Invisible Waters in a Sinking City

Exploring Adaptive Strategies for Jakarta Amid Land Subsidence

Delft University of Technology
Faculty of Architecture & the Built Environment

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Farrah Jacobs
5213827

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Farrah Jacobs
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Agnes van der Meij
Nico Tillie
Ruurd Kuijlenburg

Abstract

This research investigates the ongoing land subsidence crisis in Jakarta, revealing it as not merely an environmental issue but a product of deep-rooted social, historical, and infrastructural inequalities. Drawing from theoretical frameworks of speculative urbanism, urban resilience, and environmental justice, the study traces the origins of Jakarta's vulnerability to colonial water systems, unregulated urbanization, and inequitable access to piped water. Through a comprehensive literature review and case study analysis, the paper evaluates current and global strategies, highlighting both top-down interventions and community-led innovations. A key outcome of this research is the development of an architectural design proposal for a resilient coastal community in Muara Baru, integrating local knowledge, decentralized water systems, and nature-based solutions. The study argues that meaningful adaptation must be inclusive, context-sensitive, and grounded in lived experience. Jakarta's future resilience depends not only on technical solutions but also on just governance and community empowerment.

Keywords

land subsidence, flooding, Jakarta, strategies, speculative urbanism, environmental justice, urban resilience

1. Introduction

An abandoned mosque is the face of many news articles as it slowly drowns in the sea. All of them cover the same topic: The capital city of Indonesia, Jakarta, is sinking at an alarming rate. While “sinking” might typically be associated with being submerged by water, Jakarta’s sinking crisis stems primarily from a lack of access to water - clean, piped water systems, to be exact. This lack of access has forced residents and industries to rely heavily on groundwater extraction, which causes land subsidence (Goh, 2019). In recent years, the Indonesian government has responded to the pressures of land subsidence with a bold plan: relocating the national capital to a newly designed city, Nusantara, in East Kalimantan. While this strategy aims to ease Jakarta's burden, it risks leaving the city’s most vulnerable communities behind to face the worsening impacts of subsidence and flooding (Widodo, 2017; Siriwardane-de Zoysa et al., 2021). Unless urgent and coordinated measures are taken, Jakarta’s future remains precarious (Erkens et al., 2015).

This research was conducted within the framework of the graduation studio City of the Future, part of the Architecture track of the Master Architecture, Urbanism and Building Sciences program at TU Delft. While the main goal of the research is to investigate the sinking crisis in Jakarta, it also serves a design-oriented purpose: to inform the development of an architectural project that responds meaningfully to the pressures of land subsidence and flooding. Therefore, this research aims to explore not only which strategies are currently being employed to combat land subsidence in Jakarta but also to evaluate which approaches have proven most effective or warrant more consideration moving forward. It investigates where interventions are most urgently needed and which communities are most at risk or underserved. These insights will help guide the selection of a target group for the design project and support a more equitable and site-specific response to the crisis.

Ultimately, the goal is to understand how Jakarta can adapt to the pressures of land subsidence and flooding - pressures that are not unique to this city alone and are, therefore, relevant to other sinking cities. By drawing lessons from both local and global innovations, this research considers how Jakarta might move toward a more resilient and inclusive urban future.

Figure 1: 2017 - Abandoned Mosque, Masjid Wal Aduna in Muara Baru, Jakarta Utara (Estrin, 2017)

Figure 2: 2024 - Submerged Ruins of Masjid Wal Aduna in Muara Baru, Jakarta Utara (Nugroho, 2024)

1.1. Theoretical framework

This research is grounded in three interrelated theoretical perspectives to frame Jakarta's complex future amid land subsidence: speculative urbanism, urban resilience, and environmental justice. Together, these perspectives provide a foundation for understanding the city's socio-environmental vulnerabilities and for imagining more adaptive, inclusive, and context-sensitive strategies that could inform architectural and urban design interventions.

1.1.1. Speculative urbanism

Fields (2022) describes speculative urbanism as the intersection of real estate speculation and urban development, often leading to social and spatial changes that may displace vulnerable communities. This perspective is essential for examining how speculative forces could reshape Jakarta's neighbourhoods, particularly under the pressures of environmental challenges.

1.1.2. Urban resilience

Urban resilience refers to a city's ability to recover from hardships and return to its normal state, encompassing responses to climate change, natural disasters, and other adversities (Jagannath, 2018). This theory supports the analysis of Jakarta's capacity to adapt to land subsidence and flooding by focusing on strategies for creating resilient urban design solutions.

1.1.3. Environmental justice

Environmental justice focuses on "documenting and understanding the disproportionate and unequal environmental burdens that certain communities face" (Taylor, 2020). This theory allows the study to analyse how Jakarta's most vulnerable communities may be impacted by environmental pressures, ensuring that proposed solutions are inclusive and support community resilience.

1.2. Methodological framework

This research adopts a qualitative, multi-method approach to explore the urban and environmental crisis of land subsidence in Jakarta. The methodology integrates urban, ecological, and social perspectives to inform the development of a contextually grounded architectural proposal. At its foundation is a comprehensive literature review drawing from academic publications, government reports, spatial data, and global case studies. This review supports an understanding of the historical roots, social dynamics, and technical factors that contribute to Jakarta's ongoing sinking.

To better understand the local context and its vulnerabilities, the research incorporates analysis of mapping data, media narratives, and policy documents. These sources help illuminate not only the areas most affected, but also the ways in which different actors define the problem and propose solutions.

To broaden the lens, the study also engages with international case studies of cities facing similar risks related to subsidence and water management. These comparisons serve to identify strategies and frameworks that may be relevant or adaptable to Jakarta's specific conditions.

The methodology is guided by theoretical frameworks including environmental justice, urban resilience, and speculative urbanism. Together, these perspectives position the research as a spatial and social inquiry — one that interrogates not only environmental degradation, but also the political, economic, and cultural systems that shape its impact and the possibilities for response.

