for a more integrated and holistic solution.

(2) Theoretical Connotation

The sponge city refers to a city that, through scientific planning and feasible construction, possesses good "resilience" in adapting to environmental changes and responding to natural disasters. It can absorb, store, infiltrate, and purify rainwater when it falls, and "release" and utilize the stored water when needed [2]. Its core connotations include four aspects:

The essence of the sponge city is to transform the traditional concept of urban development and achieve coordinated development with resources and the environment. Conventional urban development methods have altered the original water ecology, whereas the sponge city protects the original water ecology, enabling harmonious coexistence between humans and nature, land use, water environment, and water cycle.

The goal of the sponge city is to enable the city to "resiliently adapt" to environmental changes and natural disasters. This includes protecting the original water ecosystem, restoring damaged water ecosystems, promoting low-impact development (LID), and effectively reducing surface runoff through various low-impact measures.

It transforms the approach to drainage and flood prevention, shifting from the traditional "rapid drainage" model to the six-character principle of "infiltration, retention, storage, purification, utilization, and drainage" [28]. Experience has shown that under normal climatic conditions, a typical sponge city can intercept more than 80% of rainwater.

Through sponge city construction, the total runoff volume and peak flow rate before and after development remain essentially unchanged, and the time of peak runoff also remains largely the same [4].

From the perspective of ecosystem services, the core of the "sponge city" lies in constructing water-related ecological infrastructure across multiple scales. Unlike traditional engineering-based grey infrastructure, water-related ecological infrastructure is a living

system designed to comprehensively, systematically, and sustainably solve water problems, maintaining crucial water ecological processes such as urban stormwater storage and regulation, water source protection and conservation, groundwater recharge, rainwater and sewage purification, and habitat restoration.

(3) Theoretical Foundations and Implementation Approaches

The theoretical foundations of sponge cities primarily include Best Management Practices (BMPs), Low Impact Development (LID), and Green Infrastructure (GI) [8]. These concepts, while differing from one another yet partially overlapping in the field of stormwater management, provide strategic guidance and technical support for the construction of sponge cities.

The construction of sponge cities should be based on a multi-scaled ecological planning theory and methodological system (Yu Kongjian et al., 2015). At the macro level, through the analysis of water ecological security patterns, water-related ecological infrastructure is integrated into land use master plans and urban master plans, becoming the region's ecological infrastructure. In the case of Beijing, by constructing a comprehensive water ecological security pattern and delineating bottom-line security pattern, satisfactory security pattern, and ideal security pattern, the locations of victims from the extraordinary rainstorm event of July 21, 2012, were highly consistent with the stormwater security pattern studied seven years earlier, validating the scientific rigor of this approach [27].

At the meso level, taking Liupanshui as an example, ecological infrastructure centered on water processes was constructed to connect existing streams, wetlands, and low-lying areas, forming storage ponds and wetland chains with purification capacity. The demolition of concrete riverbanks and reconstruction of natural riparian wetland systems effectively slowed down hillslope runoff, transforming an industrial city into a livable one.

At the micro level, the Harbin Qunli Stormwater Park, the first national-level urban wetland park in China aimed at solving urban waterlogging, utilized cut-and-fill techniques to create a "sponge terrain" and a multi-level, multifunctional wetland system for "water purification – storage and retention – groundwater recharge." Since its completion in 2011, it has effectively played a role in mitigating urban stormwater flooding.

The technical system for sponge city construction includes interception techniques (green roofs, canopy interception), infiltration promotion techniques (permeable pavement, green parking lots, green streets), and storage and regulation techniques (ecological swales, rain gardens, multi-functional storage tanks) [8]. Research indicates that ecological swales suitable for Shanghai can reduce runoff by 22%–35% and reduce pollutants by 55%–95% under heavy

rain and storm conditions; rain gardens can reduce runoff by 20%–40% and reduce pollutants by 45%–70% [8].

(4) Policy Promotion and Construction Practice

In October 2014, the Ministry of Housing and Urban-Rural Development (MOHURD) issued the technical Guide for Sponge City Construction – Low Impact Development Stormwater System Construction (Trial), which provides systematic guidance on goals, indicators, processes, measures, and management. In January 2015, the construction of sponge cities was launched in 16 pilot cities, including Zhenjiang, Jiaxing, Xiamen, Jinan, Wuhan, Changde, and Nanning. In September 2015, the Executive Meeting of the State Council deployed measures to accelerate sponge city construction, with the total investment in the first batch of sponge city pilot projects exceeding 30 billion RMB [2].

The technical Guide for Sponge City Construction statistically analyzed daily rainfall data from approximately 200 Chinese cities spanning the period 1983–2012, dividing mainland China roughly into five zones. It provides minimum and maximum limits for the annual total runoff control rate (α) for each zone, as follows: Zone I ($85\% \leq \alpha \leq 90\%$), Zone II ($80\% \leq \alpha \leq 85\%$), Zone III ($75\% \leq \alpha \leq 85\%$), Zone IV ($70\% \leq \alpha \leq 85\%$), Zone V ($60\% \leq \alpha \leq 85\%$) [28].

2.2.4 Exploration of Stormwater Management in Other Countries

In addition to Australia, the United States and the United Kingdom have developed distinctive technical systems and policy guarantee mechanisms for stormwater management based on their respective national conditions, offering valuable lessons for the development of sponge cities in China.

(1) Formation and Development of Best Management Practices (BMPs) in the United States

The systematic development of stormwater management concepts in the United States began in the 1970s. In 1972, the U.S. Federal Water Pollution Control Act Amendments first introduced the concept of "Best Management Practices" (BMPs) as a technical system for controlling non-point source pollution. Liao Chaoxuan et al. (2016) pointed out that BMPs initially focused on the reduction and control of non-point source pollution. In 1987, the U.S. revised the Clean Water Act, incorporating stormwater runoff pollution control requirements into the National Pollutant Discharge Elimination System (NPDES) permit program. The Federal Water Pollution Control Act Amendments passed in 1997 elevated the BMP concept to the legislative level for the first time.

Research by Zhang Yupeng (2015) indicates that the fundamental goal of BMPs is to alleviate the conflict between urban construction and the water ecological environment by strengthening stormwater runoff control. Specific objectives include suppressing peak stormwater flow rates, increasing water resource utilization, improving water quality during storm events, reducing non-point source pollution, maintaining groundwater recharge, and ensuring biodiversity. At the technical level, BMPs encompass the integrated application of engineering measures (such as retention ponds, wetlands, and infiltration basins) and non-engineering measures (such as management practices).

(2) Source Control Concept of Low Impact Development (LID)

Due to issues associated with the implementation of BMPs, such as large land occupation, high construction and maintenance costs, and relatively low treatment efficiency, Prince George's County in Maryland, USA, introduced a micro-scale concept and technical system known as Low Impact Development (LID) in 1990 as a supplement to macro-scale BMPs. Compared with BMPs, LID emphasizes the use of various stormwater control techniques—such as storage, infiltration, evaporation, filtration, purification, and retention—to restore post-development runoff conditions as closely as possible to pre-development conditions.

Zhang Yupeng (2015) further explains that LID emphasizes the use of decentralized, small-scale source control mechanisms, employing techniques such as infiltration, filtration, storage, and evaporation to intercept runoff close to its source, thereby controlling runoff and pollution generated by storm events. At the technical level, LID encompasses a range of interconnected measures, including bioretention systems, infiltration trenches, vegetative filter strips, green roofs, permeable pavements, rain barrels, and others. By enhancing infiltration, collection, and utilization of rainwater, these measures achieve scientifically sound stormwater management.

(3) Origins and Objectives of the UK Approach

To address the problems arising from traditional urban drainage systems, the UK's national working group on sustainable urban drainage systems issued the Interim Code of Practice for Sustainable Urban Drainage Systems (SUDS) in 2004, which proposed conceptual approaches and technical specifications for implementing SUDS [2]. SUDS integrate environmental and social factors into urban drainage regimes and systems, comprehensively considering water quantity, water quality, wastewater and recycling, community participation, economic development, natural habitat conservation, landscape design, and ecological value. Through integrated measures, SUDS aim to improve the overall

urban water cycle.

According to the definition by the UK Environment Agency, SUDS encompass a range of techniques for the sustainable management of surface water and groundwater [29]. The objective of SUDS is to establish a sustainable drainage system that balances economic development and environmental protection while maintaining a healthy water cycle. This is achieved by addressing stormwater management from three perspectives: flow rate of surface water treatment and discharge, water quality, and environmental amenity.

2.2.5 WSUD and Sponge Cities

1. Differences in Conceptual Origins and Background

Water Sensitive Urban Design (WSUD) originated in Australia in the 1990s as a systemic solution to the problems of traditional drainage systems. Its core principle is to treat the urban water cycle (stormwater, wastewater, water supply) as an integrated whole, embedding water sensitivity from the outset of urban planning and design, and emphasizing the comprehensive resolution of water quality, water quantity, and aquatic ecosystem health through spatial design measures [29][37]. Australia's arid and low-rainfall climate places particular emphasis on water recycling and ecological protection.

The sponge city concept, on the other hand, was first explicitly proposed by Chinese scholar Yu Kongjian and his colleagues (2012), and later elevated to a national strategy following its emphasis at the Central Urbanization Work Conference in 2013. It emerged against the backdrop of prominent "urban diseases" during China's rapid urbanization process, notably frequent waterlogging, water scarcity, and deterioration of water ecology [28]. The sponge city emphasizes the restoration of the natural hydrological state that existed prior to urban development through "natural accumulation, natural infiltration, and natural purification," with the core goal of enhancing urban "resilience" to cope with environmental changes and natural disasters.

2. Commonalities in Core Objectives and Principles

Despite their different origins, the two concepts are highly consistent in their core principles and objectives.

Mimicking the natural water cycle: reducing peak runoff, recharging groundwater, and mitigating non-point source pollution through ecological measures.

Synergistic multiple benefits: pursuing integrated improvements in water security, water resources, water environment, and water ecology, while simultaneously enhancing biodiversity, landscape aesthetics, and recreational value.

Source control and decentralized management: promoting decentralized, small-scale green infrastructure (e.g., rain gardens, permeable pavements, green roofs) as a substitute for or supplement to traditional grey infrastructure.

Yu Kongjian has pointed out that the essence of the sponge city is to "achieve harmonious coordination between urbanization and resources and the environment," which fully aligns with the value of "human-water harmony" pursued by WSUD [27].

3. Comparison of System Frameworks and Technical Measures

Table2 - 3 Comparison of Water Sensitive Urban Design and Sponge Cities

Table2 - 3 Comparison of Water Sensitive Urban Design (WSUD) and Sponge Cities		
Dimension	WSUD	Sponge Cities
Theoretical Framework	Originating in Australia with a mature system, it strongly emphasizes the comprehensive integration of water cycle management (stormwater, wastewater, and water supply) with urban design and landscape planning [31].	It absorbs and integrates international experiences such as LID, BMP, GI, and WSUD, with greater emphasis on the technical principle of "infiltration, retention, storage, purification, utilization, and drainage." Its technical system and indicator-based construction guidelines are more clearly defined [60].
Technical Emphasis	Its technical system prioritizes water quality management and aquatic ecological health, placing wastewater reuse, rainwater harvesting, and ecological wetland purification on an equal footing.	While also emphasizing water quality, due to the prominent issue of urban waterlogging in China, the initial focus was more on stormwater storage and regulation as well as total runoff volume control, with solving the problem of "cities looking at the sea" (i.e., severe urban inundation) as the primary objective.
Implementation Scale	It emphasizes cross-scalar integration, spanning from macro-scale watershed planning to micro-scale site design, requiring deep interdisciplinary integration among urban design, water supply and drainage engineering, and landscape architecture.	It also emphasizes the integration of macro, meso, and micro scales. However, in domestic practice, it is often delineated and advanced through four subsystem levels—"building, community, city, and region"—with clearer policy leverage [28].
Policy and	It is typically integrated with	In China, it is strongly promoted at the

Table2 - 3 Comparison of Water Sensitive Urban Design (WSUD) and Sponge Cities

Dimension	WSUD	Sponge Cities
Governance	local water regulations, stormwater discharge permitting systems, and economic incentive measures (e.g., stormwater fee discounts).	national level and implemented through mechanisms such as pilot cities, financial subsidies, and the integration of special plans into the statutory framework of urban planning, exhibiting distinct characteristics of "top-level design" [30].

4. Integration and Complementarity: A Comprehensive Urban Water System Governance Paradigm

Although both Water Sensitive Urban Design (WSUD) and Sponge City Design aim at sustainable stormwater management, WSUD places greater emphasis on the concept of the "liveable city" [32] and aligns more closely with the six core objectives of urban development proposed by the Chinese government for the new era: "innovation, liveability, beauty, resilience, civility, and wisdom."

For the renewal of waterfront industrial heritage sites in the Greater Bay Area, the two approaches are not substitutes for one another but are highly complementary. WSUD provides a systemic integration framework. Its philosophy of deeply integrating water management with urban spatial design is particularly applicable to complex projects such as the Zini Sugar Refinery, which require comprehensive solutions for industrial pollution remediation, stormwater management, heritage conservation, and spatial regeneration. Sponge cities offer a localized technical system and implementation pathways. Their clear control targets (e.g., the annual total runoff control rate) and rich LID technical toolkit (e.g., sunken green spaces, storage tanks) provide specific technical options and quantitative bases for project implementation.

Therefore, in practice, the holistic and integrative thinking of WSUD should be combined with the specific technical standards and implementation mechanisms of sponge cities to construct a water-sensitive regeneration model that is both aligned with international concepts and adapted to local needs. As Liao Chaoxuan et al. have pointed out, China's sponge city construction can draw on international concepts such as WSUD to "carry out urban drainage system retrofitting and stormwater management information system development according to local conditions" [29].

2.2.6 Summary: Comparison of Core Concepts and Implications

Based on the above review of mainstream international stormwater management concepts and China's sponge city theory, it can be observed that different countries and regions have developed distinctive theoretical systems and technical pathways shaped by their respective natural geographical conditions, stages of social development, and practical challenges. A comparative analysis of these concepts helps to identify common patterns in the evolution of stormwater management and provides a theoretical reference for the case study of this paper—the stormwater management design for the Guangzhou Zini Sugar Refinery waterfront industrial heritage site.

(1) Comparison of Core Concepts

From the perspective of management objectives, U.S. BMPs and LID focus on "source control," emphasizing the restoration of post-development hydrological conditions to pre-development levels through decentralized facilities, with the primary aim of reducing anthropogenic interference with the natural environment. Australian WSUD, by contrast, adopts a "holistic water cycle" approach, integrating stormwater, water supply, and wastewater, treating stormwater as a usable resource and pursuing comprehensive optimization of urban water systems. The UK's SUDS emphasize the multidimensional nature of "sustainability," achieving integrated benefits across four aspects—flow rate, water quality, environmental amenity, and biodiversity—while balancing economic development and ecological protection.

China's sponge city theory, built upon the absorption of international experience, represents a systemic solution tailored to the country's complex water problems. Its core lies in establishing cross-scaled water ecological infrastructure to comprehensively address multiple issues, including urban stormwater storage and regulation, water source protection, groundwater recharge, rainwater and sewage purification, and habitat restoration. Compared with Western concepts, the sponge city places greater emphasis on the ecological values of "natural accumulation, natural infiltration, and natural purification," marking a shift from "water adapting to humans" to "humans adapting to water."

From the perspective of technical emphasis, U.S. LID focuses on micro-scale source measures such as bioretention and permeable pavements; Australian WSUD emphasizes integration with urban design and landscape spaces; the UK's SUDS establish a three-tier technical chain of "source-conveyance-reception"; and China's sponge city emphasizes multi-scalar nesting—the systematic integration of macro-scale water ecological security patterns, meso-scale town sponge systems, and micro-scale green sponge technologies.

(2) Common Patterns and Evolutionary Trends

Although different countries have different emphases, the following common patterns can be identified.

Shift in management focus from "end-of-pipe treatment" to "source control." From the centralized end-of-pipe treatment of BMPs to the decentralized source control of LID, and from the traditional "rapid drainage" model to the sponge city's six-character principle of "infiltration, retention, storage, purification, utilization, and drainage," all reflect the core concept of retaining and absorbing runoff at its source.

Expansion of management objectives from singular to multiple dimensions. From initial flood control and pollution reduction, objectives have gradually expanded to include ecological protection, landscape creation, community participation, climate adaptation, and other comprehensive values. The "four pillars" of SUDS and the ecosystem service orientation of sponge cities both reflect this trend.

Transition of technical approaches from grey to green. Shifting from reliance on grey infrastructure such as pipes and pumping stations to green infrastructure that mimics natural hydrological processes, emphasizing the integrated application of ecological techniques such as permeable pavements, bioretention, and constructed wetlands.

Evolution of institutional design from government-led to multi-stakeholder governance. Through economic incentives (e.g., stormwater discharge fees, subsidy schemes), public participation (e.g., downspout disconnection programs in Canada), and community co-construction, social forces are mobilized to engage in stormwater management.

(3) Implications for Stormwater Management of Waterfront Industrial Heritage Sites

The above international experiences and sponge city theory offer important implications for the design of the case study in this paper—the Guangzhou Zini Sugar Refinery site:

Integrate source control with process management. Given the high impervious surface ratio and poor soil permeability typical of industrial heritage sites, the LID concept can be adopted by installing source-control facilities such as bioretention strips and permeable pavements around buildings and along roadsides. At the same time, drawing on the three-tier SUDS framework, a complete stormwater management chain of "source–conveyance–reception" can be established based on the existing site drainage pathways.

Integrate stormwater management with industrial heritage landscape. Drawing on WSUD and sponge city practices, facilities such as vegetated swales, rain gardens, and storage ponds can be combined with industrial structures, abandoned railway tracks, and wharf spaces to

create a landscape system that serves both stormwater management functions and place memory. For example, original sedimentation tanks could be repurposed into multi-functional storage wetlands, and abandoned factory roofs could be converted into green roofs, embodying the ecological values of "natural accumulation, natural infiltration, and natural purification" [27].

Adopt adaptive technologies tailored to local conditions. Drawing on Japanese experience, and in response to the hot, humid, and rainstorm-prone climate of Guangzhou, the proportion of infiltration facilities to storage facilities should be rationally configured to avoid prolonged water accumulation, which can lead to mosquito breeding and root rot [6]. Site grading design can be combined with hydrological modeling to optimize catchment delineation and improve the accuracy of design solutions. Studies have shown that ecological swales suitable for South China can reduce runoff by 22%–35%, and rain gardens can reduce runoff by 20%–40% [8].

Explore diversified institutional safeguards. Drawing on the stormwater discharge fee and subsidy systems in Canada, a stormwater management maintenance fund could be established at the site operation level. By implementing measures such as stormwater discharge fees or facility construction subsidies, enterprises and the public could be incentivized to participate in the maintenance and management of stormwater facilities. Meanwhile, drawing on Japan's subsidy system, corresponding policy support could be provided for different types and scales of stormwater facilities [7][59].

Emphasize public participation and community co-construction. Drawing on the experience of downspout disconnection programs in Canada, public participation workshops can be organized during the site redevelopment process to solicit suggestions from local residents on the design of stormwater facilities. Additionally, interpretive signage and educational programs can be used to disseminate knowledge of stormwater management, thereby enhancing public awareness and a sense of ownership. The success of sponge cities is inseparable from the "collaboration of multiple stakeholders, seeking joint construction by government, research institutions, the market, and the public" [7].

Develop multi-scalar systems thinking. Drawing on the sponge city's theoretical framework of "macro–meso–micro" multi-scalar nesting, the design of the Zini Sugar Refinery must consider three levels holistically. At the macro level, analyze the site's position within the regional water system and protect its hydrological connection to the Pearl River. At the meso level, establish a site-scale sponge system that links various stormwater management facilities. At the micro level, implement green sponge technologies at specific locations to form a complete stormwater management network.

In summary, the evolution of international stormwater management concepts and sponge city theory provides a rich theoretical resource and practical reference for the construction of sponge cities in China. In the design of the Zini Sugar Refinery, it is necessary to build upon the unique conditions of the industrial heritage site, integrate multiple concepts, and explore stormwater management design strategies suitable for waterfront industrial heritage sites. This will achieve the synergistic enhancement of ecological benefits, landscape value, and social functions, offering a reference for the practice of similar projects.

2.3 The Entry Point of This Study

2.3.1 Summary and Critique of Existing Research

Existing research has laid a solid foundation for the renewal of industrial heritage sites, yet there remains room for further deepening and expansion in specific directions.

Abundant theoretical research but insufficient cross-disciplinary integration. Although a value recognition system and renewal models for industrial heritage have been established, the systematic integration of Water Sensitive Urban Design (WSUD) concepts with the renewal of waterfront industrial heritage remains inadequate. WSUD has been primarily applied to new town development, with weak integration into heritage conservation in built environments.

Active practical exploration but increasingly homogeneous models. Despite the richness of domestic and international practices, common problems persist, including a disconnect between ecological restoration and heritage preservation, excessive commercialization, and spatial homogenization [35]. This is particularly pronounced in Greater Bay Area projects, where insufficient attention has been paid to regional climatic adaptability and fine-grained hydro-ecological restoration.

