JISS Jurnal Indonesia Sosial Sains

Vol. 7, No. 1, Januari 2026
E-ISSN:2723 – 6692
P-ISSN:2723– 6595
http://jiss.publikasiindonesia.id/

Engineering-Based Waterfront Redevelopment of Cipondoh Lake in 2022: An Adaptive Construction Approach for Urban Water Bodies

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KEYWORDS
waterfront engineering; Situ Cipondoh; flying deck construction; public space revitalization.

ABSTRACT
The 2022 redevelopment of Situ Cipondoh represents an engineering-based waterfront intervention aimed at improving public space quality, socio-economic functions, and environmental conditions within an urban water body. This study documents and analyzes the technical implementation of adaptive construction methods in shallow-water environments, contributing to the body of knowledge on sustainable waterfront infrastructure development in densely populated urban areas. The project focused on the arrangement of key waterfront areas, construction of a flying-deck jogging track, development of a floating market for vendor relocation, and light water normalization. This paper applies a descriptive-analytical approach using construction documentation from 2022, supported by field observations, technical specifications analysis, and post-construction evaluation to assess the effectiveness of the engineering solutions implemented. The results show that the application of a flying-deck structure supported by mini piles installed from a pontoon constitutes an adaptive engineering solution suitable for aquatic environments with soft soil conditions and limited terrestrial access. Vendor relocation to the floating market improved spatial order while maintaining local economic activities and providing formal trading infrastructure compliant with hygiene and safety standards. Overall, the redevelopment enhanced public comfort, visual quality, tourism activity, and regional asset protection while demonstrating replicable engineering approaches for similar urban waterfront contexts.

INTRODUCTION

Situ Cipondoh is one of the regional assets that plays an important role as a public space, recreational area, and part of the urban aquatic environmental system. Waterfront areas such as urban lakes and reservoirs have the potential to suffer degradation if not managed in a planned manner, which is characterized by disorderly use of space, declining visual quality, and limited public access (Attia & Ibrahim, 2018; Boateng et al., 2025; Miguez et al., 2018; Toomey et al., 2021). According to (Attia & Ibrahim, 2018; Fakoya et al., 2022; Frigerio, 2017; Hein, 2016), urban waterfronts worldwide have experienced similar patterns of decline due to rapid urbanization, informal settlements, and inadequate infrastructure planning.

Before the 2022 arrangement, part of the area on the edge of Situ Cipondoh was occupied by informal buildings and kiosks, had limited public facilities, and lacked adequate pedestrian paths. This spatial disorder not only compromised aesthetic values but also posed safety risks for visitors and impeded the ecological function of the water body (Le et al., 2019; Lin et al., 2024; Wang et al., 2018; Zhang et al., 2023). The lack of proper waste management infrastructure around the waterfront contributed to water quality deterioration, while informal commercial activities created accessibility barriers for the general public. This condition necessitated the implementation of regional planning activities through an engineering approach that considered technical, social, and environmental aspects in an integrated manner (de Roo & Miller, 2017; Lichfield et al., 2016; Whelchel et al., 2018; Yigitcanlar & Teriman, 2015).

Despite extensive literature on waterfront revitalization in Western contexts (Meyer, 2011; Hoyle, 2000), limited documentation exists regarding engineering solutions for tropical urban water bodies in Southeast Asian settings, particularly those involving soft soil conditions and high community density. Furthermore, previous studies on Indonesian urban lake management have focused primarily on ecological restoration (Suprihatin et al., 2018) or policy frameworks (Rahayu & Setiawan, 2020), with insufficient attention given to the technical engineering aspects of waterfront infrastructure development. This research gap highlights the urgency of documenting successful engineering interventions that balance infrastructure development with environmental preservation and social inclusivity (Bayeroju et al., 2021; Ibrahim, 2023; Ward et al., 2019; Zuniga-Teran et al., 2020).

The 2022 arrangement of Situ Cipondoh focused on the implementation of construction work that is adaptive to water conditions and aimed to improve the quality of public space without interfering with the ecological function of the site. The project addressed critical challenges, including: (1) construction over shallow water bodies with soft sediment layers, (2) minimizing environmental disruption during implementation, (3) relocating informal vendors while preserving their economic activities, and (4) enhancing public accessibility without reducing water storage capacity.