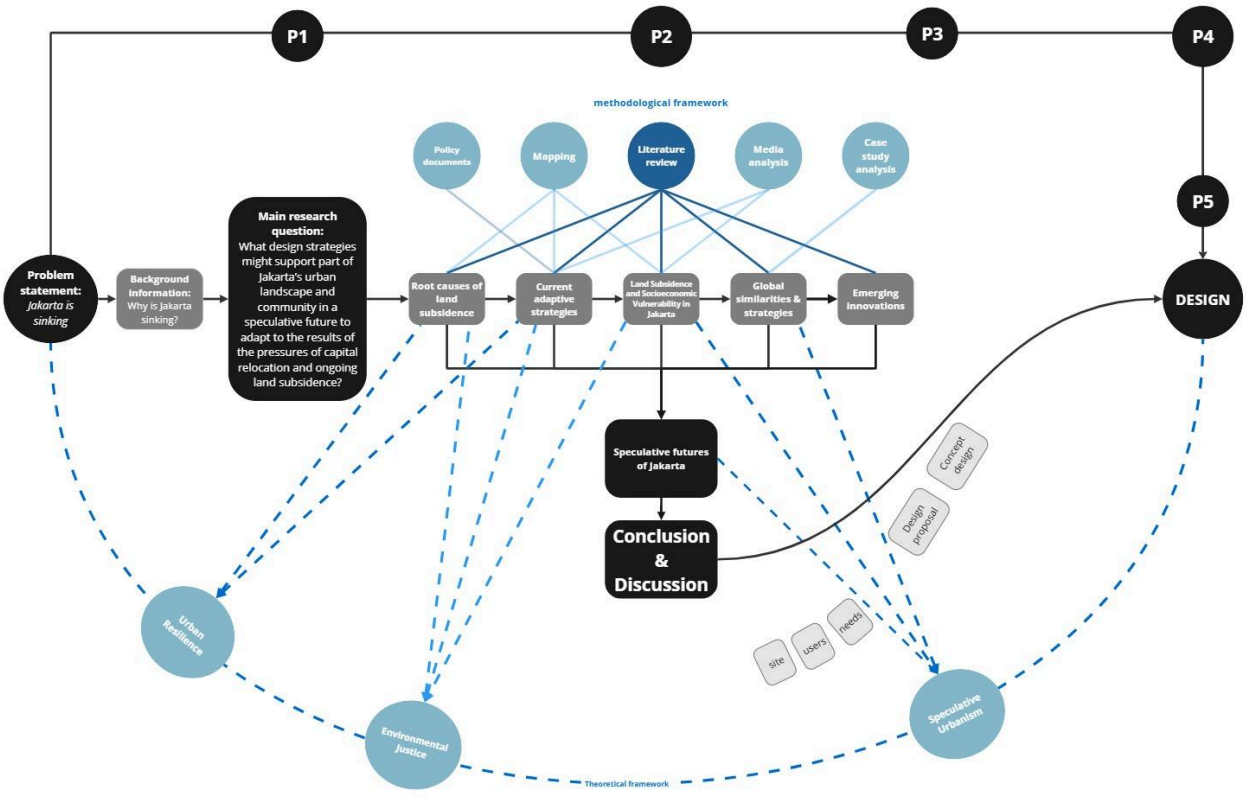

Figure 3: Methodological Framework Diagram

2. Root causes of Jakarta’s sinking crisis

Jakarta's sinking crisis did not happen overnight, it is rather the cumulative outcome of centuries of environmental manipulation, unequal development, and infrastructural neglect. Its roots trace back to the Dutch colonial era, when the city, then known as Batavia, was transformed to serve as a port vital to the Dutch trade in Southeast Asia. This transformation involved the extensive drainage of swamps for land reclamation and the construction of a canal network modeled after Dutch water systems (Batubara et al., 2023). The canals and reclaimed lands were created to decrease flooding in the area, which is a natural occurrence in coastal Jakarta. While seemingly effective at the start, these canals deteriorated over time due to poor maintenance and eventually became a source of urban flooding instead of a solution to it.

The canals had an additional role of segregating the indigenous population from the Dutch settlers. However, the division of the population through the canal system extended further into the city’s broader water infrastructure. By the late 19th century, Dutch settlers had relocated to higher southern areas of the city and developed a modern piped water system to serve their districts (Colven, 2020). The indigenous population, on the other hand, which was concentrated in informal settlements, was left without access to clean water. They had to rely on street vendors or were forced to use the water from the neglected canals that became increasingly polluted (Bakker, 2003) For decades, piped water remained unavailable to most, and when it did arrive, it came in the form of scattered public standpipes rather than household connections like the southern Dutch districts (Kooy & Bakker, 2008; VOX, 2021). This inequitable distribution of basic infrastructure laid the groundwork for widespread groundwater extraction, which became the default solution for underserved communities well into the post-colonial period.

Following Indonesia’s independence, Jakarta underwent a period of rapid and largely unplanned urbanization. The removal of natural flood buffers continued, with concrete and asphalt replacing much of the landscape. The city’s population grew rapidly, growing from 1,5 million people in the 1950s to an estimated population of over 10 million people in 2016 (World Population Prospects, 2024). However, infrastructure failed to keep pace, especially in the water sector. Piped water systems expanded slowly, and much like during colonial times, they often excluded low-income neighborhoods (Bakker, 2003).

As piped water infrastructure continued to lag behind the pace of urban growth, many residents turned to groundwater extraction to meet their daily needs. However, access to clean deep groundwater has not been distributed equally. While Jakarta’s urban poor often rely on contaminated shallow groundwater, the extraction of cleaner water from the deeper confined aquifer has been primarily carried out by industries and members of the political and social elite. Major users include factories, government offices, foreign embassies, and the residences of high-ranking officials such as former President B. J. Habibie and former Jakarta Deputy Governor Sandiaga Uno (Batubara et al., 2023). In addition, a significant portion of new real estate developments depends on deep groundwater pumped through privately funded infrastructure. This widespread and largely unregulated extraction has led to the depletion of vital aquifers and has contributed directly to severe land subsidence, with some areas sinking by as much as 22 centimeters per year (Chaussard et al., 2021).

In addition to excessive groundwater extraction and ecological degradation, the physical weight of urban development itself has also contributed significantly to Jakarta's subsidence. Marasabessy and Manik (2010) describe this phenomenon as the "megacity load," referring to the stress placed on the ground by the cumulative mass of high-rise buildings, commercial infrastructure, and densely packed settlements. Despite its critical role in worsening subsidence, the influence of structural load is rarely acknowledged in urban planning and regulatory frameworks, highlighting a broader neglect of the geological limits of Jakarta's urban footprint.

Jakarta's vulnerability to flooding and structural instability reflects this long history of environmental exploitation and infrastructural inequality. The legacy of colonial water management, the loss of ecological barriers, and the continued overreliance on groundwater have all contributed to the city's subsidence. Understanding the layered, historical roots of Jakarta's sinking problem is not just useful for analysis - it is essential for crafting equitable and sustainable solutions moving forward.