Initial progress in Greater Bay Area research but lacking specificity and systematicity. Research on the Greater Bay Area has largely remained at the level of phenomenon description and individual case summaries, with a lack of systematic design methodology construction centered on specific concepts (e.g., WSUD) that address the region's characteristics of high density, high-intensity development, and prominent stormwater flooding issues.

2.3.2 Theoretical Approach and Innovation of This Study

In response to the research gaps identified above, this study takes the Guangzhou Zini Sugar Refinery as a case study to explore a renewal pathway for waterfront industrial heritage

sites in the Greater Bay Area based on the concept of Water Sensitive Urban Design (WSUD). The innovations of this study are primarily reflected in the following three aspects.

Regional adaptation of design methods: this study proposes adaptive design strategies suitable for the high-density, hot and humid region of the Greater Bay Area, with a focus on the organic integration of WSUD elements (e.g., rain gardens, ecological purification ponds) with industrial spaces, buildings, and landscapes, thereby transforming them simultaneously into ecological facilities, carriers of memory, and public spaces.

Empirical generalization of practical samples: using the Zini Sugar Refinery, a typical waterfront industrial heritage site, as an empirical case, this study provides systematic design examples ranging from planning to technical details. It also explores phased implementation and governance pathways based on WSUD, offering a full life-cycle reference for similar projects.

Cross-disciplinary innovation in theoretical framework: this study places WSUD at the core of the renewal process, constructing an integrated framework of "ecology as the foundation, heritage as the core, and vitality as the goal." It promotes a paradigm shift from "spatial functional renewal" to a systemic renewal encompassing "hydrology–ecology–space–culture."

2.4 Chapter Summary

This chapter systematically reviews the theory and practice of Water Sensitive Urban Design (WSUD) and industrial heritage renewal. Regarding WSUD, it clarifies the theoretical connotation centered on holistic water cycle management, outlines its core principles and technical systems, and reveals its characteristics of systematicity, multi-objective synergy, and design integration through comparison with sponge cities and international case studies. Regarding industrial heritage renewal, it summarizes the evolution of value recognition, major renewal models, and the specific challenges faced by waterfront industrial heritage sites. Based on the literature review, it identifies that current research suffers from insufficient application of WSUD to industrial heritage in built-up areas, as well as weak ecological integration within industrial renewal strategies. This establishes the theoretical innovation direction of this study—introducing WSUD into waterfront industrial heritage renewal and exploring an integrated approach to ecology and heritage—thereby laying the foundation for subsequent research.

Chapter 3: Investigation of the Current Situation and Stormwater Management Issues of Waterfront Industrial Heritage in Guangzhou

3.1 Research Design

3.1.1 Overview of Research Objectives and Key Points

The core purpose of this chapter's field investigation is to move beyond the macro-level perspectives of literature and theory, by conducting empirical research on a series of representative waterfront industrial heritage projects within Guangzhou's administrative territory that have either been regenerated or are currently undergoing regeneration. The specific objectives are as follows:

Establish localised knowledge: to intuitively and explicitly understand the general conditions and common problems of waterfront industrial heritage in Guangzhou in terms of spatial form, heritage characteristics, ecological environment, and adaptive reuse models, with particular focus on stormwater management issues that are often weakened or mishandled in current regeneration practices.

Analyse regeneration models and implementation challenges: to systematically examine, under different regeneration objectives, the strategic application, actual effectiveness, and limitations of landscape design in responding to hydrological processes and ecological functions. This further enables the summarisation of practical conflicts and challenges encountered in the process of integrating heritage conservation, public vitality enhancement, and ecological performance optimisation.

Extract design principles and implications: to provide direct, context-derived empirical experience and problem warnings of high referential value for the regeneration of the core design site of this thesis—the Zini Sugar Factory site—ensuring that the subsequent design proposal is both targeted and innovative, while avoiding common pitfalls.

In essence, the regeneration and adaptive reuse of waterfront industrial heritage constitute a process of integrating multiple values and multiple objectives. Within this process, four elements—heritage conservation, water resource utilisation, heritage revitalisation, and public life—form the core thematic framework. These four elements are both interrelated and inherently in tension. How to establish organic connections among them and reasonably balance their weights in the regeneration design is the key determinant of project success.

Heritage conservation focuses on the authentic preservation of industrial historical

information and the maintenance of physical spatial integrity. Water resource utilisation centres on stormwater management, with attention to the hydrological health of the site, runoff pollution control, and the potential for water reuse. Heritage revitalisation emphasises the functional reprogramming and value regeneration of industrial spaces, reintegrating them into contemporary urban life. Public life concerns the openness, accessibility, and quality of daily use of public spaces. These four elements do not exist in isolation: sound water resource utilisation can become a distinctive feature of heritage revitalisation (e.g., transforming old settling tanks into ecological stormwater treatment landscapes) and can also enrich the experiential dimension of public life (e.g., waterfront promenades, rain garden interpretation). Conversely, overemphasising conservation may constrain the flexibility of revitalisation, while pursuing economically driven revitalisation may encroach upon ecological space and the public realm.

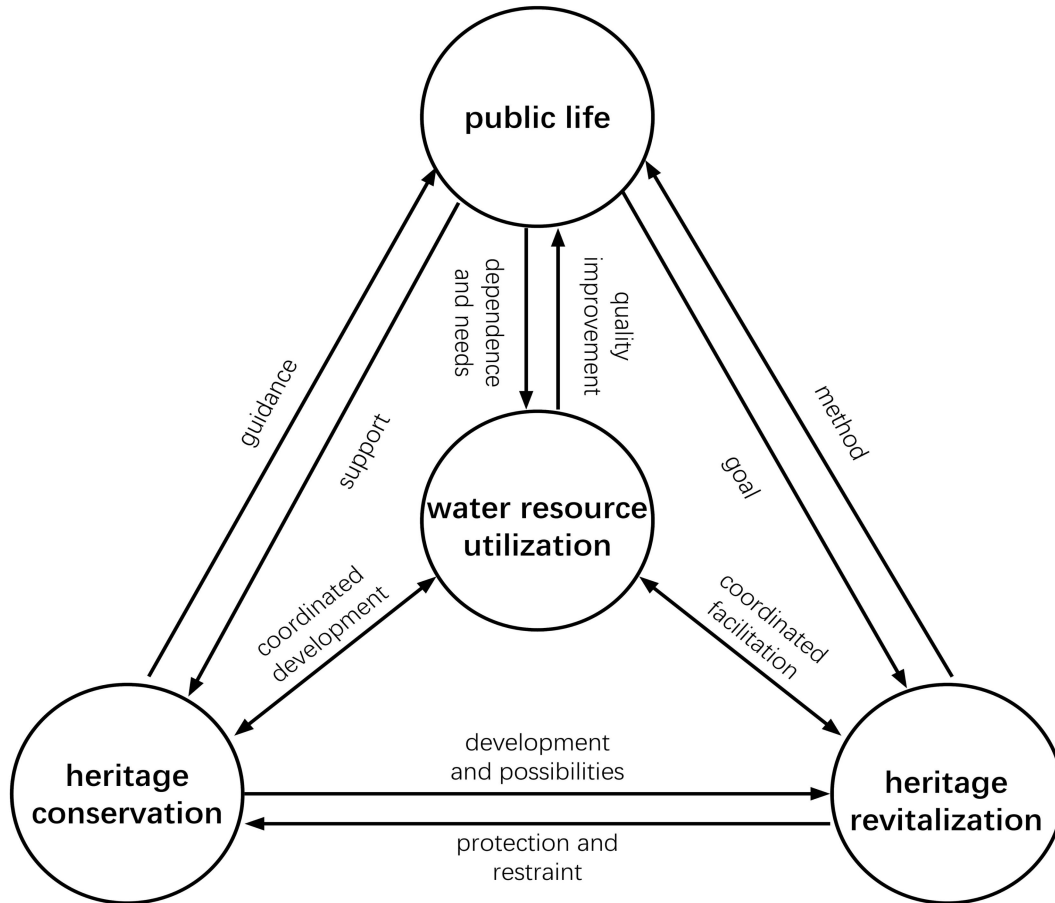


Figure3 - 1 Key Research Points(drawn by the author)

The investigation reveals that the six cases exhibit different strategic tendencies in managing the relationships among the four elements. Some projects, while preserving core industrial symbols, integrate water resource utilisation facilities with riverfront public spaces,

allowing the public to perceive the flow and purification processes of water through recreation, thereby achieving a preliminary integration of the four elements. Other projects place greater emphasis on the combination of heritage revitalisation and public life, activating social vitality through riverfront terraces, performance venues, and similar interventions. However, stormwater management in these cases remains largely conventional drainage-oriented, with the ecological function and demonstrative value of water resources being relatively weak. Still other projects adopt a cautious approach to heritage conservation, yet their public accessibility and ecological performance are both limited.

These differences indicate that designers are consciously establishing connections among the four elements and allocating weights based on project positioning, site conditions, and operational models. One noteworthy trend is that an increasing number of cases attempt to move water resource utilisation from the technical background to the spatial foreground—by integrating landscape-designed features such as rain gardens, ecological swales, and stormwater retention water bodies, the stormwater management process becomes visible and experienceable, allowing the public to perceive the utility and beauty of water during their daily recreation. This "water-mediated" design strategy provides an important reference for the Zini Sugar Factory project. The core proposition that this research strives to explore is how to transform the stormwater management system into a spatial vehicle that integrates ecological benefits, public vitality, and aesthetic experience, while preserving the industrial heritage.

3.1.2 Selection and Justification of Research Objects

To ensure the typicality of the research sample and the coverage of the research conclusions, this study selected six iconic waterfront industrial heritage regeneration cases within Guangzhou as research objects, based on dimensions such as regeneration model, waterfront location, transformation intensity, and degree of ecological intervention. The selection basis and typicality explanation for each case are presented in the table below.



Figure3 - 2 Distribution of Case Studies(drawn by the author)

Table3 - 1 Basis for Selection of Research Objects

Table3 - 1 Basis for Selection of Research Objects			
Research Objects	Primary Regeneration Orientation	Waterfront Type	Selection Basis and Typicality Analysis
Party Pier Beer Culture and Creative Art Zone	Catering & Entertainment, Cultural Exhibitions	Pearl River Front Channel	A mature commercial regeneration model. It features a high intensity of transformation, extensive commercial utilisation of waterfront public space, and strong public visibility. However, the integration between ecological treatment measures and the industrial heritage itself is relatively weak, reflecting a common market- driven model that prioritises "spatial consumption".
Haizhu Bay Creative Park	Creative Office, Art District	Inner Creek (Haizhu Creek)	A representative of "campus-style" cultural and creative regeneration. The project is large in scale, focusing on

Table3 - 1 Basis for Selection of Research Objects

Research Objects	Primary Regeneration Orientation	Waterfront Type	Selection Basis and Typicality Analysis
			the creation of internal office environments and brand image building. The connectivity of its waterfront interface with the urban community, as well as the water environment management of the internal creek, are particularly prominent issues.
Yuanchuang Elements Creative Park	Creative Design, Office	Inner Creek (Shixi Creek)	A small-to-medium-sized park case within a high-density built-up area. The site is spatially compact, surrounded by a complex built environment, effectively reflecting the tensions and possibilities between industrial heritage regeneration and microclimate and micro-hydrological regulation under conditions of limited space and high-intensity development.
Julong Bay Area Pilot Zone	Urban Comprehensive Development (Showcase)	Pearl River Rear Channel	A large-scale, holistic regeneration example of an entire district. It represents the macro-scale transition from "old industrial zone" to "future urban mixed-use urban complex". Whether and how systematic stormwater management concepts have been integrated into its early-stage planning is indicative of the status of ecological thinking within strategic regeneration projects.
Gongmei Port International Digital	Cultural & Creative, Technological	Pearl River Front Channel /	A pioneering exploration of integrating ecological concepts with cultural creativity. The project explicitly

Table3 - 1 Basis for Selection of Research Objects

Research Objects	Primary Regeneration Orientation	Waterfront Type	Selection Basis and Typicality Analysis
Innovation Centre	Innovation, Exhibition	Island	emphasises ecological design in its publicity and has implemented large-scale landscaped green spaces and constructed wetlands, providing a direct sample for observing the integration methods and effectiveness of active ecological technology measures with industrial heritage spaces and buildings.
Xinyi International Hall	High-end Commercial, Cultural, and Office Functions	Bai'etan Section of the Pearl River	An early pioneer of boutique-style regeneration. Renowned for its low-intervention, meticulous approach to transformation and its emphasis on creating an environmental atmosphere. However, its relatively enclosed management model and limited public accessibility provide an important comparative perspective for reflecting on the value of publicness in heritage regeneration.

Summary of Selection Logic: the above cases form a differentiated spectrum in terms of core functions, locational characteristics, degree of intervention, and ecological orientation, collectively establishing a "real-world sample library" for understanding the diverse regeneration practices of waterfront industrial heritage in Guangzhou. Through cross-comparative analysis of this spectrum, multi-dimensional decision-making bases can be provided for identifying potential risks and defining a differentiated positioning for the Zini Sugar Factory project.

3.1.3 Research Content and Methodological Framework

This research adopts a multidisciplinary mixed-methods approach, integrating qualitative observation and semi-quantitative analysis to obtain comprehensive and multi-dimensional primary data. The specific methodological framework is as follows:

Spatial Morphology and Physical Heritage Survey

Methods: panoramic and detailed photographic documentation; comparative analysis of historical and current drawings.

Content: focus on the overall layout and fabric of the site, the preservation status and transformation methods of buildings and structures, the retention and adaptive reuse of representative industrial features (structures, pipelines, rails, etc.), the engineering form and degree of ecological enhancement of the waterfront shoreline, site topography and natural drainage paths.

Hydrological Process and Ecological Status Diagnosis

Methods: systematic on-site observation, photographic evidence recording, simple physical tests (e.g., intuitive assessment of surface permeability), supplemented by unstructured interviews with site management personnel or long-term users.

Content: permeability of underlying surfaces (estimation of impervious surface ratio); stormwater management infrastructure (presence and condition of open channels, underground pipes, catch basins, ecological retention facilities, etc.); identification of potential waterlogging points (based on ground surface traces and materials); ecological quality of the waterfront area (sensory indicators of water quality, ecological structure of revetments, nativeness and diversity of plant communities); connectivity between the site and the external water system.

Usage Patterns and Public Perception Assessment

Methods: non-participatory behavioural observation, spatiotemporal behaviour mapping, ad hoc brief conversations with users.

Content: dominant business formats and degree of functional mix, intensity of use and types of activities in public spaces across different time periods, accessibility of waterfront spaces, design and actual use of water-responsive features, maintenance conditions of landscape facilities. Special attention is paid to changes in spatial usage patterns before, during, and after rainfall events, as well as functional deficiencies or safety problems exposed by stormwater.

Graphic, Textual, and Archival Review

Methods: systematic literature search, collection of official project promotional materials, summaries of planning and design documents, relevant media reports, and existing academic case analyses.

Content: synthesis of background information for each project, stated design concepts and

objectives, claimed technical highlights (particularly those related to sustainable drainage and ecological restoration), aiming to compare these with field observations and analyse the gap between "claims" and "actual conditions".

3.2 Trade-offs Between Water Resource Utilisation and Heritage Conservation

3.2.1 Hydrological Site Characteristics of Waterfront Industrial Heritage

The hydrological site characteristics of waterfront industrial heritage are jointly shaped by the logic of industrial production and the conditions of the waterfront location.

(1) High-impervious, fast-drainage industrial substrate

Industrial production requires level sites and convenient material transport. Consequently, factory grounds generally adopt high-intensity impervious pavements with gentle surface slopes, and drainage is organised with the objective of "rapid removal". This results in inherent hydrological characteristics of "high runoff coefficient, short concentration time, and low infiltration capacity". Any ecological retrofitting must seek breakthroughs upon this substrate.

(2) Tide-constrained waterfront drainage conditions

The Guangzhou section of the Pearl River is influenced by marine tides. During high tide, the water level may approach or even exceed the ground elevation of the site, creating a "backwater effect" that restricts gravity-driven drainage of stormwater from the site. The research found that some parks experience outfall backflow and ponding during heavy rain events, the root cause being insufficient consideration of tidal constraints.

(3) Transformable "hydrological heritage"

Hydraulic facilities left over from the industrial period, such as sedimentation tanks, cooling ponds, open channels, and drainage ditches, although no longer in use, provide existing resources for stormwater management retrofitting in terms of their spatial forms and drainage paths. For example, sedimentation tanks can be transformed into stormwater treatment wetlands, and open ditches can be rehabilitated as ecological swales. The research revealed that the degree of reuse of such facilities varies considerably across cases.

(4) Disturbed soil environment

Long-term industrial production may lead to local soil and groundwater contamination. When installing stormwater infiltration facilities, contaminated areas must be avoided or impermeable measures must be taken to prevent rainwater from leaching contaminants into the groundwater. This requires a site environmental investigation prior to retrofitting,

delineating "permeable zones" and "impermeable zones".

3.2.2 Constraints of Heritage Conservation on Hydrological Intervention

The investigation reveals that the lack of hydrological process management and the degradation of ecological functions are among the most overlooked core issues in the current regeneration of Guangzhou's waterfront industrial heritage sites. These issues manifest in the following three aspects.

(1) Surface runoff problems: high proportion of impervious surfaces, and overburdened or inadequate stormwater drainage networks.

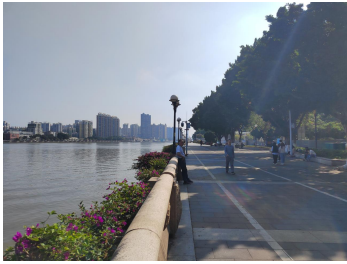
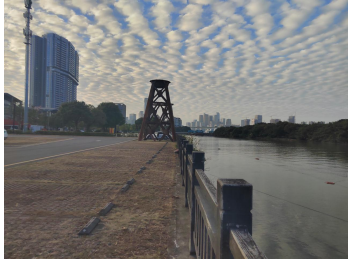
Most sites adopt a "rapid drainage" approach to stormwater management. The high imperviousness rate (estimated to commonly exceed 70%) leads to a sharp increase in the runoff coefficient, resulting in high peak flow volumes and concentrated rainfall runoff peaks. Existing drainage facilities present two typical predicaments: first, in early redevelopment projects such as the Xinyi Club, the underground drainage system is insufficiently resilient to increasingly extreme rainfall events; second, in some newly built industrial parks, although new pipe networks have been installed, they rely entirely on grey infrastructure and lack green measures for source reduction and process regulation. Pollutants such as dust and oil accumulated on impervious squares, roads, and roofs are directly discharged via runoff into municipal drainage networks or adjacent waterways during early rainfall, creating significant non-point source pollution from first-flush runoff. However, none of the surveyed sites are equipped with any first-flush diversion or purification facilities.

(2) Water environment problems: first-flush rainwater pollution, underdeveloped ecological functions of waterfront banks, and room for improving connectivity with the urban water system.

The characteristics of the waterfront banks are relatively uniform. Apart from the Gongmei Port site, where a deliberate partial ecological restoration has been carried out, the banks in the other cases remain largely as vertical hard revetments (e.g., rubble masonry or concrete) or have been transformed into such. These engineered banks sever the ecological exchange between land and water, losing essential ecological functions such as runoff filtration, habitat provision, and water-level fluctuation buffering. In sites adjacent to inner rivers (e.g., Haizhu Bay and Julong Bay), the hydraulic connection between the site's internal water bodies and the external rivers is mostly provided by rigid culverts, lacking ecological transition zones. Moreover, the vegetation along the waterfront is dominated by ornamental horticultural species, resulting in a simplified ecological structure. Overall, the

"water-bank-city" relationship remains clearly demarcated. The waterfront space currently serves primarily as visual scenery or a single-purpose activity venue, and is gradually transitioning toward an ecologically rich and vibrant corridor with diverse activities. For example, the waterfront at Party Pier combines tram sightseeing with dining and leisure, while the Haizhu Bay waterfront, together with its internal plaza, has been adapted into a temporary market.

Table3 - 2 Current Status of the Waterfront Environment in the Investigated Cases

Table3 - 2 Current Status of the Waterfront Environment in the Investigated Cases		
		
Yuanchuang Elements Creative Park Waterfront	Xinyi Club Waterfront	Julong Bay Waterfront
		
Party Pier Waterfront	Haizhu Bay Waterfront	Gongmei Port Waterfront

(3) Ecological resilience needs improvement: lack of spongy space for coping with stormwater and flooding, yet high biodiversity potential.

Under the current regeneration model, landscape design largely serves visual beautification and activity support, while there remains considerable room for improvement in ecosystem services such as microclimate regulation, stormwater retention and detention, and ecological habitat provision. The green spaces in most sites exhibit characteristics of fragmentation, carpet-like coverage, and shallow rooting. Only Gongmei Port features sunken green spaces, rain gardens, or bioretention strips that effectively infiltrate and retain stormwater. In most industrial parks, a pronounced site-scale heat island effect persists,

biodiversity remains low, and it is difficult to observe intact native plant communities or habitats for birds and insects.

In summary, while the regeneration of Guangzhou's waterfront industrial heritage has achieved notable success in heritage conservation, there remains a systemic and widespread deficiency in deeper ecological dimensions, including the integration of hydrological cycle management, restoration of water-land ecological functions, and enhancement of climate adaptability. This underscores the urgent practical necessity and provides a clear direction for improvement, which justifies the introduction of stormwater management concepts into the Zini Sugar Refinery project in this study.