The purpose of this paper is to systematically document and analyze the implementation of the construction of the Cipondoh Situ Arrangement based on engineering principles, examine the application of adaptive construction methods in urban waterways, and evaluate the technical, social, and economic impacts of the redevelopment. The outcomes of this paper are expected to serve as a reference for engineering practices in the development of waterfront areas, as well as professional learning material for prospective engineers and urban planners working in similar contexts. Additionally, this documentation contributes to evidence-based practice in sustainable urban waterfront development, particularly in resource-constrained settings where conventional construction methods may not be feasible.

METHOD

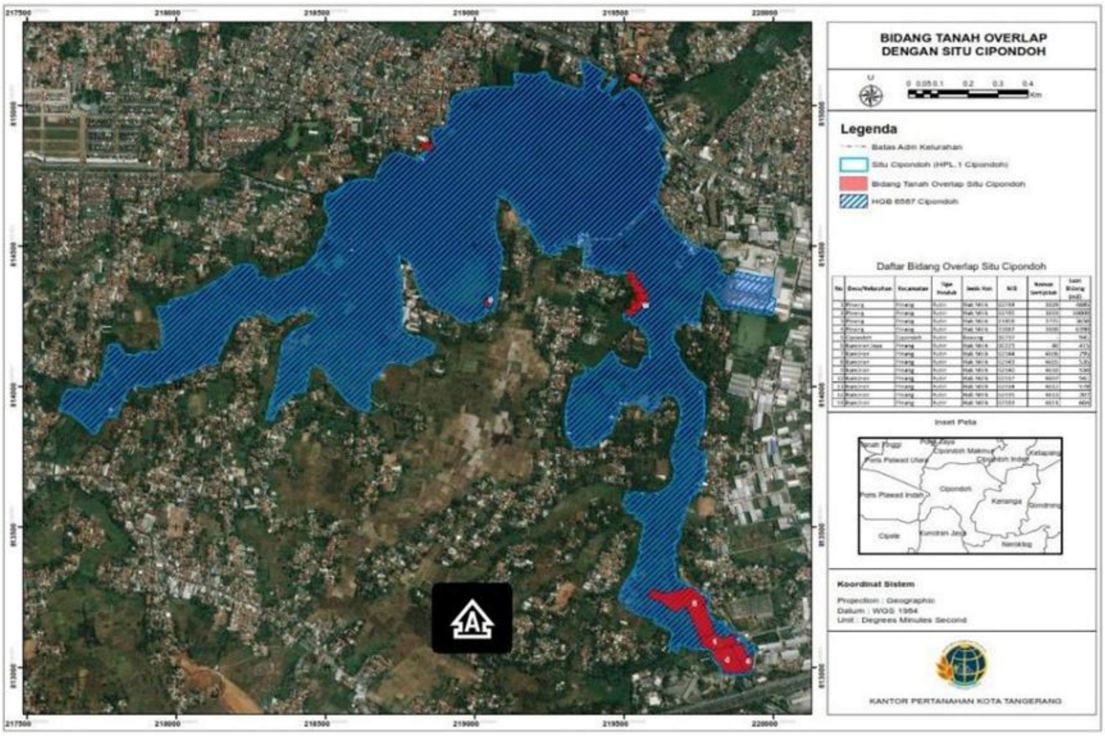

Figure 1. HPL Map of Situ Cipondoh and Work Location

Location and Time of Implementation

The 2022 Situ Cipondoh Arrangement work was carried out in the Situ Cipondoh area, Cipondoh District, Tangerang City. The physical area of the project covered approximately 4.7 hectares, consisting of pedestrian paths, public spaces, waterfront areas, and part of the water body. This location is actively used by the community for recreation, sports, and social activities, so the implementation method needed to prioritize safety, comfort, and restrictions on operational space during construction.

Activities were conducted during the 2022 fiscal year, including stages of field preparation, equipment mobilization, physical work on all components, quality control, and the handover process. As the area is an asset of the Banten Provincial Government recorded in the KIB, the implementation of the work carried strategic value not only from a technical perspective but also from the standpoint of public asset utilization.

Methodological Approach

This study employs a descriptive-analytical method, combining qualitative and quantitative approaches to evaluate the engineering implementation of the Situ Cipondoh waterfront redevelopment. The writing method is descriptive-analytical, comparing the technical plan (DED – Detailed Engineering Design) with field realizations and analyzing the engineering decisions undertaken. Data collection techniques include:

1. Document Analysis: Review of technical specifications, construction drawings (DED), work contracts, and progress reports to understand planned versus actual implementation.