Figure 4: Water Vendors Filling Jerrycans at a Public Hydrant in Batavia, 1918

Figure 5: Child Collecting Water from a Public Pump in Jakarta, 2019

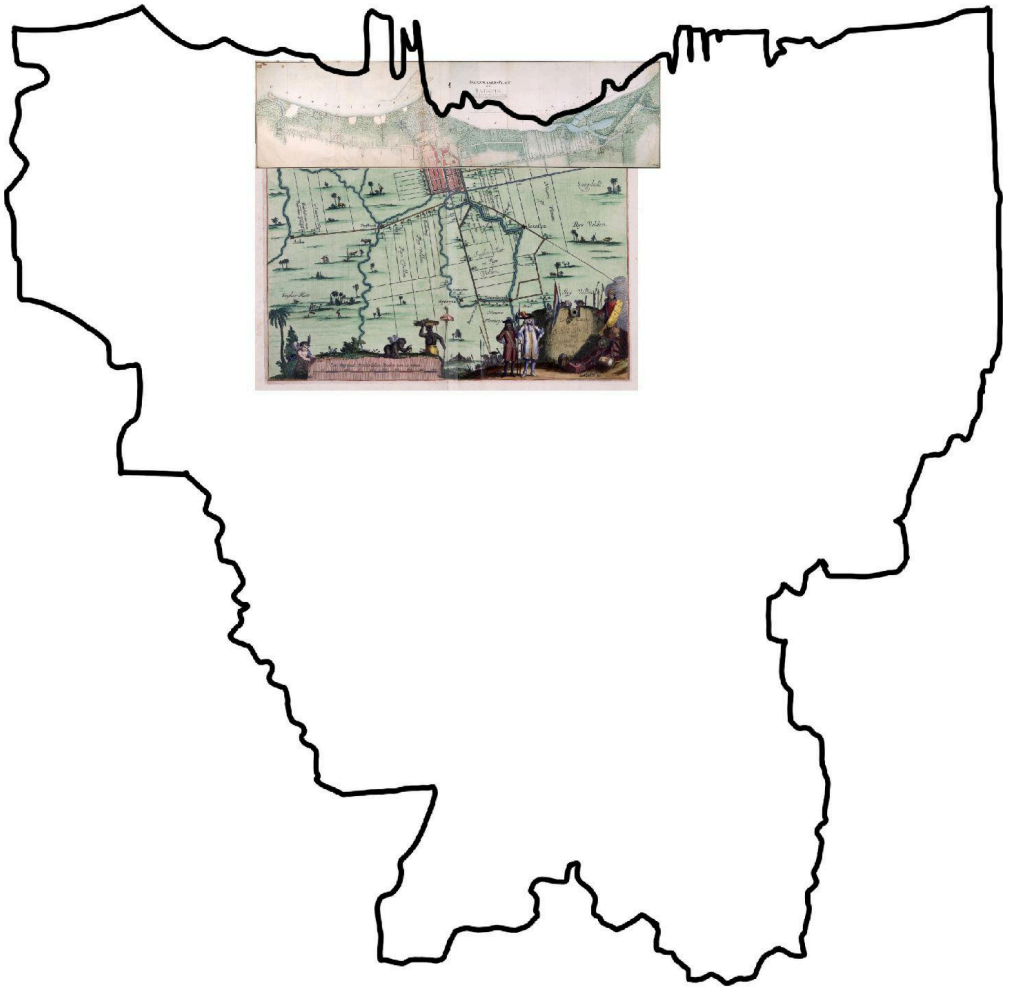

Figure 6: Old maps of Batavia in comparison to the map of Jakarta now

Figure 7: Map of Batavia and environs, 1682

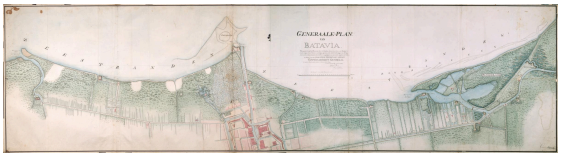

Figure 8: Map of Batavia and Surrounding Areas, 1798

3. Land Subsidence and Socioeconomic Vulnerability in Jakarta

Subsidence in Jakarta is occurring at an alarming pace, with rates ranging from 3 to 10 centimeters per year (Abidin et al., 2015). Surveys using geodetic GPS and InSAR technologies have identified particularly severe impacts in the city's coastal, western, and northeastern regions (JICA, n.d.). One of the main drivers is the excessive reliance on groundwater extraction due to the lack of access to piped water systems. As aquifers are depleted, the soft alluvial soils, common in coastal areas, become destabilized, contributing significantly to the ongoing subsidence crisis (Hakim et al., 2020). This condition is further aggravated by the physical stress placed on the ground by the cumulative weight of high-rise buildings, commercial infrastructure, and densely packed settlements. The effect is particularly acute in North Jakarta, where unstable alluvial soils dominate the landscape. When combined with aquifer depletion, the vertical pressure of urban density accelerates soil compaction and deepens land settlement (Marasabessy & Manik, 2010).

Coastal neighborhoods in North Jakarta such as Muara Baru, Muara Angke, Pantai Mutiara, and Kampung Pulo are among the most vulnerable areas in Jakarta. Here, subsidence is driven by a combination of deep groundwater extraction, the weight of new buildings, and inherently weak soil conditions (Hakim et al., 2020, p. 75; Batubara et al., 2023). For example, luxury developments like Pantai Kapuk and Pantai Mutiara have seen the land sink by as much as 60 cm and 50 cm, respectively (Batubara et al., 2023). In Muara Angke, subsidence has reached up to 37.5 mm per year, with tidal floods regularly disrupting daily life in low-income communities (Hakim et al., 2020, pp. 78–79).

While flooding affects many parts of the city, its impacts are far from equal. Wealthier residents may face inconvenience or property damage, but they often have the resources to recover and adapt. In contrast, Jakarta's urban poor, many of whom live in informal settlements along rivers and coastlines, are disproportionately affected (Colven, 2020). These communities endure near-daily tidal flooding, lack reliable infrastructure, and often depend on shallow, contaminated groundwater for basic needs (Colven, 2020; Batubara et al., 2023). They are also the most vulnerable to displacement and eviction, especially when urban development projects prioritize land use over their needs (Goh, 2019, pp. 257–259). In addition to infrastructural neglect, many residents also lack access to accurate information about the causes of their environmental risks. A survey by Takagi et al. (2021) found that a significant number of residents in a subsiding coastal community were unaware of the connection between land subsidence and increased flooding. This knowledge gap highlights another layer of vulnerability, one that may hinder the capacity for effective adaptation, advocacy, and participation in planning processes.

While data clearly shows which areas are sinking the fastest, government efforts often overlook and leave the most at-risk communities without the protection they need (Hasibuan et al., 2023). Other parts of western and northeastern Jakarta face similar risks, as unregulated urban expansion and continued groundwater extraction accelerate subsidence (JICA, n.d.).

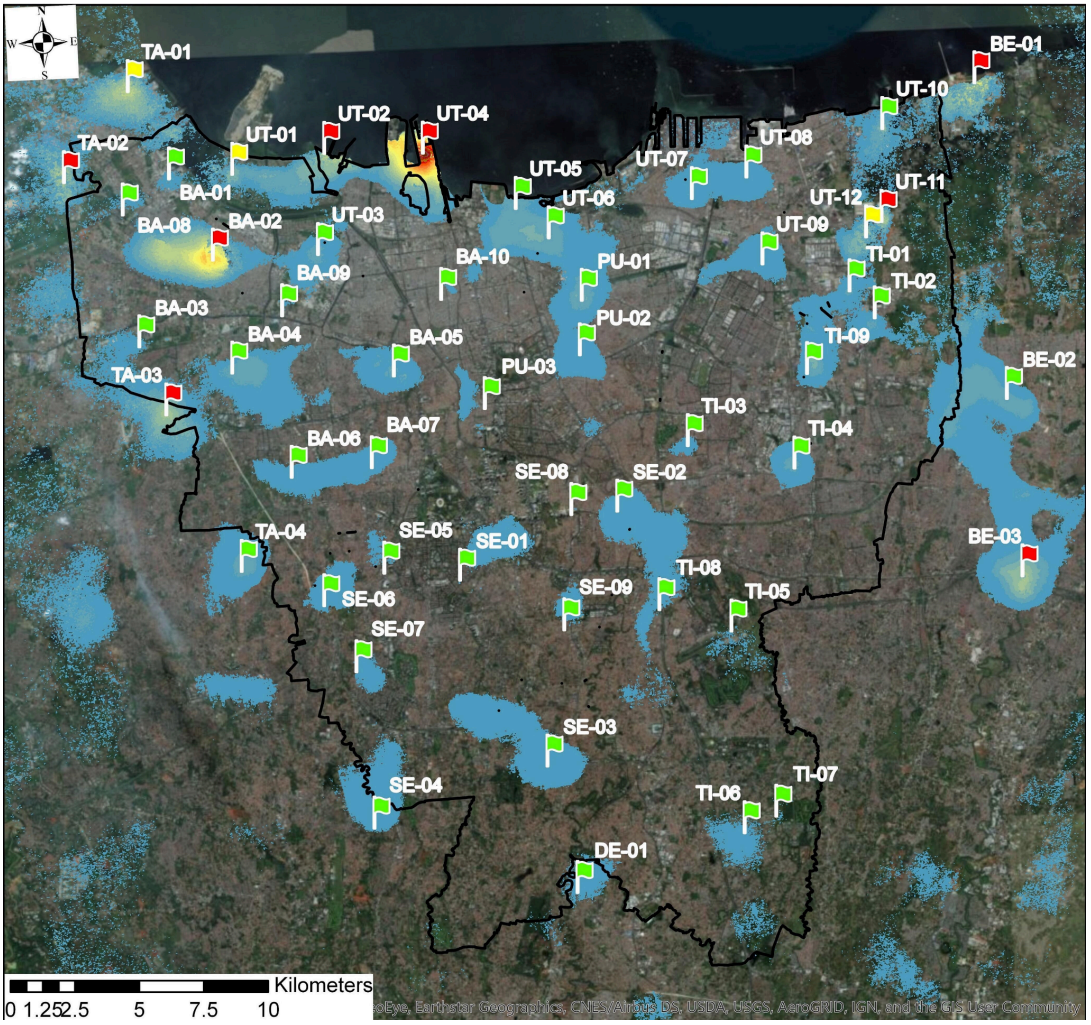

Figure 9: Land Subsidence Mapping in Jakarta

4. Current adaptive strategies

Jakarta faces growing environmental pressures due to the combined effects of land subsidence and urban flooding. These challenges are deeply rooted in the city's reliance on groundwater extraction, unregulated urban expansion, inadequate infrastructure, and a legacy of socio-spatial inequality. In response, multiple adaptive strategies have emerged, led by the national and local governments, NGOs, and local communities. While these efforts signal an awareness of the city's vulnerabilities, their effectiveness varies widely and often falls short of addressing the root causes.