Table3 - 3 Current Status of the Ecological Landscape in the Investigated Cases

Table3 - 3 Current Status of the Ecological Landscape in the Investigated Cases		
		
Integration of Shrubs and Buildings at Yuanchuang Elements Creative Park	Predominance of Trees at Xinyi Club	Vertical Greening at Julong Bay
		
Artificial Landscape Ornaments at Party Pier	Sparse Greenery at Haizhu Bay	Large-Scale Rain Garden at Gongmei Port

3.3 The Relationship between Heritage Revitalization and Public Life

3.3.1 The Publicness Dimension of Heritage Revitalization

The revitalization of industrial heritage encompasses two aspects. The first is the reuse of

physical space—that is, the functional conversion and adaptation of industrial buildings, structures, and sites. The second is the reproduction of social meaning—namely, reintegrating industrial spaces into the daily lives of the public, allowing them to serve as vessels for urban public life. Both aspects are indispensable; the latter often determines the long-term vitality of the regeneration.

Based on the investigation, all six cases have achieved notable success in functional conversion—industrial factory buildings have been transformed into spaces for creative offices, commercial retail, dining and entertainment, art exhibitions, and so on, with generally high occupancy rates and commercial vitality. However, significant differences exist in the openness to public life. Party Pier Beer Culture and Art Creative Zone, built on the former site of the Pearl River Brewery, has developed into a nightlife hub dominated by dining, bars, and performances. Its riverside terrace has become a popular spot for citizens to enjoy views and take walks, demonstrating a relatively high level of publicness. Haizhu Bay Creative Park has preserved industrial symbols such as old ship docks and gantry cranes, and, together with a riverside promenade, has formed a continuous urban public space with high daily usage frequency. In contrast, although the spatial transformations at Yuanchuang Elements Creative Park and Xinyi International Club are relatively refined, their internal public spaces are largely occupied by commercial tenants or office uses, offering limited openness to the general public. They resemble enclosed office communities rather than open public spaces.

The degree of publicness in heritage revitalization depends not only on the design of the physical transformation but also on the operational model and functional orientation. Parks dominated by commercial and office uses naturally experience a compression of publicness. In contrast, those that intentionally preserve or create public activity spaces—such as riverside promenades, plazas, and performance venues—are more likely to establish meaningful connections with the daily lives of citizens.

3.3.2 Spatial Carriers and Usage Patterns of Public Life

Public life requires concrete spatial carriers.

The waterfront interface is the most attractive type of public space. All six cases are located along the Pearl River, where riverside promenades, viewing platforms, and dock plazas have become preferred places for citizens to walk, jog, enjoy river views, and take photographs. The riverside promenade at Haizhu Bay Creative Park connects with the old ship dock plaza, forming a continuous public space of approximately 1.5 kilometers, with a considerable number of daily users. Although the starting area of the Julong Bay district is

still under construction, its planning emphasizes the continuity of waterfront public space.

Spontaneous gathering points often emerge around industrial structures. Abandoned chimneys, gantry cranes, storage tanks, old railway tracks, and other industrial relics—owing to their visual impact and historical memory—serve as nodes for citizens to take photos, rest, and linger. The beer fermentation tank cluster at Party Pier, the gantry crane at Haizhu Bay, and the large chimney at Gongmei Port all function as spatial landmarks and anchors of public life.

Internal plazas and courtyards constitute the core of public life within the sites. The investigation reveals that details such as plaza scale, paving materials, greening arrangements, and seating facilities directly affect users' willingness to stay. The central courtyard at Xinyi International Club is pleasantly proportioned; however, due to the surrounding predominance of office functions, its occupancy rate is moderate during lunchtime but quickly becomes deserted after the evening. This reflects that the vibrancy of public life is positively correlated with the degree of functional mix.

Temporary event spaces serve as an important supplement for activating public life. Party Pier regularly hosts music festivals, markets, exhibitions, and other events, using open spaces to gather crowds. The old ship dock at Haizhu Bay has been used for press launches and fashion shows. Temporary events not only enhance space utilization efficiency but also strengthen the legibility and attractiveness of the sites.

3.4 Trade-off between Heritage Conservation and Revitalization

3.4.1 Trade-off Patterns in the Investigated Cases

(1) Appearance-priority type

Represented by Xinyi International Club and Yuanchuang Elements Creative Park. In such projects, the facades, structural systems, and spatial forms of industrial buildings are preserved to a high degree, with renovations focused mainly on interior updates and functional infill, while site grading and external spaces undergo minor changes. The advantage lies in the integrity of the heritage appearance and strong historical legibility; the disadvantage is that ecological performance improvements are limited, stormwater management still relies on conventional pipe networks, and the high rate of impervious surfaces results in weak infiltration capacity.

(2) Function-priority type

Represented by Party Pier Beer Culture and Art Creative Zone and Gongmei Port

International Digital Innovation Center. Such projects place greater emphasis on the economic returns and usage efficiency of spaces, undertaking substantial functional conversions and spatial reconfigurations of industrial buildings, with relatively extensive site transformations. The advantage is high space utilization and strong commercial vitality; the disadvantage is that some low-value industrial elements are either demolished or excessively packaged, compromising the integrity of heritage information. In terms of stormwater management, function-priority projects typically incorporate more permeable pavements and green facilities, yet due to the pursuit of a "tidy" image, the scale and distribution of ecological facilities remain insufficient.

(3) Balanced integration type

Represented by Haizhu Bay Creative Park and the starting area of Julong Bay district (under planning). Such projects preserve core industrial symbols (e.g., ship docks, gantry cranes, significant factory buildings) while undertaking moderate ecological retrofitting of peripheral sites, forming a layered strategy of "core preservation + peripheral activation." In terms of stormwater management, Haizhu Bay has repurposed an old ship dock into a landscaped stormwater storage and regulation water body, and the riverside promenade uses permeable pavements, establishing a dialogic relationship between industrial elements and ecological facilities. This pattern achieves a relative balance between heritage conservation and functional activation, offering considerable reference value for the Zini Sugar Refinery project.

3.5 Summary of Findings: Implications for the Design Project

Based on a systematic investigation of six typical waterfront industrial heritage regeneration projects in Guangzhou, this study identifies universal challenges and core contradictions, thereby clarifying key implications for the regeneration design of the Zini Sugar Refinery and establishing a solid empirical foundation for the introduction of water-sensitive urban design strategies.

3.5.1 Summary of Common Challenges of Guangzhou's Waterfront Industrial Heritage

The investigation reveals that, despite differences in positioning and models among the projects, they face a series of profound and similar challenges in the ecological dimension, particularly in hydrological process management. These can be summarized into the following three core aspects.

(1) "Hardening and fragmentation" at the spatial level

Surface hardening: To meet modern functional and aesthetic demands, sites are generally subject to intensive hard paving, resulting in the near-complete loss of natural infiltration capacity, a sharp increase in surface runoff coefficients, and an alteration of the original hydrological cycle.

Waterfront engineering: Most waterfront banks adopt vertical hard revetments, which sever the ecological connection between land and water and eliminate their natural functions as ecological buffer zones and purification corridors.

Systemic fragmentation: Elements such as green spaces, pavements, buildings, and water systems are often designed in isolation, lacking a coherent ecological infrastructure network that integrates stormwater runoff pathways, leaving the site in a state of "ecological fragmentation."

(2) "End-of-pipe and singular" approach at the management level

Outdated mindset: Stormwater management generally remains at the engineering-oriented stage of "drain as quickly as possible," relying or over-relying on grey pipe network facilities, with insufficient understanding and application of green infrastructure principles such as "source reduction, process control, and systemic management."

Ineffective measures: First-flush rainwater pollution is not effectively intercepted or purified; rainwater resources are not collected or utilized; ecological treatment facilities (e.g., rain gardens, ecological swales), where present, are mostly ornamental and are not effectively integrated with building drainage or site catchment systems, thus failing to achieve their full performance potential.

Lack of resilience: Site design lacks adaptive capacity to cope with extreme rainfall events. The drainage networks on which they depend are prone to saturation and failure under heavy rain, while the surface lacks necessary storage and retention space, resulting in a tangible risk of waterlogging.

(3) "Conflict and imbalance" at the objective level

Tension between conservation and development: Strict heritage conservation requirements restrict large-scale excavation, filling, and structural modifications to building fabric, making many conventional stormwater engineering measures difficult to implement.

Trade-off between economy and ecology: Commercial development orientation tends to crowd out ecological space, prioritizing leasable floor area and parking spaces, leading to a severe shortage of green spaces capable of performing hydrological storage and regulation functions.

Discord between appearance and function: The pursuit of a "tidy" industrial aesthetic creates cognitive and practical conflicts with the "visible" processes required by ecological stormwater management facilities, as well as with the temporary ponding and naturalistic vegetation forms that may accompany them.

These common challenges collectively point to a core issue: while the current regeneration model activates the commercial and cultural values of space, it has failed to restore—and has even further compromised—the ecological value of the site as an integral component of the urban ecosystem, particularly its hydrological cycle health and water ecological security.

3.5.2 Necessity of Introducing Systemic and Low-Impact WSUD Strategies, and Derivation of Design Principles

In response to the above challenges, the Zini Sugar Refinery project must pursue a different path. Introducing the concept of Water Sensitive Urban Design (WSUD) is not only necessary but also offers critical insights through its core principles of "systemic integration" and "low impact" to address the existing dilemmas.

(1) Analysis of necessity

An inevitable choice given the site's particularities: As a well-preserved large-scale industrial heritage site, the Zini Sugar Refinery is subject to a conservation-first principle that demands any intervention be minimal and refined. The distributed, small-scale, nature-based green infrastructure advocated by WSUD aligns precisely with the requirements of Low Impact Development (LID), minimizing disruption to the heritage fabric and site morphology.

A systemic solution to complex problems: The hydrological challenges facing the site (e.g., runoff pollution, waterlogging risk, ecological degradation) are interrelated systemic issues. WSUD provides a framework for integrated management across the entire process—from "source to pathway to receptor"—enabling the synergistic resolution of water quality, water quantity, ecological, and landscape issues, rather than treating symptoms in isolation.

An effective bridge for achieving synergistic multiple objectives: WSUD treats stormwater management as an opportunity to generate multiple benefits. Through design, stormwater facilities can be transformed into distinctive landscape elements (e.g., rain garden amphitheaters), ecological habitats, or public education spaces. This offers the potential to bridge the gaps between heritage conservation, public activity, ecological benefits, and flood safety, thereby enhancing overall integrated value.

(2) Design principles derived for the Zini Sugar Refinery

Based on the dilemmas identified through the investigation and the guidance of the WSUD concept, this study extracts the following core design principles applicable to the regeneration of the Zini Sugar Refinery:

Heritage compatibility and minimum intervention principle: The design of all stormwater management measures must first respect and adapt to the existing spatial layout, architectural character, and site features of the industrial heritage. Priority should be given to the ecological retrofitting of existing pools, ditches, low-lying areas, roof drainage paths, and similar features, avoiding large-scale earthworks and destructive additions to historic structures and buildings.

Systemic integration of hydrological processes principle: It is essential to move beyond the mindset of "ornamental" greening and construct a visible, traversable, and functional ecological water cycle system at the site scale. This system should clearly demonstrate the entire process of stormwater runoff collection, conveyance, treatment, storage, retention, and reuse—from building roofs and impervious surfaces to green spaces and finally to the riverbank—forming a complete "water narrative" thread.

Spatial multifunctionality principle: Ecological infrastructure should be designed as public spaces with multiple functions. For example, a sunken green space could serve as a camping lawn or open-air amphitheater in the dry season and as a stormwater retention basin in the rainy season; a constructed wetland could simultaneously function as an ecological education trail and a viewing platform. Through careful design, the temporal and spatial conflicts between public activity safety and the functional demands of stormwater facilities can be resolved.

Regional technology and aesthetic integration principle: The selected ecological technologies (e.g., filter media, vegetation) should prioritize locally sourced materials and native plant species to reduce maintenance costs and enhance ecological value. Aesthetically, the forms, materials, and detailing of stormwater management facilities should be integrated with the raw, powerful, and mechanical aesthetic qualities of the industrial heritage, making them positive elements that reinforce rather than diminish the spirit of the place.

In summary, the experiences and lessons from existing projects in Guangzhou clearly indicate that the regeneration of the Zini Sugar Refinery must achieve a paradigm shift in the ecological dimension, particularly in stormwater management. The systemic, low-impact WSUD strategies and the corresponding design principles provide clear theoretical and

practical guidance for transforming this challenge into a historic opportunity to shape unique place character and enhance overall resilience. The subsequent design practice of this thesis will be developed on this basis.

3.6 A Targeted Work Framework for Stormwater Management

3.6.1 Design Analysis Table

Based on the systematic investigation of six typical waterfront industrial heritage regeneration projects in Guangzhou presented above, the common challenges and core contradictions identified provide a clear empirical foundation for the design of the Zini Sugar Refinery. The investigation demonstrates that while the current regeneration model activates the commercial and cultural values of space, it has failed to restore—and has even further compromised—the ecological value of the site as an integral component of the urban ecosystem, particularly its hydrological cycle health and water ecological security. In response to this core issue, the following analysis table, guided by the Water Sensitive Urban Design (WSUD) concept and adhering to the four core principles of "heritage compatibility and minimum intervention," "systemic integration of hydrological processes," "spatial multifunctionality," and "regional technology and aesthetic integration," constructs a targeted work framework applicable to the regeneration of waterfront industrial heritage sites in Guangzhou.

Table3 - 4 Design Analysis Table

Table3 - 4 Design Analysis Table			
Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
1. Design Process	LID standard four-step process: ① Site stormwater hydrological analysis ② Site LID landscape planning ③ Site LID landscape design ④ Site LID stormwater management	Five-stage progressive framework: ① Coupled diagnosis of industrial heritage value and hydrological processes ② Reconfiguration	Research basis: The investigation found that waterfront industrial heritage sites in Guangzhou commonly face a "tension between conservation and development"—strict heritage protection requirements restrict large-scale excavation, filling, and structural modifications to building

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
	evaluation.	of catchment areas based on industrial fabric ③ Integrated design of grey-green infrastructure and industrial heritage spaces ④ Multi-scenario hydrological simulation and facility adaptation ⑤ Design of adaptive operation and maintenance mechanisms	fabric, making many conventional stormwater engineering measures difficult to implement. Explanatory note: Common practices are suitable for conventional urban development sites but do not fully account for the historical value and spatial particularities of industrial heritage. For the Zini Sugar Refinery, it is necessary to add a "coupled diagnosis of industrial heritage value and hydrological processes" at the initial stage, taking heritage protection requirements as a precondition to ensure that all subsequent stormwater management measures first respect and adapt to the existing spatial layout of the industrial heritage (the principle of heritage compatibility and minimum intervention).
2. Site Hydrological Analysis	Identify impervious/pervious areas, stormwater runoff generation sources, runoff pathways,	Overlay analysis: ① Refined classification of industrial land cover (abandoned factory roofs,	Research basis: the investigation reveals that sites commonly face the problems of "surface hardening" and "systemic fragmentation"—intensive

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
	watershed divides and catchment lines, and collection points (zones), and produce a stormwater hydrological analysis map.	hardened storage yards, rail track gaps, dock pavements, old pools and ditches, etc.) ② Investigation of existing drainage traces and the industrial-era drainage system ③ Zoning assessment of soil contamination risk ④ Overlay of historical waterlogging points and tidal level influences ⑤ Delineation of catchment units based on industrial fabric	hard paving leads to the near-complete loss of natural infiltration capacity, while elements such as green spaces, pavements, buildings, and water systems are often designed in isolation, lacking a coherent ecological infrastructure network that integrates stormwater runoff pathways. Explanatory note: conventional hydrological analysis does not distinguish the surface types unique to industrial heritage (e.g., rail track gaps have infiltration potential, abandoned factory roofs can be retrofitted as green roofs, and old pools and ditches can be transformed into storage and regulation spaces). For the Zini Sugar Refinery, it is necessary to combine historical industrial drawings with on-site surveys to identify reusable existing drainage facilities and to incorporate soil contamination risk assessment into the analysis, avoiding contaminant mobilization due to stormwater infiltration (Yu Kongjian et al., 2015). This refined analysis forms the basis for achieving "minimum

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
			intervention" retrofitting.
3. Types of Stormwater Management Facilities	Twenty-one common stormwater management landscape facilities (SLFs): green roofs, rain gardens, infiltration trenches, grassed swales, permeable pavements, rain barrels, detention ponds, constructed wetlands, etc.	Industrial heritage adaptive facility library: ① Green roofs retrofitted from flat roofs of abandoned factory buildings ② Gap infiltration strips integrated with dock stone pavements ③ Linear infiltration trenches utilizing old railway track subgrades ④ Multifunctional storage and treatment wetlands converted from sedimentation/cooling ponds ⑤ Vertical green walls integrated with industrial structures (chimneys, silos) ⑥ Large-scale rain gardens utilizing abandoned storage yards ⑦ Storage and	Research basis: The investigation reveals that current stormwater management commonly suffers from the problem of "ineffective measures"—ecological treatment facilities, where present, are mostly ornamental and are not effectively integrated with building drainage or site catchment systems, thus failing to achieve their full performance potential. Furthermore, there exists a "discord between appearance and function"—the pursuit of a "tidy" industrial aesthetic creates a cognitive conflict with the "visible" processes required by ecological stormwater management facilities and the temporary ponding that may accompany them. Explanatory note: Common facility libraries do not account for integration with industrial heritage spaces. The Zini Sugar Refinery possesses a substantial number of

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
		regulation pools incorporating dock spaces ⑧ Ecological grassed swales retrofitted from existing open drainage ditches ⑨ Rainwater collection and display installations integrated with building downspouts	industrial structures and buildings, from which stormwater management facilities can be created by repurposing abandoned industrial spaces, drawing on the experience of multifunctional stormwater detention tanks in Japan (Wang Yang et al., 2019). More importantly, these facilities should be designed to transform "visible" hydrological processes into a medium for industrial heritage interpretation, ensuring that stormwater management becomes a positive element that reinforces rather than diminishes the spirit of the place (the principle of regional technology and aesthetic integration).
4. Landscape Integration Strategy	Integrate stormwater management landscape facilities into the overall site landscape to achieve unity between stormwater management and landscape	Industrial narrative landscape integration: ① Construction of a dual-theme trail system combining "industrial memory – rainwater process" ② Linear landscapes	Research basis: the investigation indicates that sites generally lack "systemic integration" of hydrological processes—elements such as green spaces, pavements, buildings, and water systems are often designed in isolation, resulting in a state of "ecological fragmentation." Furthermore, the "trade-off between economy and

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
	aesthetics.	integrating grassed swales parallel to old railway tracks ③ Dialogic placement of rain gardens in relation to industrial equipment relics ④ Visual connectivity and functional integration between treatment wetlands and dock spaces ⑤ Terraced rainwater purification demonstration zones utilizing site elevation differences ⑥ Visualisation of rainwater runoff integrated with industrial building facades	ecology" leads to a severe shortage of green spaces capable of performing hydrological storage and regulation functions. Explanatory note: common integration strategies pursue landscape beautification. For the Zini Sugar Refinery, this must be elevated to the level of genius loci (spirit of place) reconstruction. Drawing on the WSUD concept of integrating stormwater management with urban design (Zhang Yupeng, 2015), the construction of a dual-theme trail system enables stormwater facilities to become vehicles for narrating industrial history and disseminating ecological concepts. More importantly, the "principle of spatial multifunctionality" must be implemented—sunken green spaces can serve as camping lawns or open-air amphitheaters in the dry season and as stormwater retention basins in the rainy season; constructed wetlands can simultaneously function as ecological education trails and viewing platforms,

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
			thereby resolving the temporal and spatial conflicts between public activity safety and the functional demands of stormwater facilities.
5. Technical Assessment Methods	Apply the SWMM (Storm Water Management Model) to calculate and evaluate the total stormwater runoff volume, peak flow rate, flow velocity, duration, and water quality of the site before and after planning and design.	Multi-objective integrated performance evaluation framework: ① Stormwater management performance (total runoff volume reduction rate, peak flow delay time, annual SS pollutant reduction rate) ② Industrial heritage conservation performance (industrial element retention rate, retrofitting reversibility, heritage value interpretability) ③ Hot and humid climate adaptability performance (ponding duration control, mosquito breeding risk)	Research basis: The investigation reveals that current stormwater management suffers from an "outdated mindset"—it generally remains at the engineering-oriented stage of "drain as quickly as possible," with insufficient understanding and application of green infrastructure principles such as "source reduction, process control, and systemic management." At the same time, site design exhibits a "lack of resilience"—an absence of adaptive capacity to cope with extreme rainfall events, resulting in a tangible risk of waterlogging. Explanatory note: Common assessments focus solely on the single performance metric of stormwater management and fail to comprehensively reflect the integrated value of industrial heritage regeneration. The Zini Sugar

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
		assessment, plant waterlogging tolerance) ④ Social value performance (public participation level, educational function, spatial usage satisfaction) ⑤ Cost-benefit performance (life-cycle cost, comparison with conventional grey infrastructure solutions)	Refinery is located in the hot and humid rainy region of South China, necessitating the inclusion of hot-humid climate adaptability assessment to avoid problems such as mosquito breeding and plant root rot caused by prolonged stormwater ponding (Feng Xianhui et al., 2021). Furthermore, the incorporation of heritage conservation performance ensures that stormwater management measures genuinely achieve "minimum intervention" rather than destroying industrial value under the guise of ecology.
6. Spatial Multifunctional Design	Stormwater facilities are predominantly single-function, or the landscape function and stormwater management function are simply superimposed.	Spatio-temporal multifunctional design: ① Dry-season/ wet-season functional switching design (dry-season activity space / wet-season storage and regulation space) ② Water-level adaptive design (landscape legibility	Research basis: The investigation clearly indicates the "trade-off between economy and ecology"—commercial development orientation tends to crowd out ecological space, prioritizing leasable floor area and parking spaces, leading to a severe shortage of green spaces capable of performing hydrological storage and regulation functions. Explanatory note: This

Table3 - 4 Design Analysis Table

Analytical Dimensions	Common Practices	Targeted Practices	Research Basis and Explanatory Notes
		under varying water levels) ③ Multifunctional use of edge spaces (composite functions of buffer zones around buildings) ④ Layered use of vertical space (integration of vertical greening and rainwater harvesting) ⑤ Multifunctional transformation of industrial components (conversion of old equipment bases into rain gardens)	contradiction necessitates a design approach of "spatial multifunctionality," enabling every parcel of land to assume multiple functions simultaneously. Drawing on the experience of the Scharnhauser Park community in Germany ,dry-season/wet-seas on functional switching design allows limited green space to be used in a temporally composite manner, meeting commercial operational needs while achieving eco-hydrological goals, thereby resolving the fundamental contradiction between "economy and ecology."