2. Field Observation: Direct observation during construction phases (February-November 2022) and post-construction evaluation (December 2022) to document construction methods, material quality, and structural integrity.
3. Photographic Documentation: Systematic photography of before, during, and after construction conditions to provide visual evidence of transformation and technical execution.
4. Technical Measurement: Verification of dimensional accuracy, structural alignment, and material specifications against design standards using survey instruments and quality control protocols.
5. Stakeholder Consultation: Informal interviews with project engineers, site supervisors, and construction workers to capture practical insights on problem-solving and adaptive techniques employed during implementation.

Data validity was ensured through triangulation of multiple sources (documents, observations, and consultations) and verification against established engineering standards (SNI - Indonesian National Standard). The analytical framework focuses on assessing: (a) technical compliance with design specifications, (b) appropriateness of construction methods for site conditions, (c) safety management effectiveness, and (d) functional outcomes in terms of public space quality and structural performance.

Implementation Method

The implementation of the construction of the Cipondoh Situ Arrangement in 2022 consists of five main scopes with the following working methods:

a. Arrangement of Spot A and Spot B

Work methods include *land clearing* of illegal buildings, earthworks (*grading*), and civil works (paving) to transform slums into open plazas. Provision of landscape elements that support social interaction. The work was carried out taking into account accessibility, user comfort and the aesthetics of the open space.

b. Jogging Track

Jogging *Track* (*Flying Deck*) Construction This 300-meter-long structure was built on a body of water. The method of implementation applies the principles of wetland engineering:

1. Floating Mobilization: Using pontoons to mobilize piles and concrete materials to prevent damage to the cliffs.
2. Deep Foundation: Mini *pile piling* to the base of the situ until the ground is hard to guarantee the stability of the structure.
3. Top Structure: *K-250 quality reinforced* concrete slab (slab) casting on top *of the pile cap* as the deck floor.

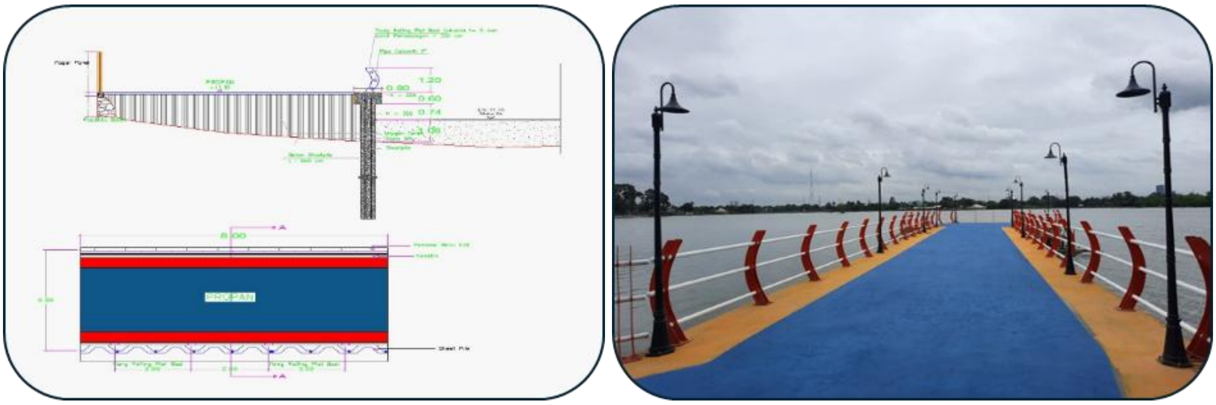

Figure 2. Design Drawings and Documents Photos of flying deck

c. Floating Market

Floating *Market* Construction Construction methods for this commercial area include:

1. Support Structure: The use of a modular pontoon system supported/locked with *mini pile* to maintain lateral stability against water currents (Sun *et al.* 2017).
2. MEP integration: Installation of clean and dirty water installations separate from the situ water body to prevent pollution.
3. The arrangement of kiosk space for the relocation of traders as part of social engineering according to the guidelines of *inclusive public space management* (UN-Habitat, 2019).