4.1. Capital Relocation

At the governmental level, one of the most prominent and controversial strategies has been the planned relocation of the national capital to Nusantara in Borneo. Introduced in 2019, this policy aims to relieve Jakarta of some of its population and institutional burdens. However, the relocation has faced considerable setbacks, including the withdrawal of investors and skepticism about its long-term impact on Jakarta's environmental crisis. As Batubara et al. (2023) argue, such large-scale projects risk reinforcing uneven socio-spatial development and may divert attention from addressing local needs.

4.2. Giant Sea Wall

Another flagship project is the construction of the Giant Sea Wall under the National Capital Integrated Coastal Development (NCICD) plan. Intended to protect the northern coastline from tidal flooding, the seawall has so far achieved only partial implementation. Of the 39 planned kilometers, only 22.9 kilometers have been constructed. Even these completed sections are marred by poor maintenance, including visible cracks and ongoing seepage, particularly in areas like Muara Baru (Tempo, 2024). Alarmingly, the seawall itself is subsiding, which raises questions about its long-term viability in a city experiencing such high rates of land settlement. Scholars have noted that in regions like Jakarta, the performance of hard infrastructure diminishes quickly without ongoing maintenance and adaptation (Zhang et al., 2021; Takagi et al., 2017).

4.3. Policies and infiltration wells

Efforts to manage groundwater usage, the primary cause of subsidence, have included regulatory measures and technological interventions. The government has introduced policies to restrict groundwater extraction and promote groundwater recharge through infiltration wells. However, these strategies face major obstacles. Regulation is often undermined by weak enforcement and insufficient monitoring (Hakim et al., 2020). Infiltration wells, while promising in theory, are often ineffective in practice. Many sites suffer from soil saturation, improper installation, or poor maintenance, reducing their capacity to absorb stormwater or recharge aquifers (The Jakarta Post, 2019; VOX, 2022). These failures highlight the need for site-specific hydrological analysis and careful implementation. Moreover, recent spatial analyses reveal a critical gap between policy and practice, showing that areas experiencing the most severe subsidence are often not the ones prioritized by existing mitigation efforts (Hasibuan et al., 2023).

4.4. Expanding piped water infrastructure

Reducing dependence on groundwater is important to combat land subsidence. Therefore, piped water infrastructure has been expanding, but not nearly fast enough to meet the needs of Jakarta's growing and unequal population. Many neighborhoods, particularly informal settlements, still lack reliable access to clean piped water, leaving residents with no choice but to continue extracting groundwater. Meanwhile, industrial users also prefer well water due to its lower cost and ease of access (Batubara et al., 2023). Without a coordinated overhaul of Jakarta's water infrastructure, including expansion of the piped water system and reform of privatized water management, groundwater dependence is likely to persist.

4.5. Adaptive housing projects

Beyond infrastructure, the government has introduced adaptive housing measures in highly vulnerable coastal zones. In areas like Muara Angke, projects initiated by the government and the Indonesian Defense University have included floating houses, stilted homes, and mangrove reforestation to mitigate tidal surges (IDU, 2024). In many cases, however, most house adaptations are initiated by the residents themselves. Households have raised the floors of their homes or elevated their structures on their own, often without formal support (VOX, n.d.; WRI Indonesia, 2023). These bottom-up strategies, while innovative and resourceful, are often costly and borne disproportionately by low-income communities that receive little institutional assistance.

4.6. Nature-based solutions by NGOs

Non-governmental organizations (NGOs) have played a key role in supporting nature-based solutions and building community resilience. In northwestern coastal areas, NGOs have implemented mangrove reforestation programs to reduce erosion and enhance coastal protection. These programs go beyond ecological restoration; some include educational initiatives aimed at fostering environmental literacy among residents. For instance, in Serang Regency, storytelling techniques have been used to teach children about the importance of mangroves in preventing coastal flooding (Rosyid et al., 2019). Organizations such as the World Resources Institute (WRI) Indonesia and the Resilience Development Initiative (RDI) also promote integrated strategies combining urban green space development, water management, and policy research to strengthen Jakarta's adaptive capacity (Jennerjahn et al., 2022; RDI, 2023; WRI Indonesia, 2023).

4.7. Critiques on current strategies

Despite the range of strategies employed, major limitations persist. Many of Jakarta's flood prevention measures, such as dredging, river widening, pumping stations, and drainage improvements, focus heavily on technological and engineering solutions. While they offer short-term protection, they often neglect the social dimensions of risk, including housing precarity and displacement. Large infrastructural projects frequently lead to the eviction of marginalized communities under the banner of "improvement" (Goh, 2019). Moreover, maintenance and funding constraints, combined with fragmented governance, have hindered the long-term effectiveness of these interventions (Pham et al., 2021). Recent spatial analyses also reveal a critical gap between policy and practice, showing that areas experiencing the most severe subsidence are often not the ones prioritized by existing mitigation efforts (Hasibuan et al., 2023.).

Beyond the technical limitations of the Giant Sea Wall, critics argue that the NCICD reflects

what Octavianti and Charles (2018) call “disaster capitalism” where environmental crises are used to justify large-scale infrastructure that benefits elite interests. The seawall has been strategically framed as a public safety measure, but critics contend it prioritizes land reclamation and real estate development. As they note: “the project’s proponents have eloquently framed the sinking crisis to ensure preference for the seawall policy” (Octavianti & Charles, 2018, p. 394), despite failing to address root causes such as groundwater extraction. This has raised concerns about socio-spatial inequality and the displacement of vulnerable communities.

As Batubara et al. (2023) caution, the dominant solutions, whether capital relocation, infiltration wells, or large seawalls, often reinforce the same systems of capitalist urbanization that contributed to Jakarta’s vulnerabilities in the first place. They risk deepening socio-ecological inequalities rather than resolving them. Ultimately, Jakarta’s ability to address land subsidence and flooding will depend not only on the expansion of infrastructure but also on political will, inclusive governance, and a commitment to addressing the root causes of environmental injustice.

Figure 10: Visual Rendering of Jakarta’s NCICD Master Plan

Figure 11:
PAM Jaya Workers Installing Clean Water Pipes in Jakarta

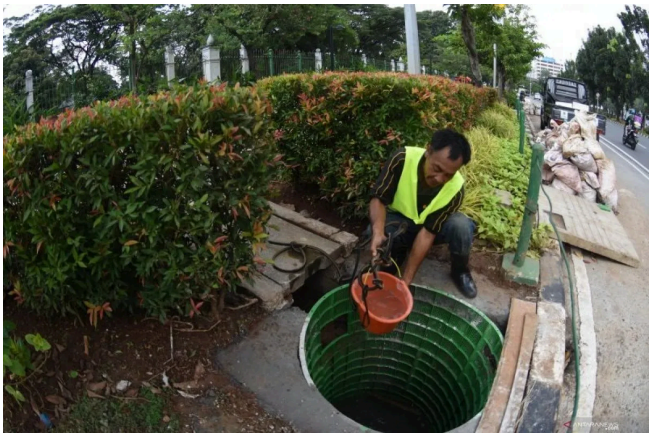

Figure 12:
Inspection of a Rainwater Infiltration Well in Central Jakarta

Figure 13:
Stilt Houses for Coastal Fishermen in Muara Angke, Jakarta

Figure 14:
Participants Engaged in Mangrove Planting at Angke Nature Park, Jakarta

5. Global similarities and strategies

Cities across the globe are grappling with the consequences of land subsidence and urban flooding, particularly in coastal regions undergoing rapid urbanization. While Jakarta faces a unique set of challenges, it is far from alone in this crisis. Drawing from international case studies, Jakarta can learn valuable lessons from cities such as Tokyo, Venice, Shanghai, and Mexico City, which have all experimented with strategies to mitigate subsidence and its cascading effects.

5.1. Tokyo and Venice

One of Jakarta's closest collaborators in tackling land subsidence is the Japan International Cooperation Agency (JICA), whose assistance is grounded in Japan's own experience with the issue. Tokyo has successfully reversed the trend through strict groundwater regulation, improved monitoring systems, and a comprehensive switch to alternative water sources, as it was once severely affected by subsidence due to industrial-scale groundwater extraction (The Jakarta Post, 2018; JICA, n.d). The city's success demonstrates that with political will, regulation enforcement, and sufficient infrastructure, subsidence can be halted.