3.6.2 Stormwater Management Performance Calculation

Stormwater management performance is primarily considered from macro to micro scales, with strategy calculations tailored to different site conditions in a context-sensitive, stepwise manner. The design hierarchy is mainly divided into three levels: the planning level, the site level, and the building level. The planning level refers to the water management layout and planning at the park or district scale; the site level refers to water management site strategies at the block or project scale; and the building level refers to the design of water management construction and functions at the individual building scale.

A. Planning Level (Park/District Scale)

Table3 - 5 Planning-Level Stormwater Management Performance

Table3 - 5 Planning-Level Stormwater Management Performance

No.	Condition (if...)	Action (then...)
A1	Conduct the overall park master planning, and determine the total stormwater storage target (V_{total}).	Use the following formula: $V_{total} (m^3) = A_{site} (ha) \times C \times R_{design} (mm) \times 10 \quad (3-1)$ Parameter C (runoff coefficient): 0.1–0.2 for green space, 0.5–0.7 for medium-density areas, 0.8–0.95 for high-density areas Parameter R design: To achieve an annual runoff volume capture ratio (e.g., 85%), a value of 40 mm may be used; for flood safety, it should be calculated according to the stormwater formula.
A2	There is a large area of unused open space or green space within the site.	Prioritize planning it as a constructed wetland or multifunctional storage pond/tank, whose volume shall satisfy the main part of V_{total} calculated by the above formula (or as referenced in A1).
A3	There are planned roads or drainage paths within the site.	Design them as ecological swales or green streets to serve as conveyance and pre-treatment channels for stormwater.
A4	The site is adjacent to rivers, streams, or waterways.	Delineate an ecological buffer zone (width ≥ 20 m). Implement ecological revetments. Design the buffer zone to function as a floodable storage, treatment, and purification space.
A5	It is necessary to calculate the storage and regulation capacity of the waterfront buffer zone.	Use the following formula: $V_{buffer} (m^3) = A_{buffer} (m^2) \times D_{design} (m) \quad (3-2)$ (D_{design}: 0.2–0.5 m)
A6	There are existing farmlands within the site.	Prioritize their preservation. They may be transformed into dry-season farmlands and wet-season flood detention areas, and pre-treatment

Table3 - 5 Planning-Level Stormwater Management Performance

No.	Condition (if...)	Action (then...)
		sedimentation ponds/tanks must be installed to pre-treat the stormwater introduced into them.
A7	There are existing fish ponds within the site.	Prioritize their preservation and optimize them into ecological ponds or storage and regulation ponds.
A8	The additional storage and regulation capacity of the existing fish ponds needs to be calculated.	Use the following formula: $V_{\text{pond}} (\text{m}^3) = A_{\text{pond}} (\text{m}^2) \times \Delta H (\text{m}) \quad (3-3)$ $(\Delta H: 0.3\text{--}0.8 \text{ m}; \text{ shoreline stability must be assessed})$
A9	The underground utility network within the site is complex, or the space is extremely constrained.	Prioritize grey infrastructure such as underground storage tanks and storage modules, and integrate them with green spaces, plazas, etc., to achieve composite land use.

B. Site Level (Block/Project Scale)

Table3 - 6 Site-Level Stormwater Management Performance

Table3 - 6 Site-Level Stormwater Management Performance

No.	Condition (if...)	Action (then...)
B1	Designing hard pavements such as sidewalks, plazas, and parking lots.	Under the condition that load-bearing capacity permits, mandate the use of permeable pavements, with a proportion of $\geq 70\%$.
B2	There is linear space within the site (e.g., roadside) with a slope $< 5\%$.	Design it as an ecological swale. If the slope is $> 5\%$, then design it as a stepped swale or a swale equipped with energy dissipation facilities.
B3	There is nodal space within the site (e.g., green space) that needs to treat runoff.	Design it as a rain garden / bioretention basin.
B4	The area (A_{facility}) of	Use the simplified formula: $A_{\text{facility}} (\text{m}^2) =$

Table3 - 6 Site-Level Stormwater Management Performance

No.	Condition (if...)	Action (then...)
	the rain garden / bioretention basin needs to be calculated.	$A_{\text{contributing}} (\text{m}^2) \times K$ (3-4) K : 5%–7% for soils with good permeability; 7%–10% for soils with poor permeability (commonly found in the Greater Bay Area).
B5	Stormwater needs to be discharged into farmlands, fish ponds, or sensitive water bodies.	Pre-treatment facilities (e.g., sedimentation basins, vegetated buffer strips) must be installed at the inlet. Furthermore, for areas with high traffic volumes, the installation of oil and grease separators is strongly recommended.
B6	The site has a high groundwater table (<1.5 m) or extremely poor soil permeability.	The rain garden / bioretention basin shall be designed as a "storage-type" facility with an impermeable bottom liner, and underdrain pipes shall be installed to convey the treated stormwater quickly to the municipal drainage network or nearby waterways.

C. Building Level (Individual Building Scale)

Table3 - 7 Building-Level Stormwater Management Performance

Table3 - 7 Building-Level Stormwater Management Performance

No.	Condition (if...)	Action (then...)
C1	The building has a flat roof or a low-slope roof, and the structural load capacity permits.	Prioritize the use of green roofs. The load of extensive green roofs is approximately 60–150 kg/m ² ; structural verification is required.
C2	There is a demand for rainwater reuse (e.g., toilet flushing, irrigation).	A complete rainwater reuse system must be installed, with the core process being: collection, first-flush diversion, storage, treatment, reuse.
C3	It is necessary to determine the treatment capacity and process of	The determination shall be based on the reuse purpose: If the reused water is for green space irrigation or road

Table3 - 7 Building-Level Stormwater Management Performance

No.	Condition (if...)	Action (then...)
	the rainwater reuse system.	sweeping, the treatment process shall include: filtration (e.g., sand filtration, screen filtration) + disinfection (e.g., chlorine, ultraviolet). If the reused water is for indoor toilet flushing, the treatment process shall be enhanced. It is recommended to adopt finer filtration (e.g., membrane filtration) + disinfection, and the water quality must comply with the standards specified in The Standard for Urban Reclaimed Water Quality – Urban Miscellaneous Use. If the site is located in a tidal saltwater intrusion area and the reused water is intended for irrigating salt-sensitive plants, the electrical conductivity (EC) of the rainwater shall be monitored. Where necessary, desalination processes shall be added, or rainwater reuse for such purposes shall be avoided.
C4	The effective volume (V_{tank}) of the rainwater collection tank needs to be estimated.	Use the following formula: $V_{\text{tank}} (\text{L}) = A_{\text{roof}} (\text{m}^2) \times R_{\text{monthly_avg}} (\text{mm}) \times 0.8 \quad (3-5)$ and ensure that $V_{\text{tank}} \leq$ average daily reuse water demand for 3–5 days to prevent deterioration of rainwater due to long-term storage.
C5	The rainwater reuse system is the primary water conservation measure of the project.	A water balance analysis must be conducted: Calculate the average annual collectable rainwater volume. Calculate the annual reclaimed water demand. Then, the theoretical water saving rate of the system = $\text{Min}(\text{collectable volume, demand}) / \text{total water consumption}$ (3-6) . When the collectable volume far exceeds the demand, the storage tank volume should be optimised; when the demand exceeds the collectable volume, other water conservation measures should be supplemented.

3.6.3 Core Conditions and Specific Considerations for Guangzhou

D. Special Topic on Cost, Maintenance, and Resilience

Table3 - 8 Special Topic on Cost, Maintenance, and Resilience

Table3 - 8 Special Topic on Cost, Maintenance, and Resilience		
No.	Condition (if...)	Action (then...)
D1	The project budget is tight, or the capacity for long-term maintenance is limited.	Prioritise low-maintenance technologies. For rainwater reuse systems, exercise caution in selecting complex treatment processes; simple systems intended solely for irrigation (filtration + disinfection) may be prioritised. A clear maintenance manual must be developed during the design phase (with particular attention to regular cleaning of first-flush diversion devices, filters, and storage tanks).
D2	The site has a high pollution risk (e.g., adjacent to major traffic roads or industrial areas), or the water quality requirements for reuse are high (e.g., for toilet flushing).	Enhanced pre-treatment measures (e.g., swirl separators, oil and grease separators) and technologies with strong purification capacity must be adopted. Regular water quality testing shall be conducted to ensure the safety of reuse.
D3	There is a need to account for extreme rainstorm events exceeding the design standard (resilience).	Safe overflow routes must be provided to allow stormwater, once the system has reached full storage capacity, to be safely discharged into the municipal drainage network or storage facilities.
D4	The project has extremely high requirements for water supply safety and reliability (e.g., hospitals, schools).	The rainwater reuse system must be equipped with a backup water source (e.g., tap water makeup) and online water quality monitoring and alarm devices to prevent risks arising from water quality fluctuations or system failure.
D5	There is a desire to maximise the economic and environmental benefits of rainwater reuse.	Consider integrating the rainwater reuse system with the building's greywater system. When rainwater is abundant, priority shall be given to its use; when rainwater is insufficient, greywater

Table3 - 8 Special Topic on Cost, Maintenance, and Resilience

No.	Condition (if...)	Action (then...)
		shall supplement it, thereby forming a more stable reclaimed water source.

3.7 Chapter Summary

This chapter conducts a field investigation into the current status and stormwater management issues of waterfront industrial heritage in Guangzhou, clarifying the basic characteristics and core contradictions of the research cases, and providing an empirical basis for subsequent design strategies.

First, the chapter defines the research objectives, case selection criteria, and methods. Representative waterfront industrial heritage sites in Guangzhou are selected, focusing on their hydrological conditions, heritage protection requirements, and public space usage. A systematic investigation framework incorporating literature review, field surveys, and spatial diagrammatic analysis is established.

The investigation reveals three core trade-offs in waterfront industrial heritage: first, the tension between water resource utilisation and heritage protection—while hydrological site conditions offer potential for stormwater management, heritage protection imposes strict constraints on hydrological interventions; second, the relationship between heritage revitalisation and public life—insufficient attention to the public dimension hinders the effective integration of stormwater management with daily use; third, the practical conflict between heritage preservation and revitalisation in the allocation of spatial resources.

Based on these common challenges, the chapter extracts the necessity of introducing systematic, low-impact Water-Sensitive Urban Design (WSUD) strategies and proposes corresponding design principles, emphasising the integration of stormwater management facilities with public space design without compromising heritage values.

Finally, the chapter constructs a work framework tailored to stormwater management, including a design analysis table, a stormwater management performance calculation method, and specific considerations for Guangzhou's subtropical monsoon climate and high-density urban characteristics. This framework provides an operational evaluation tool and technical pathway for the subsequent design practice using the Zini Sugar Factory as a case study.

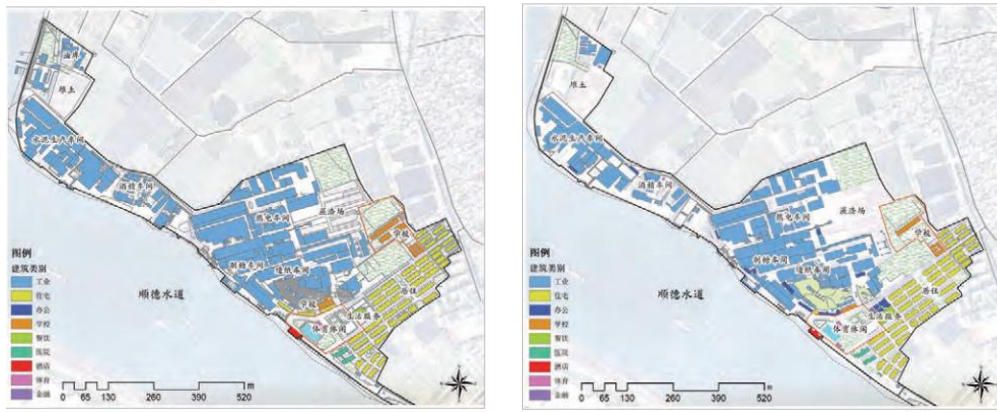
Chapter 4: Current State of Heritage Remains and Stormwater Management Analysis of the Guangzhou Zini Sugar Factory

4.1 Historical Research on the Sugar Factory

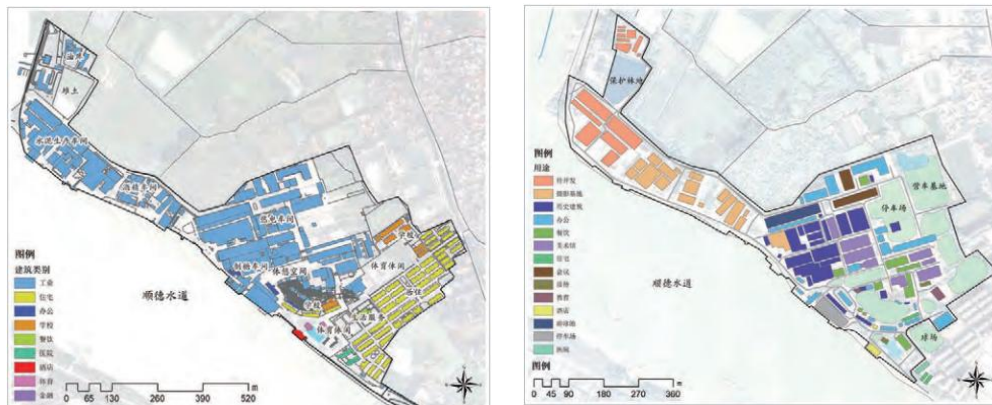
As the first state-owned enterprise in China to possess an automated sugarcane crushing production line built independently after the founding of the People's Republic, the Zini Sugar Factory was completed and put into operation in 1953, holding a significant position in China's industrial history. The factory site currently contains 88 industrial buildings, covering a total area of 250,000 m². The core heritage remains include the production area (comprising production workshops, sugar storage warehouses, and a freight wharf) and the pre-factory area (including office buildings, dormitories, and a library building featuring a Soviet-style continuous arch arcade structure). [61] Over its nearly 70 years of development, the Zini Sugar Factory has undergone transformations across multiple historical periods. In response to operational demands, adjustments were made to its functional layout and site planning during each period, reflecting the developmental characteristic of dynamic adaptation typical of industrial factory sites.

Due to the factory site being located within a water source protection area, relevant policies impose strict restrictions on production and commercial activities. As a result, business licenses could not be obtained for hospitality and catering establishments, leading to multiple suspensions and regulatory rectifications during operation. Since 2014, the Zini Sugar Factory has gradually shifted from a culture- and tourism-oriented development model to one centered on cultural and film production. A preliminary foundation for the film industry has now been established, with some of the original factory buildings converted into professional filming studios.

From the perspective of industrial heritage value, the Zini Sugar Factory not only embodies the typical technologies and spatial morphologies of the sugar industry during a specific period, but its well-preserved Soviet-style building complex and continuous production landscape also constitute significant material remains, possessing notable historical, cultural, architectural-technological, and regional social value. Furthermore, its adaptive transformation and functional transition in recent years provide a practical case study for exploring sustainable reuse pathways for industrial heritage in ecologically sensitive areas.



(a) The Sugar Factory Period (1953-2002) (b) The Thermal Power Plant Period (2004-2011)



(c) Exploration Period of the Creative Park (2012-2013) (d) Development Period of the Creative Park (2014-now)

Figure4 - 1 Historical Evolution of the Zini Sugar Factory

Image Source: Tang Qiang, Chen Yile, Zheng Liang, Chen Jian, Research on the Renewal and Transformation Strategies of Guangfu Industrial Architectural Heritage in the Context of Rural Revitalization: A Case Study of the Zinitang Art Town in Panyu, Guangzhou

4.2 Investigation of the Current State of Protection and Utilization of the Sugar Factory's Industrial Heritage

4.2.1 Basic Site Overview

Zini Island is located in the southwestern part of Shawan Subdistrict, Panyu District, Guangzhou City, Guangdong Province, within the Guangzhou-Foshan border area. Geographically embedded in the southwestern river network of Dagubei, the island is surrounded by multiple water systems including the Zini River, the Chencun Waterway, and the Shunde Waterway, forming a distinctive river-island landform. Historically, the island served as a key node in the waterway transportation route between Guangzhou and Macau, undertaking significant commercial and trade functions. At present, Zini Island has gradually developed tourism based on its natural and cultural resources, with attractions such as Baomo

Garden becoming important tourist destinations. In addition, the Zini Intake Pumping Station built on the island serves as a core facility of Panyu District's water supply system, with a daily water supply capacity of 76,000 tons, meeting over 70% of the district's water demand and reserving conditions for future emergency water source connections, thereby significantly enhancing the regional infrastructure capacity. [62]



Figure4 - 2 Site of Zini Island (adapted from online image)

To the north, the Zini Sugar Factory adjoins agricultural land (fish ponds and farmland); to the west, it faces the Shunde Waterway of the Pearl River; to the east, it borders Zini Village and educational facilities; and to the south, it neighbors the former staff residential community. The primary pedestrian flow comes from local residents in the southeast, including villagers and former factory workers. In terms of supporting services, the surrounding commercial formats are mainly small supermarkets and fast-food restaurants, lacking high-quality consumption and leisure facilities, which makes it difficult to meet the needs of the cultural industry office population. Public recreational spaces mainly consist of scenic areas such as Baomo Garden and Nanyue Yuan, as well as scattered roadside pavilions. The latter are limited in scale and susceptible to traffic interference, supporting only small-scale daily activities, with overall insufficient openness and service capacity.

Regarding population composition, the site is primarily occupied by office workers in the cultural industry (especially film and television-related), while the surrounding area is mainly

inhabited by local residents (former factory workers and villagers of Zini Village), resulting in a distinct spatial use differentiation. Currently, although the Zini Sugar Factory park functions mainly as a cultural industry office hub, the different zones within the site are separated by walls, resulting in weak spatial connectivity. Consequently, local residents have limited actual access to the interior of the park, leading to low public accessibility and restricting interaction and functional integration between the park and the surrounding community.



Figure4 - 3 Analysis of the Surrounding Environment and Population of the Site (drawn by the author)

4.2.2 Current Status of Architectural Heritage Remains

The Zini Sugar Factory currently contains 88 extant industrial buildings, covering an area of approximately 260,000 m², with the core production and office area spanning about 80,000 m². The construction periods range from the 1950s to the 1990s, forming a clear "chronological stratum." By functional type, the buildings can be classified into four categories: Soviet-style office buildings (4 units), two-story mixed-structure buildings with double-pitched overhanging gable roofs, timber trusses with tiled roofing, and circular arch decorations on the first-floor corridors, well preserved; production workshop buildings, including the old sugar refining workshop and pressing workshop, characterized by large volumes, Soviet-imported steel components retained in the frames, and continuous open interior spaces; storage and auxiliary buildings, including warehouses, repair workshops, and laboratory buildings, mostly of brick-concrete construction, with some roofs and windows

damaged; and infrastructure structures, including four reinforced concrete chimneys from the 1950s, a riverside 10,000-ton warehouse, a wharf, sedimentation tanks, cooling ponds, open channels, and a rail system.

In terms of spatial layout, the factory site exhibits a gradient pattern of "riverside–roadside–hinterland": along the riverside are the wharf, 10,000-ton warehouse, and cooling ponds; the central area contains production workshops, chimneys, and main office buildings; the hinterland comprises storage areas, stockyards, and auxiliary facilities. The rail lines, overhead pipe galleries, and paved roads between the buildings form an integrated material transport network. The overall preservation condition is good, with stable core building structures. Some auxiliary buildings, due to prolonged idleness, have issues such as roof leakage and wall weathering. Nevertheless, the overall industrial fabric remains intact, possessing high conservation and adaptive reuse value.