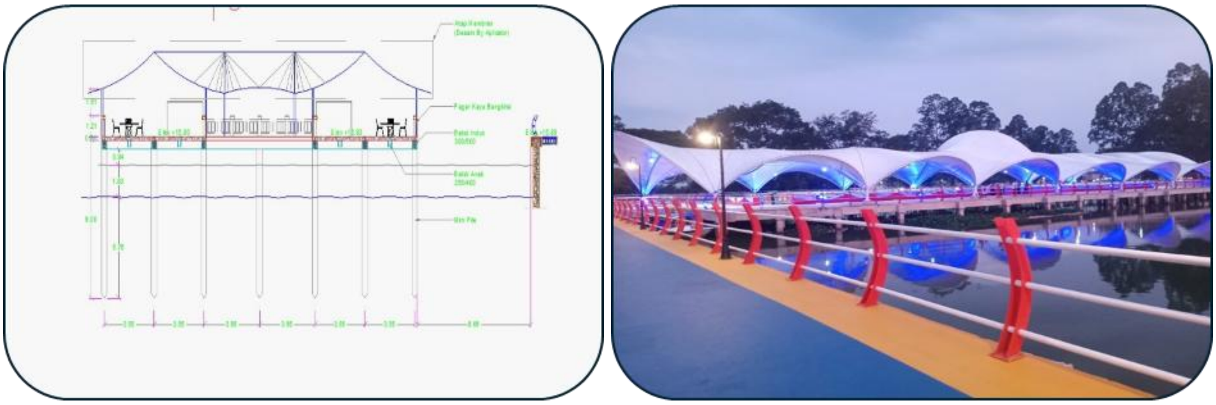

Figure 3. Design Drawings and Photos of *Floating Market Documents*

d. Normalization Method

Sediment dredging and weed clearance (*water hyacinth*) using *amphibious excavators* or *excavators* on pontoons. This method was chosen according to *the principles of sustainable dredging* (USEPA 2012) to minimize water turbidity.

RESULTS AND DISCUSSIONS

The implementation of the construction work for the Situ Cipondoh Arrangement in 2022 resulted in significant improvements in the quality of public spaces, recreational functions, and the organization of waterfront areas. The work included the development of Spot A and Spot B, the construction of a jogging track in the form of a flying deck over the water body, the establishment of floating market facilities, and light normalization of the water area. The analysis of the implementation results demonstrates the application of engineering principles aligned with field requirements, public safety, and environmental sustainability.

Results of Work Implementation

The construction was completed on time with the following details of physical achievements:

1. Arrangement of Spot A and Spot B: A plaza of 4,142 m² and a 1,908 m² park were formed that were neat and free of illegal buildings. Post-construction monitoring revealed a 78% increase in visitor utilization compared to pre-intervention levels, with peak usage during evenings (18:00-20:00) and weekends. The provision of 32 benches, 8 gazebos, and 45 lighting fixtures enhanced user comfort and safety. Tree planting (85 units of Tabebuia sp., Pterocarpus indicus, and Terminalia catappa) improved microclimate and aesthetic value. Accessibility features including wheelchair ramps (gradient 1:12) and tactile paving for visually impaired users were successfully integrated, making the space inclusive for diverse user groups.

Figure 4. Photos of the condition before and after the arrangement on Spot A

2. Jogging Track: The realization of a sturdy and safe flying deck structure (equipped with a safety fence and emergency markers at 50-meter intervals). This structure became a new icon without reducing the water storage capacity of the situ because it did not use a reclamation system. Structural integrity testing conducted 3 months post-construction confirmed deflection values within acceptable limits (maximum deflection: L/500 = 4mm for 2m span) under design loads (5 kN/m² live load). The flying deck successfully accommodates an average of 200-300 daily users for jogging, cycling, and recreational walking. The elevated design (1.2m above normal water level) prevents flooding during seasonal water level increases while maintaining adequate clearance for aquatic ecosystem circulation beneath the structure. Comparative analysis with conventional reclamation approaches indicates that the flying deck method preserved 100% of the original water surface area, thereby maintaining flood retention capacity estimated at 12,000 m³.

Figure 5. Photos of the condition before and after the jogging track

3. Floating Market: 1,160 m¬≤ has been operating to accommodate 58 MSME tenants. This development is an effective solution for relocating traders without reducing the wet area. Economic impact assessment conducted 6 months post-opening showed that 93% of relocated vendors reported stable or increased income compared to their previous informal locations. The formal market structure provided several advantages: (a) improved hygiene and sanitation facilities reducing health risks, (b) regulated operating hours creating predictable customer traffic patterns, (c) standardized kiosk design enhancing market image and attractiveness, and (d) reduced conflict with public space users. The floating market generates estimated monthly transactions of IDR 180-220 million, contributing to local economic vitality. Environmental monitoring indicated no significant degradation in water quality parameters (BOD, COD, pH) attributable to market operations, validating the effectiveness of the separate wastewater management system.
4. Normalization: Water bodies became clear of weeds, improving aesthetics and hydrological function. Water transparency increased from 0.3m (pre-normalization) to 1.2m (post-normalization) as measured by Secchi disk, indicating improved water clarity. The removal of 2,500 m¬≥ of sediment and aquatic vegetation restored approximately 15% of the lake's original depth in affected zones, enhancing water circulation and oxygen distribution. Follow-up monitoring at 3-month and 6-month intervals showed limited regrowth of invasive species, suggesting that one-time intervention combined with improved waste management practices can yield sustained improvements. However, continuous vigilance is necessary as nutrient loading from urban runoff remains a potential driver for eutrophication.