A similar emphasis on groundwater management is found in Venice, where authorities closed many groundwater wells in the 1970s after the aquifer was overexploited during the post-war industrial boom. Today, the city sources its freshwater from mountain aqueducts, and while subsidence continues, it has significantly slowed (Pattison & Cooke, 2024). Venice also demonstrates the importance of ecological interventions, including wetland restoration and adaptive land use planning, which offer valuable insights for Jakarta as it considers more sustainable and nature-based solutions (Hakim et al., 2020). In addition, advanced monitoring systems such as InSAR (Interferometric Synthetic Aperture Radar) have been deployed in both Venice and Shanghai to map and predict areas at risk, offering a data-driven approach to spatial planning (Hakim et al., 2020).

5.2. Shanghai and TIanjin

Shanghai, like other Chinese cities such as Beijing and Tianjin, also experienced severe subsidence due to rapid development and overextraction of groundwater. In response, the government implemented comprehensive zoning policies, enforced extraction limits, and promoted rainwater harvesting to reduce reliance on underground aquifers (Zhang et al., 2021). Urban planning strategies, such as zoning and land-use regulations, have proven effective in mitigating flood and subsidence risks when supported by strict enforcement and integrated groundwater management policies, as demonstrated in Tianjin, where regulatory measures (including designated no-pumping zones, water pricing, and legal controls) helped reduce subsidence rates and stabilize urban development (Lixin et al., 2010).

5.3. Bangkok, Ho Chi Minh City, and Manila

In Bangkok and Ho Chi Minh City, integrated water management systems have been introduced alongside public awareness campaigns. In Bangkok, these efforts included a pricing policy on groundwater, the expansion of the municipal tap water supply, and strict enforcement of groundwater laws, all of which contributed to a notable reduction in extraction rates and helped control subsidence in the most affected areas (Phien-wej et al., 2006). These measures are increasingly being complemented by green infrastructure, such as urban parks and floodplains, that enhance the city's ability to absorb excess water (Pham

et al., 2021). Similarly, in Manila, unregulated extraction for household, agricultural, and industrial use has caused some parts of the metropolitan area to sink up to 10 centimeters per year (Eco et al., 2020). Although the Philippine government has attempted to regulate this practice, progress has been slow, and public reliance on groundwater remains high due to insufficient surface water storage and an aging water infrastructure system (Mirano, 2019; Pattison & Cooke, 2024).

5.4. Mexico City

Perhaps the most extreme example of subsidence is Mexico City, where the ground is sinking by as much as 50 centimeters per year. Over the past century, the city has sunk by approximately 9 meters, and projections estimate that parts of it could drop another 20 meters in the coming century due to continued aquifer depletion (Chaussard et al., 2021). Despite abundant rainfall, the city's vast drainage infrastructure redirects stormwater away from aquifers instead of replenishing them, exacerbating the problem (Pattison & Cooke, 2024).

In response to this crisis, several NGOs have promoted decentralized rainwater harvesting systems (RWHS) as a way to reduce dependence on overexploited aquifers and increase household water autonomy. Organizations like Isla Urbana have installed tens of thousands of RWHS in marginalized neighborhoods across Mexico City, offering up to eight months of partial or full water self-sufficiency per year for participating households (Castelán-Cabañas et al., 2024). These systems not only help alleviate water insecurity but also contribute to reducing land subsidence by decreasing groundwater extraction and enabling stormwater infiltration (Concha Larrauri et al., 2020).

5.5. Importance of community engagement

Beyond technological and regulatory approaches, many cities have also recognized the importance of community engagement. In various urban contexts, involving residents in flood preparedness, early warning systems, and environmental restoration projects has significantly enhanced the resilience of at-risk communities (Zhang et al., 2021). This model of participatory adaptation, where citizens are not just recipients of policy but active agents of change, can be particularly meaningful in Jakarta, where informal settlements face the highest risks but are often excluded from formal planning processes.

The global experience suggests that a multi-pronged strategy combining groundwater management, ecological restoration, advanced monitoring, urban planning, and community participation offers the best path forward. However, using these strategies in Jakarta’s context comes with challenges. The city’s high population density, widespread informality, and fragmented governance systems can limit the feasibility of some solutions. Nevertheless, examples like Tokyo, Venice, and Shanghai demonstrate that with coordinated policy, sustained investment, and inclusive governance, the trajectory of land subsidence can be slowed and perhaps even reversed.

Figure 15:

Technology Deputy Director at the Japan River Front Research Center is present at the construction site of a monitoring well in northern Jakarta

Figure 16:

Benjakitti Forest Park: Urban Wetland for Flood Mitigation in Bangkok

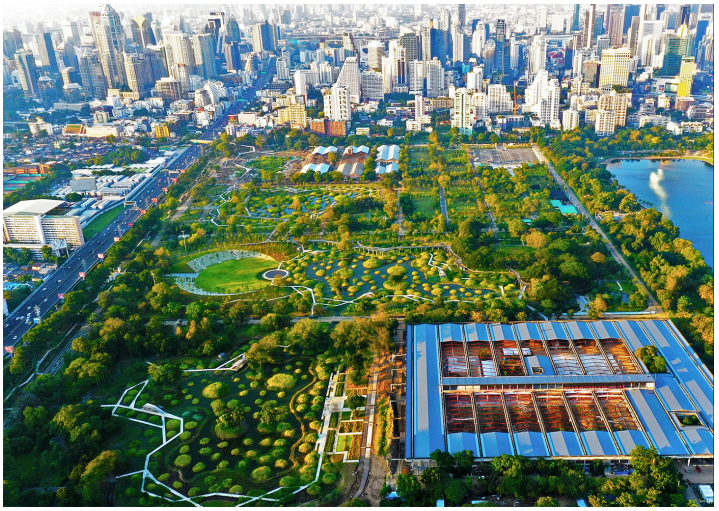

Figure 17:

Installation of Isla Urbana's Rainwater Harvesting System in Mexico City

6. Emerging innovations

As land subsidence and sea-level rise increasingly threaten urban life in Jakarta, emerging innovations are moving beyond traditional engineering solutions to address deeper, systemic challenges. It is becoming increasingly clear that the city's vulnerability is not just a technical matter but also social and political. The ability to adapt, and who benefits from it, depends largely on power dynamics, access to resources, and the inclusivity of governance. Romero-Lankao et al. (2016) remind us that urban resilience “is not merely a technical issue of infrastructure but also a matter of governance, power relations, and institutional capacity”. This insight is especially relevant in Jakarta, where fragmented governance and socio-spatial inequalities often hinder effective and equitable adaptation efforts. As a result, recent innovations increasingly focus on more inclusive and integrated strategies that center not only infrastructure, but also the communities most affected.

In coastal neighborhoods, such as Muara Baru, new forms of engagement have begun to emerge. Community-driven housing adaptations and participatory flood mapping efforts reflect a growing awareness of the dynamic boundary between land and water. These practices respond to physical threats and create platforms for local knowledge and agency to shape adaptation (Goh, 2019).

At the technical level, tools for monitoring land subsidence are becoming more advanced and accessible. For instance, the Stanford Method for Persistent Scatterer (StaMPS) enables high-resolution tracking of subsidence patterns across time, offering valuable insights into which areas are at greatest risk and informing more responsive urban planning (Hakim et al., 2020, p. 80). Complementary tools like flood susceptibility maps help planners better identify high-risk areas, especially those where traditional land-use zoning has overlooked environmental vulnerabilities such as flooding or land subsidence.

Innovation has also reached local, low-cost technologies. One such example is the development of an IoT-based Automatic Water Level Recorder (AWLR) designed for North Jakarta. As described by Pianto et al. (2023), this device is accessible to communities and provides real-time data on sea level changes. It supports early warning systems and empowers residents to make informed decisions about water management, avoiding the financial and logistical barriers of more complex monitoring systems.