Figure4 - 4 Current Status of Key Buildings of the Zini Sugar Factory (Image source: Guangzhou Cultural Financial Service Center www.gzwhjr.com)

4.2.3 Current Status of Waterfront Space

The Zini Sugar Factory faces the Zini River to the north, with a shoreline length of

approximately 1.2 km [63]. The waterfront is predominantly characterized by rigid vertical revetments, with some remnants of industrial facilities such as old wharves and unloading platforms. Waterfront structures including the 10,000-ton warehouse, coal wharf, and bagasse unloading jetty are situated directly adjacent to the shoreline, forming a continuous industrial interface. At present, the waterfront area is primarily equipped with walking paths and viewing platforms. Vegetation mainly consists of scattered weeds and a few artificially planted trees, lacking a continuous ecological buffer zone. The shoreline overall exhibits hardened and functional characteristics, with the ecological connection between land and water disrupted, and a deficiency in stormwater runoff purification and retention functions. Some old wharf platforms remain well preserved and have the potential to be transformed into water-accessible public spaces.

4.2.4 Current Status of Commercial Formats and Public Activities in the Park

Since 2013, the Zini Sugar Factory has undergone protective renovation by Guangzhou Zinitang Creative Culture Co., Ltd., and has now developed a diverse mix of commercial formats primarily focused on cultural creativity, art exhibitions, film and television production, dining and leisure, and boutique hotels. The park houses over 52 enterprises, covering fields such as design, film and television, education, and retail. In 2025, the total output value of the film and television industry reached 450 million yuan. [64] The park features the Guangdong Provincial State-owned Zini Sugar Factory Industrial History Museum and has been rated as a National 3A-level Tourist Attraction.

Public activities are mainly concentrated along the riverside promenade, the 10,000-ton warehouse square, the old equipment display area, and some renovated factory courtyards. The riverside promenade and viewing platforms serve as primary locations for citizens to stroll, view the river, and take photos, with higher foot traffic on weekends. The lotus pond converted from an old dry dock and its surrounding green space have become resting nodes. However, the distribution of public spaces within the park is uneven, with some areas occupied by commercial tenants or office uses, resulting in limited openness to outside citizens. Temporary events such as music festivals, markets, and art exhibitions are held regularly, effectively boosting visitor numbers, yet everyday public life remains fragmented, lacking a systematic public space network.

4.3 Analysis of Heritage Revitalization Potential Based on Stormwater Management

4.3.1 Current Hydrological Conditions and Planning

In 2020, the government issued the Work Plan for Strengthening Environmental Protection in the Drinking Water Source Protection Area and Quasi-Protection Area of the Shawan Waterway in Panyu District. Under this plan, the Zini Sugar Factory was designated as a "quasi-protection area," while the Shawan Waterway was classified as a "first-level protection area." Within the quasi-protection area, non-industrial land is permitted to accommodate new construction, expansion, and renovation of functional spaces for social services and service industries, including catering, entertainment, and tourism development. The plan explicitly identifies tertiary industries—such as urban construction, public facilities, ecological development, culture and education, commerce and trade, tourism, hospitality, and creative industries—as the primary development directions.

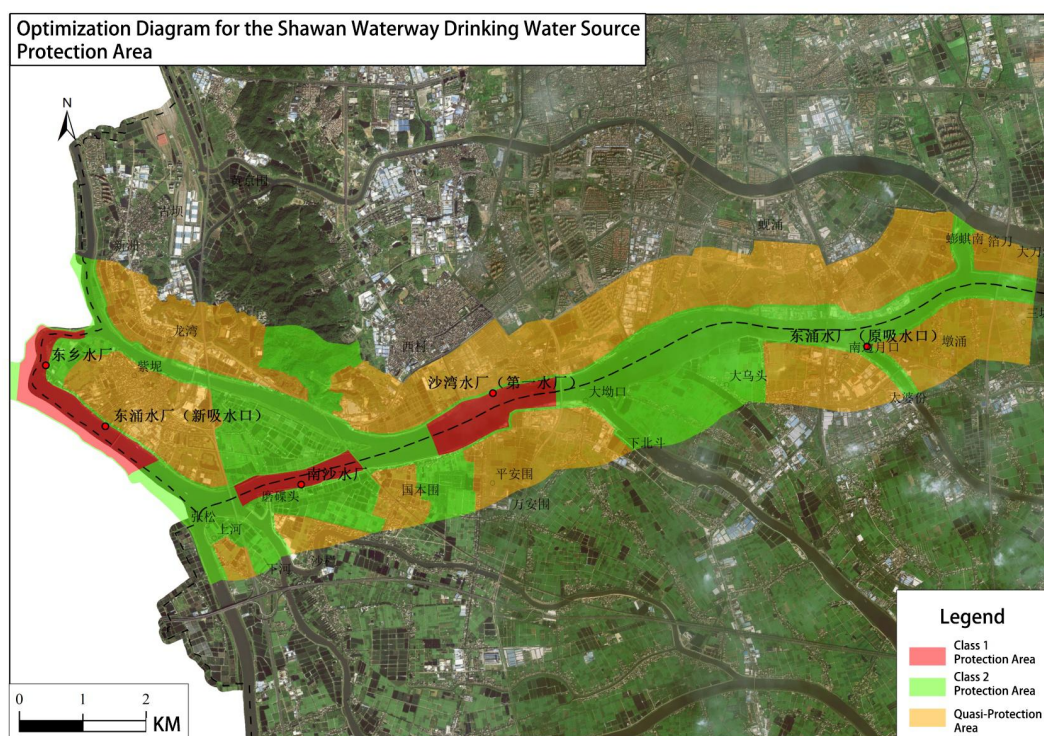


Figure4 - 5 Regulatory Optimization Map of the Drinking Water Source Protection Area of the Shawan Waterway (People's Government of Panyu District, Guangzhou: www.panyu.gov.cn)

After stormwater and sewage within Zini Island are collected into pipelines, they are conveyed from south to north across the river channel into the main pipeline of Shawan Town, without being treated or discharged around Zini Island.



Figure4 - 6 Sewage Pipeline Map of Zini Island (People's Government of Panyu District, Guangzhou: www.panyu.gov.cn)

4.3.2 Value Assessment of the Sugar Factory's Industrial Heritage

Table4 - 1 Industrial Heritage Value Assessment Table of the Sugar Factory

Value Category	Core Carrier	Relevance to Stormwater Management
Historical Value	1953 buildings, sugar production line, slogans and equipment	Low
Technological Value	Sugar production process spaces, factory structures from different periods, and water transport wharf	Medium (associated with hydraulic structures)
Social Value	Industrial community spaces, workers' dormitories, museum	Low
Artistic Value	Chimneys, Soviet-style buildings, industrial installations, shoreline landscape	Medium (related to water landscape)
Ecological Value	Waterfront shoreline, cooling	High

Value Category	Core Carrier	Relevance to Stormwater Management
	pond, drainage system	

4.3.3 Analysis of Industrial Heritage Value and Stormwater Management Potential

The core of the Zini Sugar Factory's renewal lies in how to transform "ecological constraints (W)" into "development opportunities (O)". Its greatest disadvantages—water source protection restrictions and outdated stormwater management—can be precisely addressed and resolved through the greatest opportunity: the concept of Water Sensitive Urban Design (WSUD).

Table4 - 2 SWOT Analysis Table of the Sugar Factory

S (Strengths)	Profound heritage value: As one of the first batch of automated sugar factories in New China, it possesses a significant industrial historical status and a complete Soviet-style building complex, with a grand spatial scale (250,000 m ²). It holds extremely high historical, cultural, architectural aesthetic, and landscape value, serving	Unique ecological location: Possessing a river-island landscape surrounded by multiple waterways, with a superior natural setting, adjacent to the Shawan Waterway, and endowed with inherent conditions for creating a distinctive waterfront ecological landscape.	Initial industrial foundation: Successfully transitioned from traditional cultural tourism to a film and television cultural industry base, forming a preliminary industrial agglomeration effect. The adaptive reuse practices of some factory buildings have demonstrated the potential for spatial transformation.	Important infrastructure: The Zini Intake Pumping Station on the island is a key regional water supply facility, enhancing the strategic importance of the site.
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	as a core resource for transformation and development.			
W (Weaknesses)	Rigid ecological policy constraints: Located within a Level 2 water source protection area, the policy red line of "zero pollution, low disturbance" severely restricts the introduction of commercial formats (e.g., catering, hotels) and the choice of development models.	Outdated stormwater management system: Currently suffers from systemic problems characterized by "inability to infiltrate, retain, store, or treat" stormwater. Impervious pavements lead to increased runoff, and there is a lack of green infrastructure for stormwater retention, infiltration, and purification, posing a risk of waterlogging (especially in the southern part).	Spatial and social isolation: The site is divided by internal walls, resulting in extremely low public accessibility, creating a dual physical and functional isolation from the surrounding communities (villagers and former workers), and lacking vitality and shared use.	Severe lack of supporting facilities: A deficiency in commercial services, high-quality public spaces, and cultural tourism supporting facilities, failing to meet the needs of industrial workers, residents, and potential visitors, thereby constraining the improvement of the region's service capacity.
O (Opportunities)	Application of Water Sensitive Urban Design (WSUD) principles: Regarding ecological constraints as a transformation	Driven by regional development strategies: Located within the Guangdong-Hong Kong-Macao Greater Bay Area, regional developments such as Guangzhou-Fosha	Tourism visitor base: Adjacent to established scenic areas such as Baomo Garden and Nanyue Yuan, possessing significant potential to absorb spillover visitors from these	Government policy relaxation: The designated site has been downgraded from the original Level 2 water source protection area to a

	opportunity, systematically addressing stormwater issues through WSUD techniques (e.g., rain gardens, constructed wetlands, permeable pavements), while simultaneously creating high-quality blue-green public spaces, overcoming policy restrictions, and achieving a win-win outcome for ecology and development.	n integration provide extensive market opportunities and policy support for the cultural and creative industries.	attractions, thereby injecting foot traffic into the park and exploring an integrated model of "cultural tourism + film and television."	quasi-protection area, providing more possibilities for spatial activation and the growth of commercial formats.
T (Threats)	Ecological and environmental fragility: The current water quality of the Shawan Waterway (Class III, mildly polluted) and the pollution pressure on the Zini River require	Challenge of balancing development and protection: Under strict ecological protection requirements, finding an appropriate development intensity and business model to ensure the economic	Homogeneous competition from surrounding areas: There are multiple industrial heritage renewal and cultural and creative park projects in the Guangzhou-Foshan region, which may divert industrial resources and	Complexity of community integration: Breaking the existing spatial isolation and reconciling the interests between the park's high-end transformation and the surrounding community's

	extreme caution in any renewal activities, as any pollution accident would have severe consequences.	sustainability of the project poses a significant challenge.	visitor flows, imposing higher demands on the project's unique positioning and attractiveness.	grassroots needs may be a complex and lengthy process.
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4.4 Core Contradictions and Formulation of Design Strategies

Through systematic analysis of the regional context, historical evolution, and current conditions of the Zini Sugar Factory, this study identifies that the key element of "water" has not been adequately articulated in existing preservation and revitalization efforts. As a waterfront industrial heritage site, the profound connection between the site and water—from the historical reliance on water transport for raw material delivery and product export, to the water-intensive production processes of sugar refining, and to the present locational characteristics of being situated along the waterfront—has been either overlooked or weakened in renewal and adaptive reuse. Water is not merely an object of ecological management but serves as a core medium that connects the city, shapes space, and activates place. The following sections analyze core contradictions, identify design potentials, and propose possible strategies from four dimensions: urban connectivity, infrastructure, site landscape, and building utilization, laying the foundation for subsequent renewal proposals based on Water Sensitive Urban Design (WSUD) principles.

4.4.1 Urban Connectivity Dimension: Fragmented Hydrological Connections and the Need to Reconstruct Hydrological Value

The Zini Sugar Factory faces the Zini River to the north; however, the existing waterfront is predominantly characterized by rigid vertical revetments. Industrial facilities such as wharves and warehouses form a closed industrial interface, severing the hydrological and spatial connections between the site and the urban hinterland as well as the surrounding communities. Internal walls within the factory site create "enclaves within the park," resulting in low public accessibility, with villagers from neighboring Zini Village and former factory workers excluded. The waterfront space has not been transformed into a public resource for the city, and the ecological and landscape value of the water's edge remains locked within an "industrial island."

The Zini River serves as a link between the site and the regional water system. Through ecological shoreline rehabilitation and the reshaping of waterfront public spaces, the closed industrial waterfront can be converted into an open civic waterfront, establishing hydrological connections and spatial dialogue between the site and the city. Waterfront structures such as the old wharf and the 10,000-ton warehouse possess strong industrial identity and can be transformed into anchors for waterfront activities.

4.4.2 Infrastructure Dimension: Stormwater Management Dysfunction and the Need to Reconstruct the Stormwater System

The current stormwater management capacity of the site is severely mismatched with the high standards required for water source protection, exhibiting systemic deficiencies characterized by "inability to infiltrate, retain, store, or treat" stormwater. Extensive impervious pavements lead to a sharp increase in surface runoff coefficients; stormwater rapidly enters the pipe network and is discharged into the river channel, exacerbating local waterlogging risks while also losing opportunities for stormwater resource utilization. Non-point source pollution carried by initial runoff poses a potential threat to the Zini River and the downstream Shawan Waterway. The original industrial drainage systems, such as open channels, underground pipes, and sedimentation tanks, remain idle and abandoned, failing to be converted into ecological stormwater management facilities.

Hydraulic facilities left over from the industrial period—including sedimentation tanks, cooling ponds, and open channels—provide stock resources for stormwater management retrofits due to their spatial morphology and elevation relationships. The site's spatial gradient pattern of "riverside–roadside–hinterland" naturally aligns with stormwater runoff pathways, enabling the construction of a complete stormwater management chain of "source–conveyance–terminal–receiving water body." The rigid constraints of water source protection precisely compel a low-impact, low-disturbance ecological retrofit pathway.

4.4.3 Site Landscape Dimension: Lack of Water Features and the Need to Reshape Hydrological Experience

The expression of "water" in the site's landscape design is severely inadequate. The existing landscape consists mainly of hard-surfaced plazas, lawns, and scattered greenery, lacking water-themed landscape nodes. Where stormwater management facilities (such as sunken green spaces and ecological swales) do exist, they are often relegated to marginal corners, disconnected from public activity areas. Although the waterfront interface offers

views of the river, there is a lack of spatial experiences that allow people to engage with or approach the water. It is difficult for the public to perceive the processes of water flow, purification, and circulation within the site, and the memory of water as a core element of the industrial heritage has been diluted.

Facilities from the sugar industry that used large volumes of water—such as tanks, channels, and cooling towers—can be transformed into water landscape nodes. Stormwater management facilities themselves possess landscape potential: the seasonal changes of rain gardens, the linear flow of ecological swales, and the water level fluctuations of retention wetlands can all become unique aesthetic experiences. Through the visible design of water, the public can come to understand the ecological value of the hydrological cycle in their daily recreation.

4.4.4 Building Utilization Dimension: Disconnection between Hydraulic Heritage and Building Revitalization

The existing hydraulic structures at the Zini Sugar Factory—such as cooling ponds, sedimentation tanks, and open channels—are spatially closely related to the main buildings, including production workshops and warehouses, originally forming a complete sugar production process flow. However, in current preservation and revitalization efforts, these hydraulic heritage elements are often neglected or marginalized, resulting in a disconnection between individual building retrofits and the water system. For example, some factory buildings have increased water demand after renovation but lack supporting rainwater harvesting or greywater reuse facilities; cooling ponds have been simply backfilled or abandoned without forming functional interactions with surrounding buildings. This disconnection between hydraulic heritage and building activation not only wastes resources but also weakens the integrity and narrative completeness of the industrial heritage.

Hydraulic structures and industrial buildings were originally integrated in terms of spatial morphology and elevation relationships, providing a structural basis for the integration of water systems and building functions. Water bodies such as cooling ponds and sedimentation tanks can be combined with building courtyards to form complexes for stormwater retention and microclimate regulation. Roof rainwater can be directed through downspouts into ecological swales or rain gardens around buildings, establishing a closed-loop relationship among building, water, and landscape. The adaptive reuse of hydraulic heritage serves both as a continuation of industrial memory and as a technical vehicle for ecological renewal.

4.5 Summary of This Chapter

This chapter systematically reviews the current site conditions of the Zini Sugar Factory from the perspectives of architectural heritage, waterfront space, commercial formats, and public activities, clarifying its basic characteristics: "intact industrial fabric, superior waterfront location, a nascent commercial foundation but insufficient publicness." From the perspective of architectural value, the industrial heritage is assessed in a graded manner, identifying core conservation elements and adaptable spaces for adaptive reuse. Furthermore, focusing on the key element of "water," the chapter analyzes the core contradictions from four dimensions—urban connectivity, infrastructure, site landscape, and building utilization—namely, fragmented waterfront, dysfunctional stormwater management, absence of water features, and disconnection of hydraulic heritage. Preliminary strategic directions are proposed. The analysis demonstrates that the renewal of the Zini Sugar Factory cannot be limited to functional replacement and heritage preservation; rather, water-sensitive design must be adopted as the central thread integrating heritage conservation, ecological restoration, and public activation, transforming water from a managed object into an active medium that connects the city and activates space.

Chapter 5: Revitalization Design of the Zini Sugar Factory Industrial Heritage Based on Stormwater Management

5.1 Overall Layout Analysis

5.1.1 Overall Layout and Bird's-Eye View

At the level of overall layout, this design follows the principle of integrating Water Sensitive Urban Design (WSUD) with industrial heritage conservation, adopting a strategy of "integral preservation, localized intervention, and low-impact renewal." First, the overall appearance, spatial fabric, and building structures of the sugar factory's industrial heritage are preserved to the greatest extent possible, ensuring historical authenticity and legibility. On this basis, only minor reorganization and optimization are carried out on the internal road system to improve connectivity and fire emergency access, while priority is given to ecological materials such as permeable pavements.

One of the core design measures is the low-impact renewal and transformation of the original hard-surfaced bagasse storage yard and other open areas within the factory site. Rather than large-scale demolition or reconstruction, this area is converted into a stormwater park that integrates ecological benefits with social functions. The park serves as a concentrated demonstration and application carrier of WSUD technologies. Through the construction of green infrastructure such as rain gardens, bioswales, permeable pavements, and constructed wetlands for storage and treatment, the previously impervious and rapid-runoff hard surface is transformed into a "sponge" that effectively retains, infiltrates, purifies, and harvests stormwater. This approach not only significantly alleviates regional stormwater pressure—aligning with the stringent environmental protection requirements of a water source protection area—but also converts a formerly enclosed productive space into a daily leisure and ecological education area open to surrounding residents. It effectively compensates for the lack of public open space in the district. Thus, while preserving the distinctive character of the industrial heritage, the design endows it with new ecosystem service functions and community value, achieving a "water–heritage–community" synergy.



Figure5 - 1 Master Plan (Drawn by the Author)



Figure5 - 2 Bird's-Eye View (Drawn by the Author)

5.1.2 Planning Structure and Functional Layout

The site renewal involves multiple stakeholders with differing priorities: the government focuses on the ecological protection of surrounding water resources, nearby residents seek richer and higher-quality leisure spaces, and film and creative professionals desire a more inspiring working environment along with comprehensive industrial chain support. In response to the core needs of these stakeholders, the planning scheme retains the industrial axis formed by the original factory buildings, while connecting the stormwater park—transformed from the bagasse storage yard—with the existing green space system to jointly form an ecological axis. These two axes intersect with the waterfront pedestrian system, thereby creating three functionally focused core nodes: the "Film Production Core," the "Stormwater Management Demonstration Core," and the "Recreation Activity Core." In this way, the design achieves coordinated development of ecology, industry, and community vitality.



Figure5 - 3 Planning Structure Analysis (Drawn by the Author)

Based on predictions of pedestrian flow direction and activity behavior on the site, the internal space is divided into the following three functional zones: The northwestern zone possesses superior industrial building heritage and waterfront landscape resources, with functions primarily centered on film production and exhibition, mainly serving cultural and creative workers and tourists. The southwestern zone is adjacent to the residential area and the main entrance of the site, focusing on providing leisure services for nearby residents and visitors. The northeastern zone is rich in natural resources, located close to Zini Village, and is primarily programmed for outdoor activities themed around nature experiences.



Figure5 - 4 Functional Layout Analysis (Drawn by the Author)

5.2 Urban Connectivity Dimension: Reconfiguration of Stormwater Public Space

5.2.1 Ecological Retrofitting of the Waterfront Shoreline

The hard, vertical shoreline on the southwest side of the Zini Sugar Factory is the primary obstacle disrupting the hydrological connection between the site and the Zini River. This design proposes the following ecological retrofitting measures.

Preservation and ecological reuse of the old wharf platforms. The concrete platform structures of the coal wharf and bagasse unloading wharf will be retained. Their surfaces will be roughened (chiselled) and covered with soil, where low, salt-tolerant groundcover vegetation will be planted, forming a transitional morphology of "hard substrate + soft cover." Steel grid walkways will be installed at the edges of the wharves, cantilevered over the water surface, serving as viewing and ecological observation points.



Figure5 - 5 Daytime Rendering of the Waterfront Shoreline Design (Drawn by the Author)



Figure5 - 6 Nighttime Rendering of the Waterfront Shoreline Design (Drawn by the Author)



Figure5 - 7 Rendering of the Waterfront Platform (drawn by the author)

Stormwater runoff interception design along the waterfront shoreline. A continuous pervious concrete interception trench will be constructed along the top of the shoreline to collect stormwater runoff from within the site. The collected runoff will be conveyed via the trench to a shoreline buffer zone for natural purification before being discharged into the on-site stormwater harvesting system. The surface of the interception trench will be covered with steel grids and cobblestones, serving both drainage and landscape functions.