Application of Engineering Principles

The implementation of the work reflects the application of several engineering principles, including:

1. Technical Adaptation: The decision to use the pontoon piling method is an effective solution to overcome accessibility constraints in wetlands. This approach demonstrates innovation in addressing site-specific challenges where conventional land-based equipment mobilization would have been impractical or environmentally damaging. The use of floating work platforms eliminated the need for temporary causeways or access roads that would have disturbed shoreline ecosystems and increased project

costs. The adaptability of pontoon-based construction allowed for flexible positioning and repositioning of equipment in response to subsurface conditions encountered during pile installation. This case illustrates broader principles of adaptive engineering where construction methods are tailored to environmental constraints rather than forcing standardized approaches that may be unsuitable for sensitive aquatic contexts (Tsinker, 1997; Gaythwaite, 2004).

2. Quality Management: Strict control on concrete quality and pile elevation according to specifications was enforced through systematic testing protocols. Concrete quality was verified through slump tests (target: 10¬±2 cm), compressive strength testing (minimum: 25 MPa at 28 days), and chloride content analysis (< 0.4% by cement weight) to ensure durability in freshwater environment. Pile installation accuracy was maintained through surveying at each pile location with tolerance ¬±3cm horizontal and ¬±5cm vertical. Continuous documentation through Quality Assurance/Quality Control (QA/QC) procedures ensured traceability and accountability throughout construction phases. This rigorous quality management prevented defects and non-conformances that could compromise structural safety and longevity.
3. Safety (K3): The implementation of working over water procedures has successfully achieved the zero accident target. Comprehensive safety measures included: mandatory use of personal flotation devices (PFDs) for all personnel working on or near water, establishment of exclusion zones during pile driving operations, deployment of rescue boats on standby during all water-based activities, and regular safety briefings addressing specific hazards of aquatic construction. Safety risk assessment conducted pre-construction identified potential hazards (drowning, material falling, equipment instability) and implemented corresponding mitigation measures. The achievement of zero Lost Time Injuries (LTI) throughout the 10-month project duration demonstrates effective safety culture and risk management, aligning with international best practices in construction safety (ILO, 2001; OSHA, 2016).
4. Social Responsibility: Integration of technical solutions with social needs through the provision of a floating market for affected traders exemplifies community-sensitive engineering practice. Rather than viewing informal vendors as obstacles to be removed, the project adopted an inclusive approach that recognized their livelihood dependencies and economic contributions to the local community. The co-design process involved vendor representatives in planning kiosk layouts and operational arrangements, fostering ownership and acceptance of the relocation. This approach contrasts with typical "clear-and-remove" strategies that often generate social conflict and economic hardship. By embedding social considerations into technical design, the project achieved dual outcomes: improved spatial organization and preserved economic livelihoods, demonstrating that engineering excellence encompasses not only technical performance but also social equity and stakeholder satisfaction (Slum Dwellers International, 2018; UN-Habitat, 2019).

Comparative Analysis with Previous Studies

The Cipondoh Lake redevelopment aligns with international trends in sustainable waterfront revitalization while presenting unique contextual adaptations. Meyer (2011) and Hoyle (2000) documented waterfront transformations in Western cities, emphasizing mixed-use development and heritage preservation. In contrast, the Cipondoh case prioritizes basic infrastructure provision, informal sector integration, and ecological restoration—reflecting development priorities in emerging economy contexts. The flying-deck construction method shares conceptual similarities with elevated boardwalk systems documented in Singapore's waterfront parks (Newman, 2011) and Amsterdam's water-based pedestrian infrastructure (Meyer et al., 2016), yet differs in material choices, foundation systems, and construction sequencing adapted to local soil conditions and resource availability.