Nature-based solutions are another area of innovation gaining momentum. Jakarta can draw on a range of strategies, including mangrove reforestation to restore ecological buffers, as well as technical soil stabilization methods such as geo-fabric reinforcement and dynamic compaction techniques, which aim to strengthen vulnerable ground and reduce the risk of subsidence (Pham et al., 2021). These approaches address immediate risks and contribute to long-term environmental regeneration.

Importantly, these innovations reflect a growing emphasis on “co-produced knowledge,” as described by Romero-Lankao et al. (2016), which integrates scientific expertise, local experiences, and lived realities into decision-making. The ability of governance systems to respond to changing environmental and socio-political conditions is now considered just as important as the technologies being implemented (Romero-Lankao et al., 2016).

7. Speculative futures of Jakarta

Speculative visions of Jakarta's future paint both cautionary and revealing portraits of what could lie ahead if current trends remain unchallenged. These visions are not only grounded in environmental forecasting but also critiques of policy, governance, and socio-economic dynamics.

A widely publicized response to Jakarta's environmental crisis is the planned relocation of Indonesia's capital to East Kalimantan, announced by President Joko Widodo in 2019. Framed as a long-term solution to Jakarta's overburdened infrastructure and environmental degradation, the relocation has sparked considerable debate. Critics argue that the move may serve more as a vehicle for capital accumulation and elite interests than as a genuine solution to the city's problems. Goh (2019) notes that such large-scale interventions often reflect speculative urbanism, where infrastructural and spatial strategies benefit private capital and reinforce social inequalities rather than addressing the needs of the most vulnerable. As Batubara et al. (2023) caution, such large-scale projects may catalyze new waves of "uneven sociospatial and socionatural transformations", displacing problems rather than addressing their root causes.

The emphasis on techno-managerial solutions, such as the Giant Sea Wall and other large-scale implemented infrastructure systems, has also come under similar scrutiny to the capital relocation. While these interventions may offer short-term relief or serve as visible symbols of progress, they risk deepening existing inequalities. Rather than resolving structural vulnerabilities, such solutions often redirect risk, especially onto low-income and marginalized groups who are frequently excluded from formal decision-making processes. As Pham et al. (2021) point out, these adaptation strategies fail to integrate inclusive planning and risk-perpetuating structural inequality under the guise of climate resilience.

The physical projections for Jakarta's coastal zones are equally stark. Experts from the Bandung Institute of Technology have warned that if current rates of subsidence and sea level rise continue, as much as 90 percent of North Jakarta could be underwater by 2050 (Aqil, 2018). In such a scenario, vast swathes of the city, particularly informal settlements and low-lying neighborhoods, could become uninhabitable, possibly leading to mass displacement, forced inland migration, and the collapse of already strained infrastructure systems.

Speculative urbanism, as described by Fields (2022), challenges us to think beyond immediate engineering fixes and toward reimagining the relationship between cities, land, and the communities that inhabit them. In Jakarta's case, speculative thinking may serve as both a warning and a prompt for more inclusive and forward-looking planning. Whether the city becomes a model for resilience or a cautionary tale will ultimately depend on the decisions made today by policymakers, urban designers, and local communities.

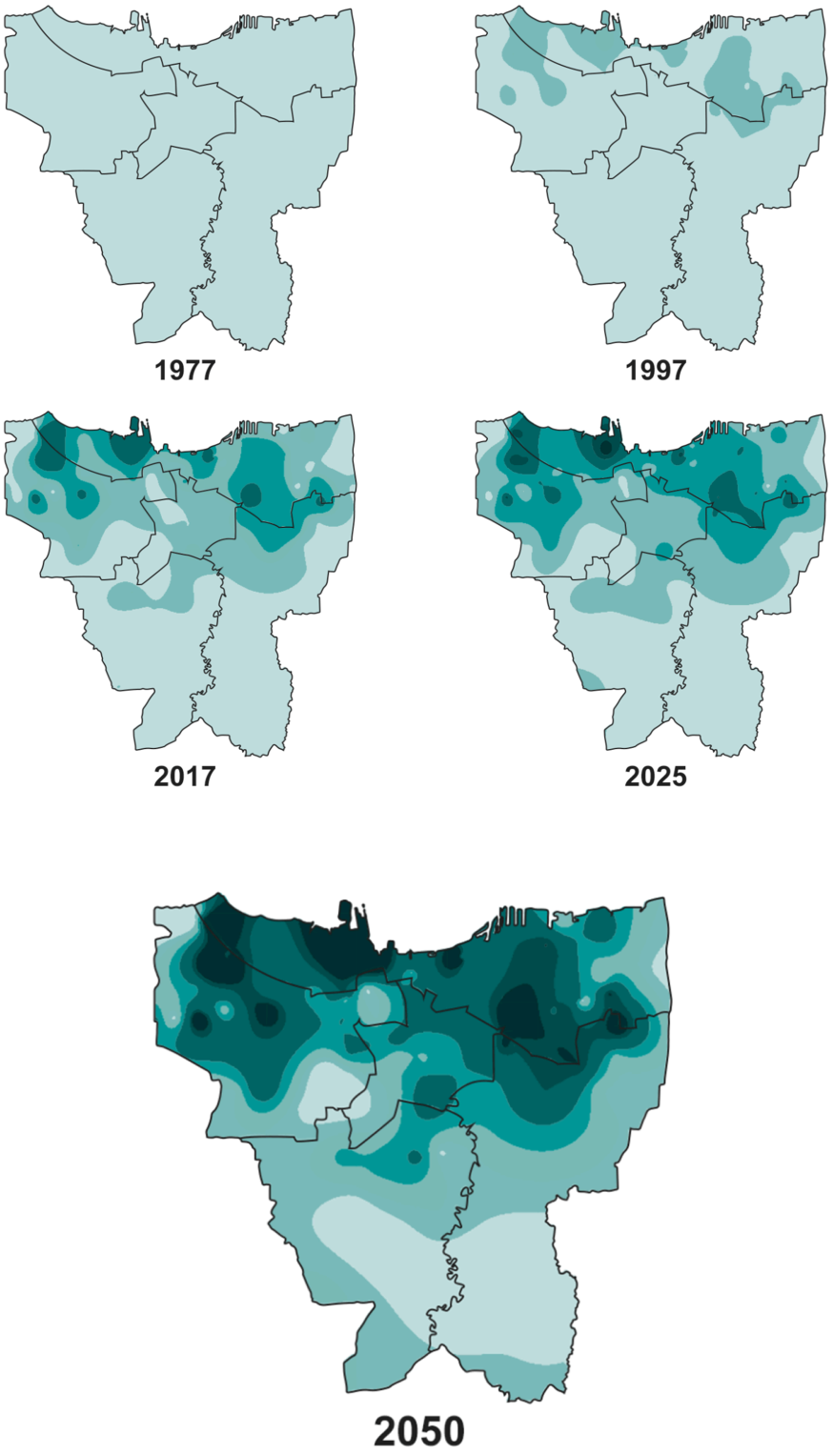

Figure 18:
Projected and Historical Land Subsidence
in Jakarta (1977–2050)

8. Conclusion

Jakarta's sinking is often portrayed as a technical or environmental crisis, but as this research has shown, it is above all a deeply social and historical issue. The roots of the city's land subsidence lie not just in overextracted aquifers or failing infrastructure, but in a long legacy of uneven development, colonial planning, and exclusionary governance. For centuries, water management systems and urban growth in Jakarta have served the needs of the powerful while sidelining low-income communities, many of whom continue to live in the city's most flood-prone and unstable areas. The result is a deeply unequal city, where the poorest residents suffer the greatest consequences of environmental degradation while having the fewest resources to adapt or respond.