5.2.2 Stormwater Public Space Enabling Urban Sharing

Through the reconfiguration of stormwater public spaces, this design breaks down the barrier of enclosing walls, enabling the sharing of waterfront resources with the surrounding community.



Figure5 - 8 Connection with Surrounding Communities (drawn by the author)



Figure5 - 9 Rainwater Aerial Connecting Corridor (drawn by the author)

Partial removal of walls and placement of entrances. Some of the solid walls on the side of the factory facing Zini Village will be demolished and replaced with openwork fences or hedges. Several main entrances and secondary pedestrian access points will be established. The elevations of these entrances will be flush with the external roads, ensuring barrier-free access for residents of the surrounding community.

Stormwater walkway system for community connection. The on-site stormwater management facilities, such as bioswales, rain gardens, and constructed wetlands, will be integrated with community pedestrian pathways to create a dual function where "stormwater routes serve as community slow-traffic routes." The walkways will be paved with permeable materials, with bioswales on both sides, allowing pedestrians to observe the collection, conveyance, and purification processes of stormwater along the way. The walkways will be open to community residents around the clock, breaking the impression of the site as a "closed

enclave."

5.3 Infrastructure Dimension: Construction of a Hierarchical Stormwater Management System

5.3.1 Overall Stormwater Management Strategy for the Site

In conventional industrial heritage renewal projects, water features often remain at the level of ornamental water bodies—the introduction of elements such as fountains, cascades, and decorative ponds may enhance the aesthetic quality of the space but lacks an intrinsic connection with the site's industrial history and hydrological characteristics. Water becomes an added ornament rather than an organic component growing out of the site's fabric. This design activates dynamic water features by utilizing the site's natural elevation differences and abandoned hydraulic structures within the industrial heritage. The flow of water is deeply integrated with the presentation of industrial memory, the demands of stormwater management, and the creation of spatial experience, thereby making dynamic water features a medium that connects past and present, nature and artifice, function and aesthetics.



Figure5 - 10 Water Infrastructure Layout Analysis (Drawn by the Author)

According to the original drainage path of the site, stormwater runoff flows from south to north into the pipe network, ultimately crossing the waterway on the northern side of Zini Island and discharging into the municipal main pipe of Shawan Town. To implement water-sensitive stormwater management, source control facilities such as green roofs and vertical greening are installed in the three-dimensional stormwater collection zone at the

upstream (southern) section of the path, achieving initial collection and retention of stormwater. In the graded green space storage zone along the middle section, infiltration and detention facilities such as permeable pavements and rain gardens are deployed to promote infiltration, filtration, and purification of stormwater. Among these, the sunken stormwater plaza can present varying water-level landscapes depending on the season, offering residents and visitors diverse experiential qualities. In the aquaponics stormwater utilization zone at the downstream (northern) end, the existing farmland and fishpond resources are fully utilized to construct water circulation systems such as aquaponics, achieving ecological purification and resource recovery of stormwater. Any excess stormwater is then discharged northward through the existing pipes into the municipal stormwater and sewage system.

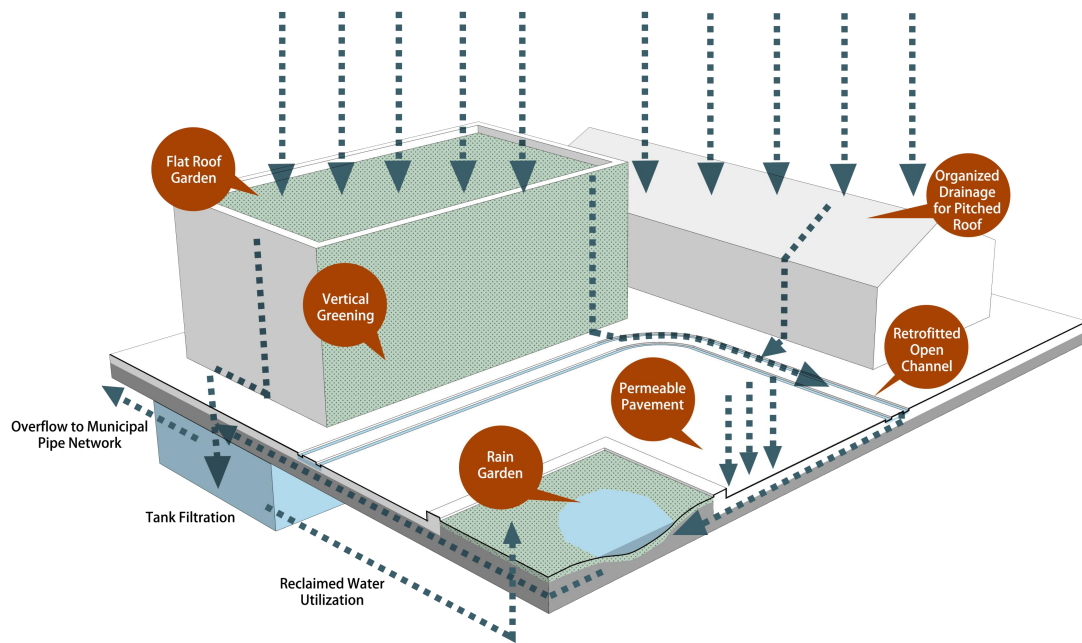


Figure5 - 11 Design of the Stormwater Management and Recycling System (Drawn by the Author)

Within the Water Sensitive Urban Design (WSUD) framework, stormwater recycling and reuse constitute a systematic, multi-stage process grounded in natural hydrological cycles. The entire process begins with source control and collection: differentiated strategies are applied to different types of building roofs within the factory site—green roof retrofitting is implemented on flat roofs to enhance retention and evapotranspiration capacity, while rain chains or diversion gutters are installed on pitched roofs to guide stormwater in an orderly manner to ground-level collection zones, achieving efficient distributed source collection. Through technical measures such as green roofs, bioswales, and permeable pavements, decentralized retention and primary purification of stormwater are achieved at the point where

runoff is generated.

Subsequently, the process enters the conveyance and pre-treatment stage, where stormwater is directed via ecological swales or infiltration trenches to detention facilities. In this stage, particular attention is paid to the innovative reuse of industrial heritage elements. For example, the original production rail tracks within the factory site are retained and transformed into open stormwater channels, which both preserve industrial memory and clearly display the flow path of stormwater, enhancing public perception and educational value, while also achieving intermediate conveyance and primary sedimentation functions.

In the central detention and purification stage, stormwater is collected in facilities such as rain gardens, constructed wetlands, or underground storage tanks, where it undergoes advanced purification through plant-soil-microorganism complex systems, improving water quality while reducing peak flood flows. Finally, the process enters the reuse and discharge stage: treated stormwater is used for non-potable purposes such as green irrigation, landscape water replenishment, and cleaning, achieving resource recovery and circulation; any excess beyond storage and utilization capacity is discharged in a controlled manner into natural water bodies or the municipal drainage network. This forms a sustainable closed-loop system from "runoff – collection – purification – reuse," comprehensively enhancing urban water ecological resilience and resource efficiency.

5.3.2 Source Control: Roof Rainwater Harvesting and Green Roofs

Source control aims to achieve on-site retention and reduction of stormwater at the initial stage of runoff generation. In response to the differentiated characteristics of the industrial building heritage at the Zini Sugar Factory, the scheme adopts an adaptive strategy: for flat roofs of factory buildings with adequate structural load-bearing capacity, lightweight extensive green roofs are implemented, using a 100–150 mm thin-layer substrate planted with Sedum species. For the Soviet-style office building and the sawtooth-roof workshop, which hold high preservation value, modular movable planting units are used instead of permanent overlay retrofits, achieving partial stormwater retention without altering the roof's original appearance. For buildings that are not suitable for green roof conditions, a roof rainwater harvesting system is installed, consisting of gutters, a first-flush diverter, filtration units, and storage modules. The collected rainwater is prioritized for green irrigation and landscape water replenishment. These measures transform building roofs from "runoff contributors" under conventional drainage patterns into "source retention units" within the stormwater management chain.

5.3.3 Conveyance in Process: Ecological Swale and Bioswale System

The conveyance system in the process stage is responsible for guiding runoff, after source reduction, in an orderly manner to downstream detention facilities, while utilizing the vegetation–soil system along the conveyance path for continuous purification. The scheme lays out three types of swales along the main roads and open spaces of the factory site—standard conveyance bioswales, dry swales, and wet swales—forming a graded conveyance network. The design fully respects the existing industrial drainage channels and pipe trench textures left on site: the original concrete drainage channels, after desilting, ecological lining, and replanting with vegetation, are transformed into conveyance swales that combine historical legibility with ecological function. Road curbs are modified with cut openings to direct road surface runoff in an orderly manner into roadside bioswales, achieving a smooth transition from hard drainage to soft ecological drainage. The flow of runoff through the swales, along with the seasonal changes of vegetation, transforms stormwater management from a concealed engineering system into a perceptible landscape experience.



Figure5 - 12 Ecological Swale and Stormwater Ditch (drawn by the author)

5.3.4 End-of-Pipe Detention and Storage: Retrofitting of Old Ponds and Multifunctional Wetlands

End-of-pipe detention and storage is based on the industrial water ponds remaining on the site (including sedimentation tanks, cooling water ponds, and fire storage tanks), which are transformed through ecological retrofitting into multifunctional detention wetlands. The scheme retains the main concrete structures of the ponds as well as their industrial components such as inlets/outlets and overflow weirs. On the basis of partially breaking the

pond bottoms to restore hydraulic connectivity, ecological floating islands and constructed wetland substrate layers are installed in stages within the ponds. Aquatic plants such as reeds (*Phragmites australis*) and cattails (*Typha orientalis*) are planted to form a combined purification unit integrating surface flow and subsurface flow. The wetlands operate in a dual-mode: "normal time – storm time." During non-rainfall periods, a normal water level is maintained to fulfill landscape and ecological functions. During rainfall events, the reserved detention volume is used for peak shaving and flood retention. After three-stage purification (sedimentation – subsurface flow – surface flow), the treated effluent is reused for on-site green irrigation and landscape water replenishment, forming an internal water recycling loop. The concrete texture of the old ponds and the seasonal succession of aquatic plants are juxtaposed within the same space, making the end-of-pipe detention facility a composite place that carries both ecological functions and industrial memory.



Figure5 - 13 Multifunctional Wetland in Sunny Condition (drawn by the author)



Figure5 - 14 Multifunctional Wetland in Rainy Condition (drawn by the author)

5.4 Site Landscape Dimension: Hydrological Experience and Placemaking

5.4.1 Rain Gardens and Bioretention Landscapes

In traditional industrial heritage renewal projects, greening is often reduced to a mere beautification measure—lawns covering open spaces, shrubs dotting the surroundings of buildings, with greenery and water systems disconnected from each other, and plants serving only as visual decoration. This approach neither realizes the ecological potential of vegetation within the hydrological cycle nor seizes the possibility of deep integration between industrial sites and natural processes. Drawing on water-sensitive stormwater management theory, this design proposes that the relationship between greening and water should shift from "ornamental embellishment" to "ecological symbiosis"—that is, employing plant communities as living filters and an ecological substrate within the water circulation system. Through the coupled design of rain gardens and aquaponics systems, the ecological functions, landscape value, and productive potential of greening mutually reinforce one another, achieving a synergistic coexistence of water, plants, microorganisms, and fish.

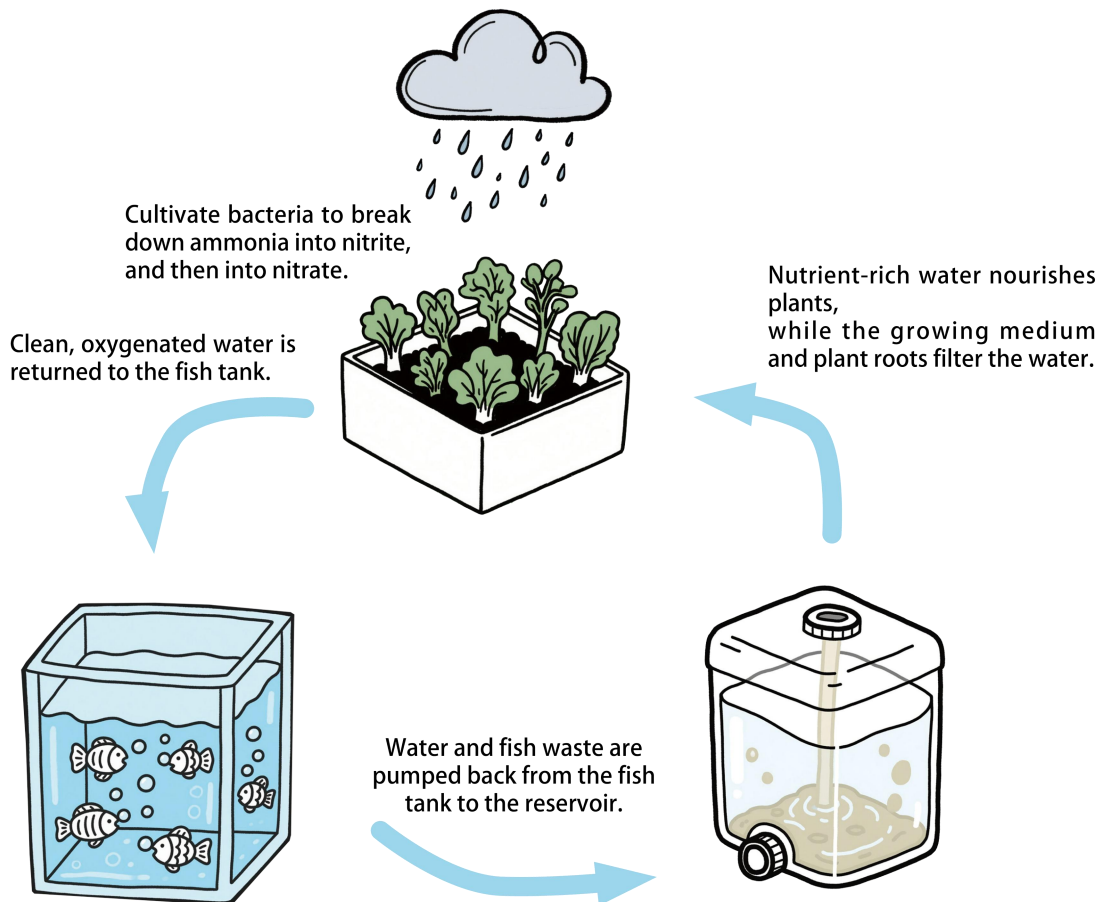


Figure5 - 15 Aquaponics System Analysis Diagram (Drawn by the Author)

Aquaponics is a circular agricultural model that organically integrates aquaculture and hydroponics. Its core principle lies in utilizing the nutrient-rich wastewater generated from aquaculture. Through microbial catalysis, the ammonia nitrogen in fish waste is converted into nitrates that plants can absorb, thereby providing nutrients for hydroponically grown vegetables. At the same time, the absorption of nutrients by plants purifies the water quality, allowing the water to be recirculated back to the aquaculture unit, thus achieving synergistic production of fish and plants within a single system [50][51]. This system uses fish feed as the sole initial nitrogen source and achieves efficient nitrogen utilization through biological transformation, significantly reducing reliance on external fertilizers and water consumption. Aquaponics is not only water-saving, fertilizer-efficient, and environmentally friendly but also alleviates, to some extent, the pollution pressure that traditional agriculture imposes on soil and water bodies, demonstrating high ecological sustainability.

Based on retaining the original roof structural framework of the building, the rain garden retrofit node introduces landscape design and public leisure functions into the building interior. Integrated with the aquaponics system, it is developed into a stormwater reuse demonstration and experience zone, incorporated into the site's sightseeing and experiential route. This allows visitors to intuitively perceive the entire process of stormwater collection, purification, and resource recovery. At the same time, dining services are added in conjunction with ecological interpretation, enabling visitors to taste vegetables and fish nurtured by harvested stormwater after their tour, thereby further enhancing the experiential and educational value of the ecological cycle. This node can also collaborate with local schools to establish a nature science education practice base. By organizing students to participate in planting, observation, and harvesting activities, it deepens young people's understanding of the hydrological cycle and ecological agriculture, forming a sustainable educational space that integrates "demonstration – experience – learning."



Figure5 - 16 Revitalization Location Map (Drawn by the Author)

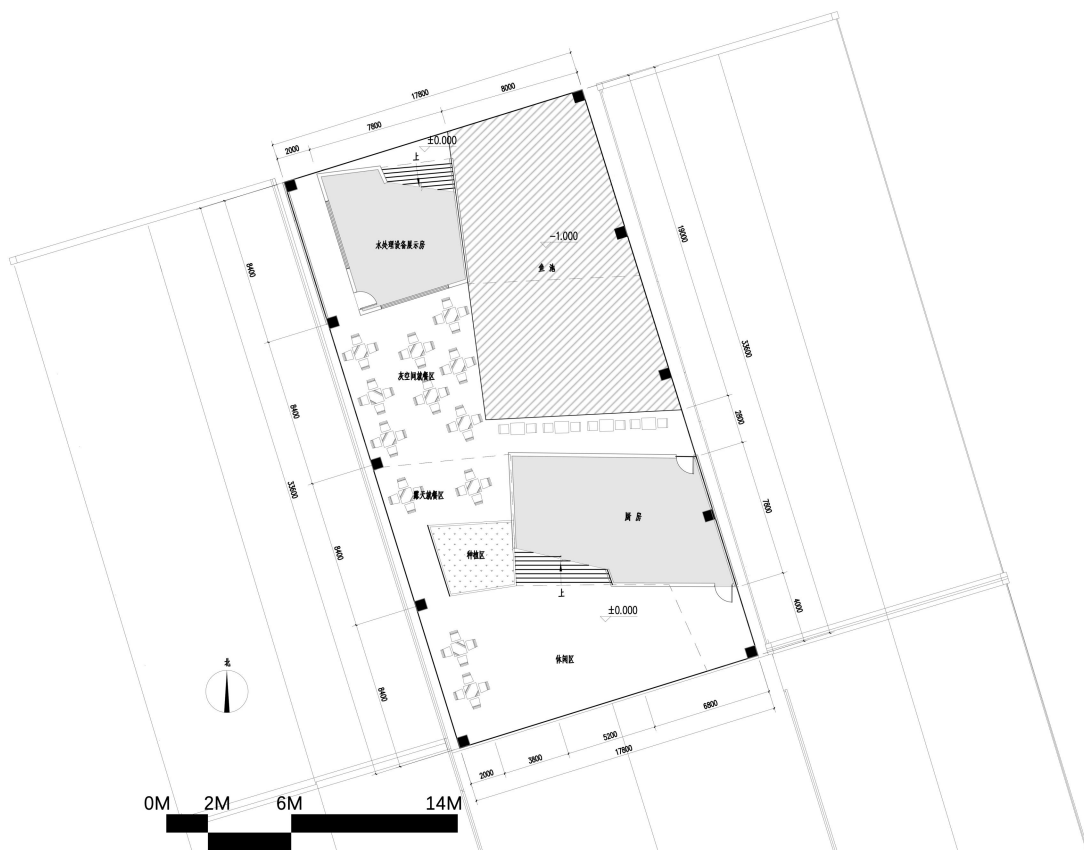


Figure5 - 17 Ground Floor Plan (Drawn by the Author)



Figure5 - 20 Rain Garden Rendering 2 (Drawn by the Author)

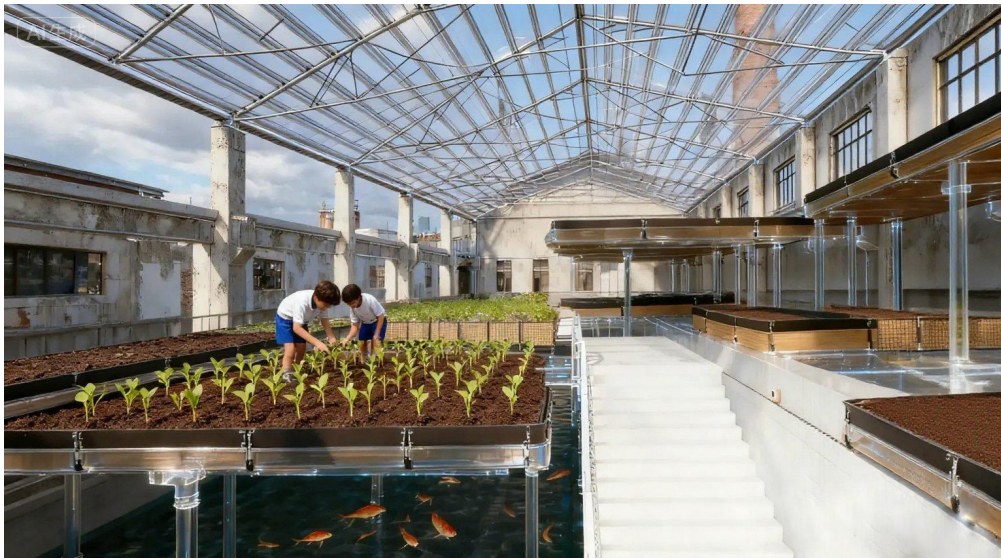


Figure5 - 21 Rain Garden Rendering 3 (Drawn by the Author)

5.4.2 Permeable Pavement and Visualized Drainage Design

This design employs permeable pavement in the main plazas, roads, and public activity areas of the site, combined with facilities such as linear drainage channels to visualize stormwater flow paths, transforming the concealed drainage process into a legible and perceptible landscape language.