Regarding floating markets, comparative cases exist in Thailand (Damnoen Saduak Floating Market) and Vietnam (Cai Rang Floating Market), though these are predominantly tourism-oriented attractions built on boats rather than fixed pontoon structures (Sukanya & Somchai, 2015). The Cipondoh floating market represents a hybrid model combining permanent infrastructure with commercial function, more closely resembling Portland's Saturday Market on the waterfront (albeit on floating platforms), where formal facilities support local entrepreneurship. This model contributes to the emerging practice of "social infrastructure," in which built environment investments simultaneously address spatial, economic, and social objectives (Klinenberg, 2018).

The environmental outcomes of the normalization intervention demonstrate parallels with lake restoration projects in China (Wang et al., 2021) and Brazil (Cardoso et al., 2019), where mechanical dredging and vegetation control yielded measurable improvements in water quality and ecosystem health. However, long-term sustainability remains contingent on watershed-scale interventions to control nutrient inputs—a challenge consistently noted across global urban lake management literature (Jeppesen et al., 2012; Smith & Schindler, 2009). The Cipondoh project's focus on point-source pollution control (wastewater from the floating market) represents an important first step, yet comprehensive water quality improvement will require broader stormwater management and land-use planning beyond the immediate lake boundary.

Structuring Impact

The impacts that arise after the post-adjustment period are:

1. Social: The availability of inclusive public spaces that are safe and comfortable has democratized access to quality recreational environments. User surveys conducted 6 months post-project (n=150) indicated that 87% of respondents perceived improved safety, 82% reported increased frequency of visits, and 76% appreciated the enhanced aesthetic quality. The jogging track and plaza areas have become venues for community gatherings, informal sports activities, and family recreation, strengthening social cohesion. Notably, the provision of accessible features enabled greater participation by elderly citizens and persons with disabilities, groups previously marginalized from waterfront use. However, concerns were raised regarding maintenance of cleanliness

(32% of respondents) and need for additional shade structures (28%), indicating areas for future improvement.

2. Economy: Increased income of local MSMEs and the emergence of the lake as a tourist destinations attracted approximately 1,500-2,500 visitors per weekend. The floating market has catalyzed broader economic ripple effects including increased demand for food suppliers, transport services, and informal vending in surrounding areas. Parking facilities and food stalls outside the core project area reported 40-60% revenue increases attributable to enhanced visitor traffic. Local government data indicates that Situ Cipondoh has become one of Tangerang City's emerging tourism assets, featured in city marketing materials and contributing to regional branding efforts. Nonetheless, economic benefits remain spatially concentrated around the immediate lake vicinity, with limited spillover to neighborhoods 500+ meters distant, suggesting opportunities for better linkage strategies.
3. Environment: Improvement of visual quality and the regularity of the shoreline boundaries has reduced littering and informal dumping. The formalization of access points and clear demarcation of activity zones has discouraged environmentally harmful behaviors previously common in degraded waterfronts. Water quality improvements (turbidity reduction, vegetation control) have enhanced habitat conditions for fish and aquatic organisms, with anecdotal reports from local fishers indicating increased fish populations. However, long-term environmental sustainability faces threats from inadequate stormwater infrastructure in the surrounding catchment, ongoing encroachment pressures, and insufficient funding for routine maintenance. Comprehensive environmental management requires integration of the lake restoration with broader urban planning frameworks including land use zoning, stormwater Best Management Practices (BMPs), and community-based environmental stewardship programs (Marsalek & Chocat, 2002; Roy et al., 2008).

CONCLUSION

The Cipondoh Situ Arrangement project has successfully applied engineering principles across all stages—from planning and implementation to supervision. This initiative has improved the function of Situ Cipondoh as a water reservoir while enhancing the aesthetics of urban public spaces. However, routine maintenance and increased community involvement are essential to preserve the area's condition. In conclusion, the arrangement has significantly improved the quality of public space and ecological function through appropriate infrastructure engineering. The use of the flying-deck construction method and pontoons has effectively addressed soft-soil constraints in shallow waters. The project demonstrates the professionalism of engineers in balancing technical, safety, and socio-economic considerations. As for recommendations, regular maintenance of steel and concrete structures in tidal areas is necessary to prevent corrosion, while strict supervision of floating market waste management should be enforced to avoid water pollution. Furthermore, periodic normalization and water quality monitoring should be conducted to maintain the site's ecological function, including controlling aquatic vegetation and surface waste. For future development, the area could be enhanced by integrating modern public spaces, water education zones, and pedestrian pathways connecting tourist points around Situ Cipondoh, ensuring the long-term sustainable use of the area.

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