While current strategies show a growing recognition of the crisis, many of the most visible solutions, such as the Giant Sea Wall or the planned capital relocation, risk repeating the same patterns of exclusion that contributed to the problem in the first place. These large-scale interventions are often framed as ambitious, forward-looking projects, yet they rarely engage with the communities most affected by land subsidence or flooding. Without inclusive planning and long-term commitment to social equity, such projects may protect infrastructure or elite developments while leaving informal settlements and vulnerable neighborhoods even more exposed.

Still, Jakarta is not without hope. Across the city, there are signs of a different kind of adaptation that draws on local knowledge, community effort, and a deep connection to place. In neighborhoods such as Muara Baru and Muara Angke, residents are creating their own responses to environmental challenges. Some have taken part in community mapping and flood monitoring initiatives, often in collaboration with NGOs or universities, contributing to more informed and responsive planning. Others have resorted to raising the floors of their homes year after year — an effort that, while resourceful, highlights the limits of individual adaptation in the face of ongoing subsidence. These examples show that while communities may lack the resources to implement large-scale solutions on their own, their lived experience and everyday knowledge remain essential to building more inclusive and sustainable forms of resilience.

International examples from cities like Tokyo, Venice, Shanghai, and Mexico City provide further evidence that land subsidence can be slowed or even reversed when there is strong political will, coordinated policy, and investment in both people and infrastructure. These cases show that technical solutions work best when combined with effective governance, public participation, and ecological sensitivity. In Jakarta's case, this means prioritizing access to clean, affordable piped water, strengthening urban planning regulations, and investing in nature-based solutions like mangrove reforestation and wetland restoration. It also means listening to the voices of those most affected and ensuring they are not just consulted, but truly included in shaping the city's future.

Speculative thinking offers another powerful lens through which to imagine Jakarta's future. It challenges the idea that the only possible outcomes are either catastrophe or capital-driven redevelopment. Instead, it opens up space to imagine alternative futures — ones that prioritize justice, community, and environmental balance. Whether Jakarta becomes a cautionary tale or a model for transformation will ultimately depend on the

decisions made today, not only by policymakers but also by the residents, researchers, and organizers who continue to fight for a more livable and equitable city.

In the end, resilience in Jakarta cannot be measured by how well it keeps the water out, but by how fairly it includes its people, how wisely it manages its resources, and how courageously it reimagines its relationship with land, water, and each other.

9. Discussion

Based on the findings of this research, I have developed a set of design principles to guide the creation of an architectural and urban project aimed at building a resilient, self-sufficient coastal community. The project will be located in Muara Baru, one of Jakarta's fastest-sinking neighborhoods and a site that has become symbolic of the city's subsidence crisis, often represented in media through images of its abandoned mosque. Choosing Muara Baru grounds the project in a place where both the physical impacts of land subsidence and the social vulnerabilities it creates are most visible and urgent.

The design will take a participatory, community-led approach that is supported by organizations and grounded in local knowledge. This approach responds directly to the failures of top-down government interventions discussed in the research, which have often overlooked or excluded the communities most affected by subsidence and flooding. Rather than imposing solutions, the project aims to create the conditions for residents to shape their own responses by prioritizing autonomy, adaptability, and ecological integration. At the same time, it acknowledges that external support is often necessary at the outset, especially in providing technical resources, training, and facilitation. The intention is not to design for the community, but to work alongside them in a collaborative process that fosters shared learning, builds long-term capacity, and strengthens local ownership of adaptation strategies.

A central element of the project will be the creation of a community research center. This space will serve as a hub where residents can learn to build flood-resilient homes using accessible techniques and locally available materials. The goal is to equip the community with practical knowledge about land subsidence and living with water, rather than fighting against it. The center is envisioned as a place of collective learning, where skills can be passed on not only within the community but also to others facing similar challenges. It will also offer space for NGOs with expertise in mangrove forestation, enabling them to lead workshops and community initiatives focused on planting and maintaining mangroves. These efforts are crucial, as true flood and coastal resilience extends beyond individual homes and depends on caring for and restoring the surrounding environment.
The center will also include a small data and monitoring facility. This part of the project draws from technological innovations explored in the research, such as the use of low-cost IoT tools like the Automatic Water Level Recorder (AWLR). These devices provide real-time sea level data and help communities prepare for and respond to flooding more effectively.

As learning to build flood-resilient homes is one of the most important goals of the community research center, I will also design a prototype of a flood-resilient house that can serve as a practical learning tool for residents. Rather than serving as a fixed or one-size-fits-all solution, the prototype is intended to be open to adaptation and reinterpretation based on the needs and knowledge of the people who will use it. Through workshops at the community research center, residents will have the opportunity to learn how to build, modify, and improve upon the design, creating the foundation for broader knowledge sharing and self-sufficiency.

Bamboo has been chosen as the primary building material due to its sustainability, local availability, and ease of construction. Its light weight and adaptability make it especially suitable for participatory building methods. Bamboo construction allows for simple

measurements and connections, encouraging community involvement in the building process.

Ultimately, this design is informed by the research's emphasis on environmental justice, adaptability, and inclusion. It seeks to provide more than just physical infrastructure; it aims to build capacity, foster knowledge-sharing, and empower the community to shape its own future. Rather than resisting the presence of water, the project embraces it, developing an architecture that learns from its environment and grows with it.

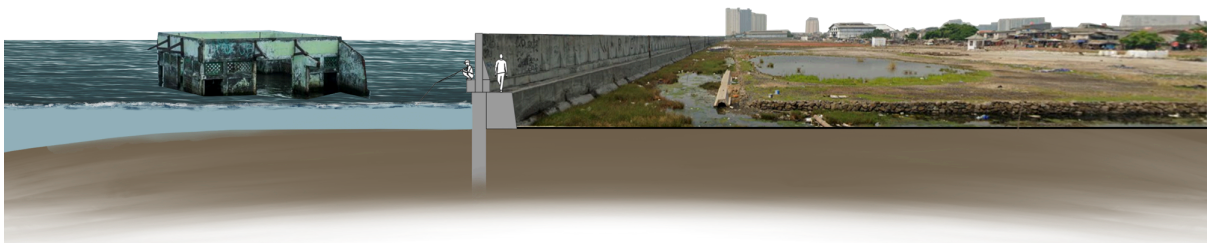

Figure 19: Section of the chosen site in Muara Baru, Jakarta

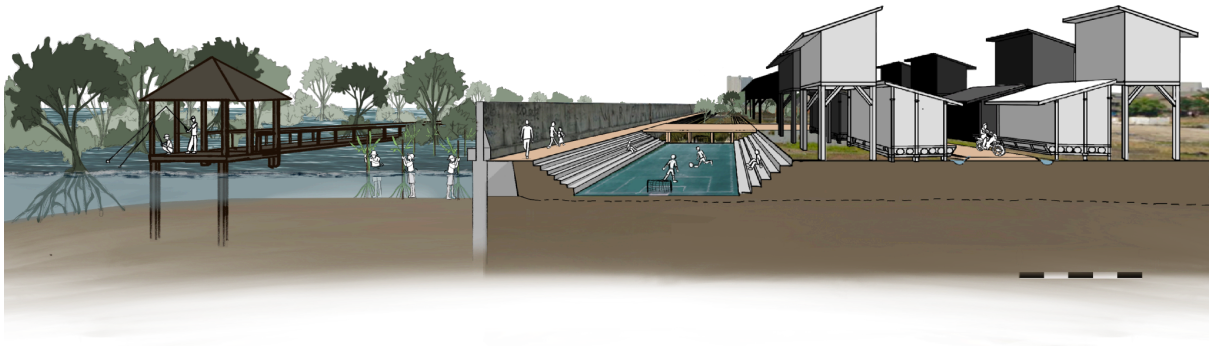

Figure 20: P2 vision of the chosen site in Muara Baru, Jakarta

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Image entry

Fig. 1:

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Fig. 3: Author's own illustration

Fig. 4

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Fig. 5

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Fig. 7:

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Fig. 19: Projected and Historical Land Subsidence in Jakarta (1977–2050)

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Fig. 20: Author's own illustration
Fig. 21: Author's own illustration

11. Reflection Report

My graduation project addresses the critical issue of land subsidence in Jakarta, a city facing increasingly severe environmental and socio-political challenges. This phenomenon, primarily caused by excessive groundwater extraction, is exacerbated by ineffective infrastructure, rapid urbanization, and climate change. Inhabitants from lower socioeconomic backgrounds are both the most affected and unintentionally involved in the cycle that perpetuates land subsidence due to their reliance on informal water sources.