(1) Zonal Selection and Structural Design of Permeable Pavement

Permeable concrete: used for high-load areas (pedestrian and light vehicle traffic) such as the main waterfront promenade and the Wanzton Granary Plaza. The structural layers from bottom to top are: compacted subgrade, graded gravel base course (200 mm thick), permeable concrete base layer (120 mm thick, porosity 15%–20%), and permeable concrete surface layer

(60 mm thick, aggregate size 3–5 mm). The surface may be treated with coloured stamping or exposed aggregate to harmonize with the red brick and concrete textures of the industrial heritage.

Permeable bricks: used for secondary footpaths, rest platforms, and areas around rain gardens (light-load areas). Dark grey and terracotta-red permeable bricks are selected, with dimensions of 200 mm × 100 mm × 60 mm, echoing the red brick tones of the original industrial buildings. The base course consists of a medium-coarse sand levelling layer plus a graded gravel base course, with a permeability rate ≥ 0.1 cm/s.

Permeable asphalt: used for cycle paths connecting the waterfront promenade with the urban slow-traffic system, balancing permeability with cycling comfort. The surface layer uses OGFC-13 permeable asphalt mixture with a void ratio of 18%–22%, underlain by a permeable base course.

(2) Landscape Treatment of Linear Drainage Channels

Linear drainage channels are installed along plaza edges, both sides of roads, and around buildings, replacing traditional catch basins, making the stormwater flow path clearly visible.

Steel grating cover drainage channels: stainless steel or cast iron grating covers are used in main pedestrian areas, with anti-slip surface treatment. Sediment traps are placed beneath the gratings for easy cleaning. The grating gaps are 10–15 mm wide, ensuring sufficient flow capacity while preventing debris from falling in. Copper strips or LED light strips may be embedded on the grating surface to outline the stormwater runoff path at night.

Cobble-filled drainage channels: open drainage channels are used along green edges or around rain gardens, filled with cobblestones or crushed stone of 30–50 mm diameter. Stormwater flows over the surface of the cobblestones, partially infiltrating into the surrounding soil and partially flowing into downstream facilities. The edge of the cobble-filled channel is flush with the lawn without obvious curbs, creating a natural transition.

Custom industrial-style covers: in line with the industrial heritage character of the Zini Sugar Factory, some drainage channel covers may be customized using materials such as discarded steel plates and railroad ties. For example, waste cast iron pipe fittings may be cut and embedded into the covers, or industrial motifs such as gears and valves may be cast into the covers, making the stormwater facilities themselves carriers of industrial memory.

5.5 Building Utilization Dimension: Activation of Hydraulic Heritage and Building Renewal

5.5.1 Classification of Building Renewal

The buildings within the industrial heritage are analyzed and classified according to their architectural value and structural quality, with different measures adopted based on actual conditions. Historic buildings of good quality are preserved. Historic buildings of average quality are restored. Other buildings of average or better quality are retained and undergo water-sensitive retrofitting, such as the addition of green roofs. Other buildings of poor quality are demolished and transformed into sunken green spaces, rain gardens, or public spaces with permeable pavement.

Table5 - 1 Classification of Building Renewal

Building Classification	Multi-story and high-rise frame buildings	Multi-story brick-concrete buildings	Brick and timber buildings	Unenclosed shed
Historic buildings	Preserve and integrate new functions	Preserve and integrate new functions	Restore and integrate new functions	Restoration and retrofitting
Other buildings	Retain and implement water-sensitive retrofitting	Retain and implement water-sensitive retrofitting	Water-sensitive retrofitting, or demolition and redevelopment into water-sensitive public space	Demolition and redevelopment into water-sensitive public space



(a) Classification by Construction Period (b) Building Condition Analysis

Figure5 - 22 Building Grading Analysis (Drawn by the Author)

5.5.2 Retrofitting of Building Roof Rainwater Harvesting Systems

The sugar factory retains a large number of long-span factory buildings with considerable roof areas, which serve as high-quality stormwater catchment surfaces. In conventional practice, downspouts are concealed at the back of buildings, allowing rainwater to be drained away "silently." This research attempts to make the rainwater harvesting process landscape-oriented and experiential—by designing vertical metal chain rain guides, artistic downspouts, or open gabion drainage strips on building facades, so that the flow of rainwater from roof to ground can be "seen" and "heard." Particularly during the rainy season in Lingnan (southern China), these nodes become dynamic "water curtain" landscapes on building facades, transforming a natural phenomenon into a spatial experience.



Figure5 - 23 Vertical Greening Rendering (Drawn by the Author)

The construction retrofit of building-integrated vertical greening is realized through layered functional reconfiguration of the building facade system, based on the principles of "lightweight, modular, and ecological" design. The core objective is to transform traditional walls into living "ecological interfaces" without compromising the structural safety of the original building. The retrofit begins with an assessment of the wall's load-bearing capacity and waterproofing performance, based on which a support system is designed. Typically, an independent steel frame or lightweight aluminum alloy framework is securely connected to the original structure, forming a secondary construction layer detached from the wall surface to ensure structural separation and proper ventilation and drainage. Subsequently, a waterproofing and drainage layer is installed: root-resistant waterproof membranes prevent plant root intrusion, while drainage channels and pipes are provided to achieve orderly

drainage, avoiding water accumulation that could damage the building envelope. On this basis, the growing substrate layer is installed, using lightweight, water-retentive, and decay-resistant media (e.g., coconut coir substrate, inorganic fiber felt). Plants are fixed via modular planting boxes or a continuous felt system. Finally, an irrigation system is integrated, using drip or micro-spray methods for precise water delivery. Some systems may also be coupled with rainwater harvesting devices to achieve water recycling, thereby synergistically enhancing ecological benefits and building performance in the vertical dimension.

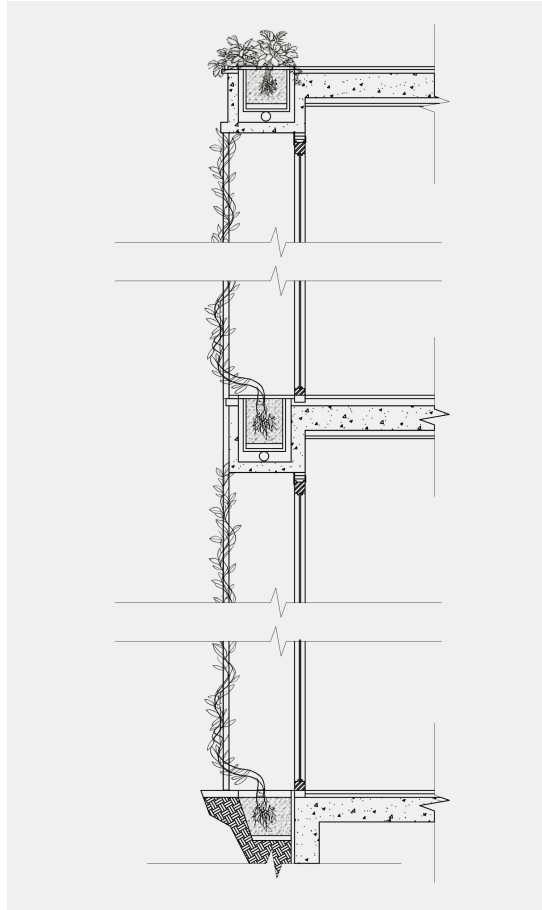


Figure5 - 24 Detail Drawing of Vertical Greening, Scale 1:50 (Drawn by the Author)

5.5.3 Open Ground Floor and Water-Interactive Retrofitting of Waterfront Buildings

Sugar factory buildings often feature semi-outdoor spaces such as corridors, eaves, and unloading platforms, which serve as key interfaces for stormwater transition from the building to the site. The design can install linear rain gardens, permeable pavements, and gravel infiltration trenches along the edges of such "grey spaces," directly connecting the building's downspout outlets into these small-scale ecological facilities. Stormwater is first directed to the retention zones around the building, filtered through plant roots and substrate layers, after which excess runoff slowly overflows into the site's drainage network. This approach

transforms the building–site interface from a rigid "hard boundary" into a flexible stitching zone that combines ecological purification with spatial transition functions.

For example, in the design, a factory building located on the northwest side of the site is adjacent to the riverbank on its western side. In the nodal retrofit, the riverside space of this building is designed as a grey space, which not only guides views toward the water but also becomes an important component of the building's overall stormwater management system.



Figure5 - 25 Location Diagram of the Factory Building Retrofit Node (Drawn by the Author)

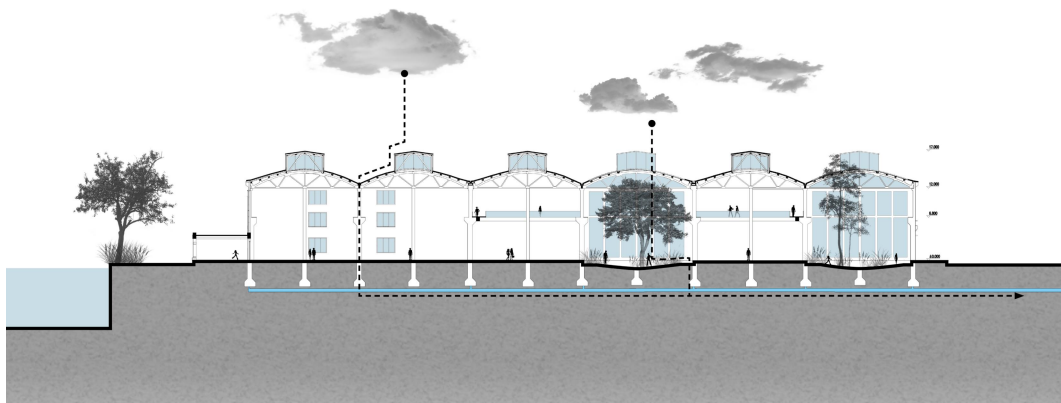


Figure5 - 26 Section Drawing of the Factory Building Retrofit Node (Drawn by the Author)

5.6 Stormwater Management Performance Calculation and Adjustment

5.6.1 Planning-Level Performance

A1: Calculate the total storage volume " V_{total} "

The planning area of this project is 566,736 m². Comprehensive runoff coefficient values: hard roof 0.9; concrete and asphalt pavement 0.9; gravel 0.4; green space 0.15; permeable pavement 0.3. The comprehensive runoff coefficient is calculated as follows:

$$\psi = (52,625 \times 0.9 + 41,091 \times 0.9 + 148,749 \times 0.3 + 190,462 \times 0.15 + 58,548 \times 0.15 + 35,587 \times 1 + 39,494 \times 0.4) / 566,736 = 0.38$$

The pre-development comprehensive runoff coefficient of the site was 0.60, while the post-development runoff coefficient is 0.38.

The design storage volume is generally calculated using the volume method, with the formula as follows:

$$V_{storage} = 10 \cdot H \cdot \psi \cdot F \quad (5-1)$$

Note: The formula is sourced from the Technical Guide for Sponge City Construction – Low Impact Development Stormwater System Construction (Trial).

From (5-1), The calculation yields:

$$V_{storage} = 10 \times 25.8 \times 0.38 \times 566,736 \div 10,000 = 5,556 \text{ m}^3$$

A2: Large unutilized open spaces within the site are designed as a stormwater park.

A3: The site has planned roads and drainage paths, along which ecological swales or open channels are set.

A4: Ecological buffer zones are designated along the river and streams.

A5: Calculate the storage volume of the buffer zones " V_{buffer} "

$$\text{From (3-1), } V_{buffer} (\text{m}^3) = A_{buffer} (\text{m}^2) \times D_{design} \text{ value (m)} = 2,500 \text{ m}^3$$

A6: Farmland exists around the site, where harvested stormwater may be considered for irrigation reuse.

A7/A8: Existing fishponds are retained, and their storage volume " V_{pond} " is calculated.

$$\text{From (3-2), } V_{pond} (\text{m}^3) = A_{pond} (\text{m}^2) \times \Delta H (\text{m}) = 830 \text{ m}^3$$

New storage volume required for the site = $V_{total} - V_{buffer} - V_{pond} = 2,226 \text{ m}^3$. This result guides the scale of the large-scale storage facility in A2.

A10:

① Calculate the volume capture ratio of annual rainfall

Definition: The proportion of total annual stormwater volume captured and managed on site relative to the total annual rainfall.

Significance: This is the core indicator, directly reflecting the overall capacity of the project to reduce runoff at source and recharge groundwater. The higher the value, the lower the risk of waterlogging and the greater the potential for stormwater resource utilization.

How to verify:

$$\text{Actual controllable design rainfall depth } h = V / (10 \cdot \phi \cdot F) \quad (5-2)$$

Where:

V = design storage volume (m^3)

Φ = comprehensive runoff coefficient

h = design rainfall depth (mm)

F = catchment area (ha)

After calculating the actual controllable design rainfall depth, the corresponding theoretical volume capture ratio of annual rainfall for the site can be determined by referring to the relevant tables in the Guangzhou Sponge City Planning and Design Guidelines (Trial) and applying the interpolation method.

Table5 - 2 Design Rainfall Depth Corresponding to Volume Capture Ratio of Annual Rainfall

Table5 - 2 Design Rainfall Depth Corresponding to Volume Capture Ratio of Annual Rainfall						
Volume Capture Ratio of Annual Rainfall	60%	65%	70%	75%	80%	85%
Design rainfall depth(mm)	19.1	22.1	25.8	30.3	36.0	43.7

Note: Data sourced from the Guangzhou Sponge City Master Plan.

The actual volume capture ratio of annual rainfall is calculated as shown in the following table.

Table5 - 3 Calculation of the Actual Volume Capture Ratio of Annual Rainfall

Table5 - 3 Calculation of the Actual Volume Capture Ratio of Annual Rainfall					
Catchment zone	Total area (m^2)	Actual storage volume (m^3)	Runoff coefficient ϕ	Actual controllable rainfall depth(mm)	Actual Volume Capture Ratio of Annual Rainfall (%)
Total site	566736	5971	0.38	26.83	71%

Upon verification, the actual controllable design rainfall depth is 26.83 mm (24-hour), achieving a volume capture ratio of annual rainfall of 71%, which meets the requirement of 70%.

Guangzhou Sponge City Master Plan (2016–2030): The target volume capture ratio of annual rainfall for built-up areas is 70%. In the near term (by 2020), 20% of built-up areas should meet this target; in the long term (by 2030), 80% of built-up areas should meet this target.

② Calculate the runoff pollutant reduction rate

Definition: The average removal rate of major pollutants in stormwater runoff—such as suspended solids (SS), chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP)—achieved through WSUD facilities on the site.

Significance: This directly measures the effectiveness of the project in controlling non-point source pollution, which is crucial for protecting the vulnerable water source areas of the Greater Bay Area.

How to verify: Among urban runoff pollutants, SS (suspended solids) often correlates with other pollutant indicators. Therefore, SS is generally used as the control indicator for runoff pollutants. The annual SS total removal rate of low-impact development (LID) stormwater systems typically reaches 40%–60%. According to Table 4.4.3 of the Guangzhou Sponge City Planning and Design Guidelines – Low Impact Development Stormwater System Construction (Trial), the reduction rates of various measures can be consulted. The annual SS total removal rate can be calculated using the following method:

Table5 - 4 Pollutant Removal Rates of Different Stormwater Control Measures

Table5 - 4 Pollutant Removal Rates of Different Stormwater Control Measures	
Individual facility	Pollutant removal rate (based on SS, %)
Permeable brick pavement	80-90
Permeable cement concrete	80-90
Permeable asphalt concrete	80-90
Green roof	70-80
Complex bioretention facility	70-95
Infiltration basin	70-80
Wet pond	50-80
Stormwater wetland	50-80

Table5 - 4 Pollutant Removal Rates of Different Stormwater Control Measures

Individual facility	Pollutant removal rate (based on SS, %)
Storage tank	80-90
Rain barrel	80-90
Conveyance grass swale	35-90(related to hydraulic retention time)
Vegetated buffer strip	50-75
Artificial soil infiltration	75-95

Note: The pollutant removal rate of conveyance grass swales is closely related to hydraulic retention time (HRT). Relevant research results indicate that when HRT is 5.5, 7, 10, and 18 minutes, the corresponding pollutant removal rates are 48%, 70%, 77%, and 86%, respectively. It is recommended that the value be determined based on the HRT of the grass swale.

Annual SS total removal rate = Volume capture ratio of annual rainfall $\times$ Average SS removal rate of LID facilities.

For this project, the total SS (suspended solids) removal rate = Volume capture ratio of annual rainfall $\times$ Average SS removal rate of LID facilities. The average SS removal rate of LID facilities is calculated as:

Average SS removal rate of LID facilities = $\sum((1-V_i)F_i) / \sum[(1-\psi_i)F_i] \times$ Removal rate of individual facility) (5-3)

Where:

V_i = runoff coefficient of the facility's catchment area (or relevant parameter; please verify from your context)

ψ_i = comprehensive runoff coefficient of the subcatchment

F_i = area of the subcatchment

For this project, the main LID facilities are sunken green spaces and permeable pavements. Based on the table above, the calculation of the annual SS total removal rate for each subcatchment of this project is as follows:

Table5 - 5 Calculation of the Integrated Annual SS Total Removal Rate for the Entire Site

Table5 - 5 Calculation of the Integrated Annual SS Total Removal Rate for the Entire Site					
LID measures	Scale (m ²)	Individual pollutant reduction rate	Average removal rate	Volume Capture Ratio of Annual Rainfall	Annual Total SS Removal Rate

Table5 - 5 Calculation of the Integrated Annual SS Total Removal Rate for the Entire Site

LID measures	Scale (m ²)	Individual pollutant reduction rate	Average removal rate	Volume Capture Ratio of Annual Rainfall	Annual Total SS Removal Rate
Sunken green space	58548	75%	77.7%	71%	55.17%
Permeable pavement	148749	80%			
Green roof	39494	70%			

The annual total SS removal rate of this project site reaches 55.17% > 50%, meeting the requirements of the Guangzhou Sponge City Planning Guidelines (Trial). Through the implementation of measures such as permeable pavement and sunken green spaces, the volume of stormwater discharged into municipal stormwater pipes and channels has been effectively controlled, significantly enhancing the sponge city characteristics of the project. This has positive significance and serves as a demonstration for achieving sponge city construction goals.

③ Calculate the green facility coverage ratio

Definition: The proportion of green facilities with stormwater storage and purification functions relative to the total green area.

Significance: This indicator intuitively reflects the "green" and "sponge" attributes of the site.

How to verify:

For this project permeable pavement area = 148,749 m²; building footprint area = 127,706 m²; green space area = 249,190 m²; roadway area = 36,759 m².

(Permeable pavement ratio = Permeable pavement area / (Total land area – Building footprint area – Green space area – Roadway area))

Permeable pavement ratio = 148,749 / 185,508 = 80.18% > 70%, meeting the requirement.

Permeable pavement refers to the use of permeable materials such as grass pavers, permeable bricks/concrete, etc., in place of traditional concrete, cement, asphalt, etc., for paving hardened surfaces such as plazas, parking lots, and sidewalks. This improves rainwater

infiltration capacity while maintaining original functions, thereby reducing the runoff coefficient of the underlying surface.

External permeable ground ratio = (Permeable pavement area + Green space area) / (Total external paved area)

External permeable ground ratio = $397,939 / 474,617 = 83.84\% > 40\%$, meeting the requirement.

Permeable ground includes natural bare ground, public green space, vegetated ground, open-grid paving with a void area $\geq 40\%$ (e.g., grass pavers), as well as permeable bricks, permeable asphalt, and permeable concrete.

Guangzhou Stormwater Runoff Control Measures for Construction Projects: For new projects, the external permeable ground ratio for hardened surfaces (excluding municipal public roads) shall not be less than 40%; the permeable pavement ratio shall not be less than 70%; and at least 50% of green areas (excluding parks) shall be sunken green spaces for stormwater retention.

5.6.2 Site-Level Performance

B1: Permeable pavement is widely used for parking lots and roads.

B2: Ecological swales are designed alongside the roads to convey stormwater to the stormwater park in the northeastern part of the site .

B5: Rain gardens are installed for pre-treatment before stormwater enters the fishponds.

B3/B4: Several rain gardens are designed to treat runoff around the buildings, with their areas determined through formula-based calculation.

5.6.3 Building-Level Performance

C1: Green roofs are applied to flat roofs of buildings whose structural load capacity meets the requirements.

C2/C3: Rain barrels are installed for green irrigation.

C6: For buildings equipped with air conditioning units, rainwater and condensate recovery is considered for indoor cooling.