My design proposal seeks to establish a flood-resilient coastal community in Muara Baru, Jakarta, specifically targeting the local fishing population that lives in the informal settlements of Muara Baru. The project envisions a modular system of amphibious housing units that can be combined into larger structures serving public functions, with the central focus being a community research center. This center aims to empower residents through knowledge-sharing, particularly in building flood-resilient houses and in mangrove cultivation for ecological coastal defense.

1. **What is the relation between your graduation project topic, your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS)?**

The core of my project lies in the design of amphibious housing that not only responds to environmental challenges like land subsidence and flooding but also resonates with the local way of life. The architectural language is inspired by traditional vernacular forms to reflect the identity of the community and to avoid the visual monotony often found in standardized or top-down interventions, such as the flood-resilient village built in Muara Angke by the government (see fig. 13). While architecture is my main focus, the project is inherently interdisciplinary. Landscape strategies play a key role, for instance, integrating mangrove reforestation to strengthen the coastline, creating a tidal zone, and designing with a possible future climate in mind.

On a broader scale, the project aims to foster a resilient coastal community shaped through bottom-up planning. Rather than relying heavily on centralized systems, which have historically failed to serve marginalized groups, I propose a more decentralized approach — one that empowers residents and builds on the existing efforts of NGOs and community initiatives. In this way, my project touches on not only architecture and landscape, but also urbanism and management in the built environment.

A core ambition of the project is to keep the construction process accessible to achieve independence for the residents. Bamboo is chosen as the primary building material not only for its regenerative and low-impact properties but also for its affordability. cultural familiarity, and its many approachable construction techniques. To further reduce environmental strain, passive cooling techniques will be employed, offering a sustainable alternative to air conditioning, which is both polluting and often out of reach for low-income households. These aspects fit within the building technology. In essence, the project proposes a locally rooted, environmentally responsive, and socially inclusive approach to climate adaptation in Jakarta’s vulnerable coastal zones using the skills and knowledge that I have gained from the master's programme.

2. **How did your research influence your design/recommendations, and how did the design/recommendations influence your research?**

My research played a central role in shaping the direction of my project, especially in understanding the environmental, political, and social dynamics that contribute to land subsidence in Jakarta. Through the study of current strategies, failures in infrastructure provision, and case studies of other countries, I recognized the limitations of top-down governmental approaches in Jakarta. This insight led me to prioritize a community-led, self-sufficient strategy, supported by knowledge transfer and capacity-building through a community research center.

As the design evolved, it prompted new research questions about construction materials, flood-resilient typologies, and how informal communities adapt spatially to recurring environmental stressors.

3. **How do you assess the value of your way of working (your approach, your used methods, used methodology)?**

I see the value of my way of working in how it combines critical research with grounded, design-driven thinking. My approach was intentionally interdisciplinary, connecting architecture with environmental, social, and political perspectives. By starting with a literature review and expanding through mapping, case studies, and policy analysis, I was able to understand Jakarta's land subsidence not just as a technical issue, but as part of a deeper pattern of inequality and neglect.

Throughout the process, I was continuously experimenting with different methods, both in how I approached the research and how I translated it into design. This openness allowed me to explore new perspectives and challenge my assumptions, but it also slowed my design process significantly. Balancing research depth with design development was difficult at times, especially when trying to work across disciplines and scale.

Still, the ongoing dialogue between research and design helped me stay connected to the realities of the site. Each step informed the next: the research grounded the project in local conditions, and the act of designing helped clarify what kinds of interventions might be meaningful. Concepts like environmental justice and speculative urbanism guided me in imagining more inclusive futures, while also keeping the project adaptable to other vulnerable contexts.

4. **How do you assess the academic and societal value, scope, and implication of your graduation project, including ethical aspects?**

Academically, the project contributes to ongoing discourse on climate adaptation, the ethics of urban development under environmental duress, and the role of architecture in addressing systemic socio-ecological challenges. It also engages with critical questions of material sustainability, informal urbanism, and participatory design.

Societally, the project speaks to the importance of marginalized communities remaining in place (or, in Jakarta's case, being "left behind") despite ecological degradation and political neglect. It proposes a model of empowerment in which knowledge, adaptability, and collaboration enable communities to take initiative and reduce their reliance on external support. Ethically, the project is rooted in a commitment to environmental justice and equitable urban futures.

5. **How do you assess the value of the transferability of your project results?**

I see my project as a replicable prototype for other coastal communities in Indonesia (and perhaps other countries in Southeast Asia) facing similar conditions of land subsidence, flood risk, and governmental insufficiency. While the architectural form of the community research center is site-specific, the core principles, like community participation and self-sufficiency, are widely applicable. If appropriately adapted, the concept could be implemented in other contexts vulnerable to flooding and land subsidence, especially in areas where informal settlements are disproportionately affected.
The exhibition "A Lot With Little" provides a valuable reference for situating the transferability of my project within a global discourse on socially responsive and resource-conscious architecture. Like the projects featured in the exhibition, my work engages with the question of how architecture can respond meaningfully to urgent environmental and social challenges, particularly in contexts marked by limited resources, infrastructural inequality, and climate vulnerability. The exhibition highlights architectural approaches from both the Global North and South that combine modest means with strong community engagement and local relevance (*A Lot With Little*, n.d.). These qualities strongly resonate with the core of my project, which proposes a flexible, modular housing prototype and a participatory design strategy grounded in Jakarta's coastal realities. The alignment between this mindset and the curatorial theme of the exhibition reinforces the potential transferability of my design principles to other flood-prone and underserved urban environments. Rather than relying on high-tech or centralized interventions, the project advocates for scalable, community-led solutions that could be adapted to similar socio-environmental contexts elsewhere.

6. **How did your motivations, background, or positionality influence your choice of topic, site, or perspective in the project?**

My background played a meaningful role in shaping both the topic and the perspective of this project. Being of both Indonesian and Dutch heritage, I have always had a personal connection to Jakarta, a city that is not only connected to my family as the capital of Indonesia but also deeply marked by its colonial past and ongoing urban challenges. I first encountered the issue of land subsidence during a small research assignment in my first year of the Bachelor's in 2021, and it immediately struck me as both technically complex and socially urgent. It stayed with me.

As a student of Architecture, Urbanism, and Building Sciences, I began to ask myself what role design could play in addressing problems like flooding, displacement, and infrastructural inequality, especially in a place that felt close to home. Choosing Jakarta as my focus felt

natural, not only because of my personal ties, but also because it allowed me to approach the subject from both an insider and outsider perspective. I could draw on my cultural understanding while also critically reflecting and expanding on my knowledge of systems of power, governance, and design practice from a distance.

This positionality made me especially sensitive to questions of justice, inclusion, and local knowledge. It also made the project feel more than academic — it felt personal, and that motivated me to engage deeply and approach the topic with care and respect.

7. **In what ways did your project challenge, expand, or change your understanding of architecture's role in addressing complex environmental and social issues?**

This project expanded my understanding of architecture as not just a matter of form or construction, but as a tool for care, empowerment, and long-term resilience. Working on a site like Jakarta, where environmental risks and social inequalities are deeply entangled, challenged me to think beyond conventional building solutions. I came to see architecture less as a solution in itself and more as a framework that can support processes, whether that's knowledge sharing, community organizing, or environmental restoration.

Rather than focusing solely on what can be built, I started to ask who architecture is for, how it is built, and how it might evolve with the people who inhabit it. This shift pushed me to explore design as something adaptable, collaborative, and rooted in the everyday realities of those most affected by climate change and infrastructural neglect. It made clear to me that even small interventions, if approached with care and relevance, can contribute meaningfully to larger systems of change.