5.7 Chapter Summary

This chapter takes "water" as the core medium and systematically elaborates on the public space renewal scheme for the Zini Sugar Factory based on water-sensitive design, across four dimensions: urban connectivity, infrastructure, site landscape, and building utilization. In the urban connectivity dimension, through ecological retrofitting of the

waterfront shoreline and reconfiguration of stormwater public spaces, the disconnection between the "industrial island" and the surrounding community is broken, transforming waterfront resources into shared public assets for citizens. In the infrastructure dimension, a hierarchical "source – conveyance – end-of-pipe – receiving" stormwater management system is constructed, utilizing existing hydraulic structures to achieve stormwater retention, purification, and reuse, thereby responding to the high standards required for water source protection. In the site landscape dimension, through permeable pavements, visualized drainage, and a "water narrative" experiential loop, the hidden hydrological processes are translated into a legible and traversable landscape language. In the building utilization dimension, measures such as roof rainwater harvesting, downspout disconnection, and green roofs turn the buildings themselves into active components of the water cycle. The designs across these dimensions support each other and progress in layers, all converging on a core objective: to transform water from an object to be managed into a positive medium that connects the city, activates spaces, and shapes experiences, thereby providing an actionable pathway for the ecological renewal of waterfront industrial heritage.

Conclusion

This study takes stormwater management as the core perspective, employs Water Sensitive Urban Design (WSUD) and Sponge City concepts as theoretical tools, and uses the Guangzhou Zini Sugar Factory as an empirical case to systematically explore the integration pathways and design methods of stormwater management strategies in the public space design of waterfront industrial heritage sites. Following a logical framework of "theory construction – current situation diagnosis – site analysis – design implementation," the study has reached the following main conclusions.

1. The theoretical coupling of stormwater management and industrial heritage renewal establishes a foundation for interdisciplinary dialogue.

Through a systematic review of industrial heritage renewal theories and stormwater management theories, this study finds a deep conceptual alignment between the two. Industrial heritage renewal emphasizes respect for historical memory and adaptive reuse, while WSUD and Sponge City concepts advocate for minimal intervention in natural hydrological processes and multi-objective integration. Both share the core values of "low impact" and "sustainability." In particular, the WSUD pursuit of multi-objective integration of water landscapes, visualization of water ecological processes, and publicization of water spaces is highly consistent with the goals of preserving site fabric, activating industrial elements, and reshaping public spaces in waterfront industrial heritage renewal. This theoretical coupling suggests that integrating stormwater management strategies into the public space design of industrial heritage is not only technically feasible but also culturally adaptive and rich in spatial narrative potential.

2. The common challenges of waterfront industrial heritage in Guangzhou establish the necessity and working framework for stormwater management intervention.

Through systematic investigation of the current conditions of waterfront industrial heritage in Guangzhou, this study reveals common challenges across three dimensions: the trade-off between water resource utilization and heritage conservation; the connection between heritage revitalization and public life; and the inherent tensions within heritage preservation and activation. Specifically: the hardened surfaces and combined drainage systems inherited from the industrial period are ill-equipped to cope with Guangzhou's climate of frequent heavy rainfall and concentrated flood seasons; heritage protection imposes rigid constraints on topographic modification and underground engineering, making conventional sponge city measures difficult to transplant directly; and stormwater

management measures in already-renewed projects remain fragmented and lack systematic, holistic consideration. Based on these findings, the study distills the design principles of "systematic, low-impact, and multi-objective" stormwater management and constructs a working framework comprising a design analysis matrix and stormwater management performance calculations, providing an operational assessment tool and technical pathway for subsequent design practice.

3. The diagnosis of core contradictions at the Zini Sugar Factory provides precise targets for stormwater management intervention.

Taking the Zini Sugar Factory as an in-depth empirical case, this study employs historical research, site investigation, stormwater management potential analysis, and SWOT analysis to accurately diagnose the site's core contradictions across four dimensions. Urban connectivity dimension: the hydrological connection between the factory site, Zini Island, and the surrounding urban area is severed by roads and embankments, and the hydrological value urgently needs reconstruction. Infrastructure dimension: the site's stormwater system is primarily based on direct discharge, with aging pipe networks and low standards, resulting in significant dysfunction in stormwater management. Site landscape dimension: water features are severely lacking, the stormwater runoff process is entirely concealed, and hydrological experience has not become part of the site's *genius loci*. Building utilization dimension: industrial heritage elements such as sugar production workshops and warehouses are disconnected from hydraulic heritage elements such as sedimentation tanks and cooling ponds in the revitalization process, lacking systematic integration. These diagnoses constitute the problem targets for the subsequent precise construction of design strategies.

4. The four-dimensional design strategies validate the feasibility of integrating stormwater management with industrial heritage revitalization.

At the level of design practice, the study proposes a public space renewal scheme for the Zini Sugar Factory centered on the core concept of "Circular Theater, Unbounded Growth," systematically constructing an integrated design strategy for stormwater management and industrial heritage revitalization across four dimensions: urban connectivity, infrastructure, site landscape, and building utilization.

In the urban connectivity dimension, the scheme transforms the originally enclosed waterfront interface of the factory site into an ecological link and public life carrier connecting the city and the island through ecological retrofitting of the waterfront shoreline and urban sharing of stormwater public spaces, reconstructing the organic connection between the site and the surrounding hydrological system.

In the infrastructure dimension, the scheme constructs a hierarchical stormwater management system of "source control – conveyance in process – end-of-pipe detention and storage." At the source level, runoff reduction is achieved through roof rainwater harvesting and green roofs. At the conveyance level, runoff transport and preliminary purification are accomplished via ecological swales and bioswale systems. At the end-of-pipe level, old sedimentation tanks are retrofitted into multifunctional detention wetlands, forming a closed-loop hydrological regulation system throughout the entire process.

In the site landscape dimension, the scheme combines rain gardens, bioretention landscapes, permeable pavements, and visualized drainage design, transforming the formerly concealed underground drainage process into a visible, perceptible, and participatory landscape experience, thereby infusing the site with a water-driven genius loci and public vitality.

In the building utilization dimension, the scheme establishes a building renewal classification system, formulating differentiated stormwater collection and reuse strategies for buildings of different protection grades. Through open ground floors and water-interactive retrofitting of waterfront buildings, it achieves positive interaction between architectural space and the water environment, transforming hydraulic heritage from forgotten industrial remains into an ecological driver of building revitalization.

At the performance verification level, the study quantitatively evaluates the scheme across three scales: planning, site, and building. The results demonstrate that the scheme effectively reduces the annual total runoff volume of the site and significantly lowers non-point source pollution loads, while simultaneously transforming stormwater management facilities into landscape nodes that combine ecological demonstration with public participation functions, achieving synchronized improvements in hydrological regulation performance and spatial experience quality.

5. The stormwater management-oriented design achieves a trinity synergy of hydrological processes, heritage memory, and public life.

The study ultimately demonstrates that the value of stormwater management strategies in the public space renewal of waterfront industrial heritage lies not only in runoff regulation and pollution reduction at the engineering level but also in their unique potential as a medium of spatial narrative. By transforming the concealed stormwater runoff process into a visible, perceptible, and participatory landscape experience, stormwater management facilities become narrative carriers connecting natural processes and human memory. In the Zini Sugar Factory scheme, rain gardens carry the historical imagery of the sugar production workshop's

cooling ponds, ecological swales continue the linear fabric of the factory's open drainage channels, and multifunctional wetlands respond to the morphological logic of the industrial sedimentation tanks—hydrological processes and heritage memory are interwoven here, ecological functions and public activities coexist here. This pathway infuses waterfront industrial heritage sites with public vitality that possesses both ecological resilience and cultural depth, while also providing a replicable design paradigm for the sustainable renewal of similar sites.

Innovations of this study are mainly reflected in the following three aspects.

1. Perspective innovation: Elevates stormwater management from an engineering and technical dimension to a spatial design dimension, using WSUD and Sponge City concepts as theoretical bridges to establish an interdisciplinary dialogue framework between stormwater management and industrial heritage public space design.

2. Methodological innovation: Constructs a dual-track working framework consisting of a "design analysis matrix + stormwater management performance calculation," providing an operational technical pathway for quantitative assessment and design feedback of stormwater management strategies in waterfront industrial heritage renewal.

3. Practical innovation: Takes the Zini Sugar Factory as an empirical case to propose an integrated design strategy across four dimensions—urban connectivity, infrastructure, site landscape, and building utilization—validating the feasibility of stormwater management as a driving force for the adaptive reuse of industrial heritage.

Limitations of this study and directions for future research are as follows:

1. This study takes the Zini Sugar Factory as a single in-depth empirical case. The generalizability of its conclusions requires cross-comparison and validation with more types of waterfront industrial heritage sites under different protection grades and different hydrological conditions.

2. Due to research constraints, the hydrological performance assessment of the scheme is primarily based on theoretical calculations and empirical parameter simulations, without long-term field monitoring. Future research may combine actual operational data from stormwater management facilities to dynamically optimize and calibrate the design strategies.

3. This study focuses primarily on strategy development at the spatial design level, with limited discussion of the construction costs, maintenance mechanisms, and operational management models of stormwater management facilities. Future research may introduce techno-economic analysis and governance mechanism perspectives to refine a life-cycle

assessment framework for integrating stormwater management into industrial heritage renewal.

Bibliography

- [1] 张玉鹏.国外雨水管理理念与实践[J].国际城市规划,2015,30(S1):89-93.
- [2] 廖朝轩,高爱国,黄恩浩.国外雨水管理对我国海绵城市建设的启示[J].水资源保护,2016,32(01):42-45+50.
- [3] 宋代风.可持续雨水管理导向下住区设计程序与做法研究[D].浙江大学,2012.
- [4] 仇保兴.海绵城市(LID)的内涵、途径与展望[J].给水排水,2015,41(3):1-7.
- [5] 张善峰,宋绍杭,王剑云.低影响开发——城市雨水问题解决的景观学方法[J].华中建筑,2012(5):83-88.
- [6] 冯娴慧,王琳婷,叶劲枫.华南湿热多雨地区城市绿地雨水管理设计研究——以深圳前海自贸区门户公园设计为例[J].南方建筑,2021(6):124-131.
- [7] 关鹏祥,李俊奇,李嘉伟,等.加拿大雨水管理保障措施与典型城市雨水排放费制度研究[J].水利水电技术,2019,50(5):10-19.
- [8] 车生泉,谢长坤,陈丹,等.海绵城市理论与技术发展沿革及构建途径[J].中国园林,2015(6):11-15.
- [9] 邓理璇.基于水敏性城市设计的广州水系空间规划研究[D].华南理工大学,2021.DOI:10.27151/d.cnki.ghnlu.2021.004675.
- [10] Government of South Australia. Stormwater Strategy - the Future of Stormwater Management [Z]. 2011.
- [11] 高洋.水敏性城市设计在我国的应用研究[D].哈尔滨工业大学,2012.
- [12] 夏镜朗,崔浩.澳大利亚水敏性城市设计经验对我国海绵城市建设的启示[J].中国市政工程,2016,(04):36-40+101-102.
- [13] BROWN R R, KEATH N, WONG T H F. Urban water management in cities: historical, current and future regimes[J]. Water Science and Technology, 2009, 59(5): 847-855.
- [14] 谭芳.基于海绵城市理念的水敏性停车场设计研究[D].大连理工大学,2017.
- [15] 孙淼,李振宇.基于城市群视角的工业遗存更新模式研究——以美国东北部城市群为例[J].国际城市规划,2021,36(02):91-99.DOI:10.19830/j.upi.2020.091.
- [16] SIGMAN H. Environmental liability and redevelopment of old industrial land[J]. The Journal of Law and Economics, 2010, 53(2): 289-306.
- [17] CURULLI I. The making and remaking of dismissed industrial sites[M]. Firenze: Alinea International, 2014.
- [18] 李骏飞,杨磊三,孟凡松.粤港澳大湾区面临的水问题探析[J].中国给水排水,2019,35(18):10-14.DOI:10.19853/j.zgjsps.1000-4602.2019.18.003.
- [19] 陈翠容.粤港澳大湾区工业遗产价值评估、适应性保护与再利用研究[D].广东工业大学,2022. DOI:10.27029/d.cnki.ggdgu.2022.002200.
- [20] 刘锐,邓理璇.水敏性城市设计及其在水网型城市中的应用[C]//中国城市规划学会,重

- 庆市人民政府.活力城乡 美好人居——2019中国城市规划年会论文集(07城市设计). 华南理工大学建筑学院; 2019: 1765-1776. DOI:10.26914/c.cnkihy.2019.018551.
- [21]LLOYD S D, WONG T H F, CHESTERFIELD C J. Water Sensitive Urban Design: A Stormwater Management Perspective[R]. Melbourne: Cooperative Research Centre for Catchment Hydrology, 2002.
- [22]赵宏宇,高洋,王耀武.山地水敏性城市设计——基于“城市、建筑、景观”三位一体理论的城市设计新思维[J].规划师,2013,29(04):86-91.
- [23]杨波.水敏性城市河道湿地公园景观规划设计策略研究[D].西安建筑科技大学,2015.
- [24]蔡凯臻,王建国.城市设计与城市水文管理的整合:澳大利亚水敏性城市设计[J].建筑与文化, 2008 (07): 96-99.
- [25]卢扬煦.基于水敏性视角的山地公园景观规划设计研究[D].重庆大学,2016.
- [26]袁嘉,向羚丰,李祖慧,等.基于水敏性设计的城市滨水空间既有建筑改造——以重庆汉丰湖宣教中心为例[J].新建筑,2022,(01):43-48.
- [27]俞孔坚,李迪华,袁弘,等.“海绵城市”理论与实践[J].城市规划, 2015, 39(6): 26-36.
- [28]仇保兴.海绵城市(LID)的内涵、途径与展望[J].给水排水, 2015, 41(3): 1-7.
- [29]郭恩章.高质量城市公共空间的设计对策[J].建筑学报,1998,(03):10-12+65.
- [30]吕红.城市公共空间的人性化设计[D].天津大学,2004.
- [31]Wong T H F. Water sensitive urban design - the journey thus far[J]. Australian Journal of Water Resources, 2006, 10(3): 213-222.
- [32]刘颂,李春晖.澳大利亚水敏性城市转型历程及其启示[J].风景园林,2016,(06):104-111. DOI:10.14085/j.fjyl.2016.06.0104.08.
- [33]TICCIH. The Nizhny Tagil Charter for the Industrial Heritage[Z]. Paris: TICCIH, 2003.
- [34]王建强,戎俊强.城市产业类历史建筑及地段的改造再利用[J].世界建筑,2001,(06):17-22.DOI:10.16414/j.wa.2001.06.001.
- [35]董一平,侯斌超.工业遗存的“遗产化过程”思考[J].新建筑,2014,(04):40-44.
- [36]RIX M. Industrial Archaeology[M]. London: The Historical Association, 1955.
- [37]张永和. 非常建筑[M]. 北京: 中国建筑工业出版社, 2002.
- [38]庄少庞,高坤铎,王静,等.滨水工业遗存的都市性重构与地方性塑造——东莞鳧鱼洲更新方法摘要[J].南方建筑,2021,(05):30-37.
- [39]蔡江宇.“粤港澳大湾区”工业文化遗产的活化再利用及存在问题[J].美术观察,2018,(05):25-26.
- [40]马荣军.日常性城市遗产概念辨析[J].华中建筑,2015,33(01):27-31. DOI:10.13942/j.cnki.hzjz.2015.01.006.
- [41]王建国,蒋楠.后工业时代中国产业类历史建筑遗产保护性再利用[J].建筑学报,2006,(08):8-11.

- [42]杨洵.城市更新中工业遗存再利用研究[D].重庆大学,2009.
- [43]张弘.广州中心城区滨水旧工业区更新研究[D].华南理工大学,2019.
DOI:10.27151/d.cnki.ghnlu.2019.003083.
- [44]徐本营.大尺度滨江公共空间营造的启示——以上海和广州滨江公共空间贯通工程为例[J].城市,2018,(10):13-18.
- [45]广州市人民政府关于印发国家历史文化名城广州历史文化名城保护规划(2021—2035年)的通知[J].广州市人民政府公报,2025,(25):1-104.
- [46]广州市规划和自然资源局.广州市历史建筑名单[Z].2014-2019.
- [47]叶青,唐魁,郭永聪.既有城市工业区更新改造模式探析[J].南方建筑,2020,(05):1-7.
- [48]住房和城乡建设部印发:《海绵城市建设技术指南——低影响开发雨水系统构建》[J].建设科技,2015,(01):10.DOI:10.16116/j.cnki.jskj.2015.01.002.
- [49]廖镜彪,王雪梅,李玉欣,等.城市化对广州降水的影响分析[J].气象科学,2011,31(04):384-390.
- [50] SOMERVILLE C, COHEN M, PANTANELLA E, et al. Small-scale aquaponic food production Integrated fish and plant farming [M]. Rome: Food and Agriculture Organization of the United Nations, 2014.
- [51]杨清富,郑安秀.鱼菜共生系统原理与方法[M].中国台湾:行政院农业委员会“台南区农业改良场”,2017.
- [52]王鹏,吉露·劳森,刘滨谊.水敏性城市设计(WSUD)策略及其在景观项目中的应用[J].中国园林,2010(6):88-91.
- [53]陈嵩.雨水花园设计及技术应用研究[D].北京林业大学,2014.
- [54]罗红梅,车伍,李俊奇,等.雨水花园在雨洪控制与利用中的应用[J].中国给水排水,2008,24(06):48-52.
- [55]刘焘玮.基于雨水管理视角的LID与WSUD对比研究[J].建筑与文化,2021,(01):93-96.
DOI:10.19875/j.cnki.jzywh.2021.01.029.
- [56]董淑秋,韩志刚.基于“生态海绵城市”构建的雨水利用规划研究[J].城市发展研究,2011,18(12):37-41.
- [57]张伟,车伍,王建龙,等.利用绿色基础设施控制城市雨水径流[J].中国给水排水,2011,27(04):22-27.DOI:10.19853/j.zgjsps.1000-4602.2011.04.008.
- [58]沈洁,龙若愚,陈静.美国LEED-ND/SITES/LPS雨水管理评价标准对中国海绵城市绩效评价的启示[J].风景园林,2019,26(03):81-86. DOI:10.14085/j.fjyl.2019.03.0081.06.
- [59]汪洋,王健,王超阳.日本的雨水管理及其应用设施[J].现代园艺,2019(20):194-196.
- [60]住房和城乡建设部《海绵城市建设技术指南(试行)》(摘要)——低影响开发雨水系统构建[J].建筑砌块与砌块建筑,2015,(01):45-50.

- [61]汤强,陈以乐,郑亮,等.乡村振兴背景下广府工业建筑遗产的更新与转型策略研究——以广州番禺紫泥堂艺术小镇为例[J].华中建筑,2022,40(10):123-127. DOI:10.13942/j.cnki.hzjz.2022.10.034.
- [62]肖桂来. 每日供水 76 万吨可供七成番禺居民[N]. 广州日报, 2019-03-29.
- [63]广州市文化金融服务中心. 终于来了! 广州文化和旅游产业风投小镇闪亮登场~[EB/OL].(2019-11-19). <http://www.gzwhjr.com/news-list.php?tab=mynews&VID=237>.
- [64]黄卓鹏, 何洋. “电影名家看广东”活动走进番禺, 导演共话产业新机遇[EB/OL]. 新浪网, (2026-01-13)[2026-04-12]. https://k.sina.cn/article_2208273904_839f95f002001pd3g.html.

攻读硕士学位期间取得的研究成果

一、已发表（包括已接受待发表）的论文，以及已投稿、或已成文打算投稿、或拟成文投稿的论文情况（只填写与学位论文内容相关的部分）：

序号	作者（全体作者，按顺序排列）	题 目	发表或投稿刊物名称、级别	发表的卷期、年月、页码	与学位论文哪一部分（章、节）相关	被索引收录情况

注：在“发表的卷期、年月、页码”栏：

- 1 如果论文已发表，请填写发表的卷期、年月、页码；
- 2 如果论文已被接受，填写将要发表的卷期、年月；
- 3 以上都不是，请据实填写“已投稿”，“拟投稿”。

不够请另加页。

二、与学位内容相关的其它成果（包括专利、著作、获奖项目等）

致 谢

行文至此，百感交集。回首研究生阶段，从选题迷茫到论文成稿，离不开师长、家人与朋友的鼎力支持。

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四、答辩委员会决议书

答辩委员会对学位（毕业）论文的评语（主要内容包括：1. 论文选题与综述；2. 学术水平与创新性；3. 论文综合能力表现；4. 学位（毕业）论文答辩情况；5. 存在的不足之处和建议等） 论文选题具有一定价值，研究方法较严谨，论证逻辑清晰，研究工作量充分，结论合理。论文撰写认真，较好掌握研究设计方法。 研究以雨水管理为核心视角，引入了水敏性城市设计与海绵城市理念作为理论工具，探索了雨水基础设施与工业遗产公共空间一体化设计的融合路径。研究根据“场地水文诊断—遗产价值评估—设计策略生成—绩效量化反馈”的技术路线，借助绿色基础设施的设计实践方法，提出以雨水管理为切入点的公共空间更新方案。 答辩过程中，汇报流畅清楚，对于答辩委员提出的全部问题能详细回应，达到建筑学硕士学位论文要求。 根据投票结果，答辩委员会一致同意吴逸姗通过硕士学位论文答辩，同意其毕业，并建议授予建筑学硕士学位。	
论文答辩日期：2026 年 5 月 21 日 答辩委员会委员 5 人 毕业表决票数：通过（5）票；不通过（0）票 学位表决票数：通过（5）票；不通过（0）票 答辩委员会决议（打“√”）： 毕业：通过（√）；不通过（ ） 学位：通过（√）；不通过（ ）	
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