Year 2025 Chalmers School of Architecture Department of Architecture & Civil Engineering

BIOPHILIUS

Embracing nature-loving biophilic park design in Gothenburg

Author: Frida Tengblad Supervisor: Roos Teeuwen Examiner: Meta Berghauser Pont

The single raindrop never feels responsible for the flood. But for you and me - it will be different from today onwards - we will take responsibility for anything within our sphere of influence. (Adams, n.d)

BIOPHILIUS: Embracing nature-loving biophilic park design in Gothenburg

Chalmers School of Architecture
Department of Architecture & Civil Engineering
Urban and Rural Design and Planning

Frida Tengblad
Master´s Thesis 2025
Examiner: Meta Berghauser Pont
Supervisor: Roos Teeuwen

ABOUT THE AUTHOR

Frida Tengblad tengblad.f@gmail.com
+46 725363228

2025 - 2025 MSc Architecture
Chalmers university of technology
Gothenburg, Sweden

2023 - 2024 Junior architect
Schäublin Architekten AG
Zürich, Switzerland

2022 - 2023 MSc Architecture
Politecnico di Milano
Milan, Italy

2019 - 2022 BSc Architecture
Chalmers university of technology
Gothenburg, Sweden

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Roos Teeuwen, for providing guidance, feedback, and support throughout this process. Your expertise and constructive input have helped me refine my ideas, improve my analysis, and stay focused on the key aspects of this thesis. I appreciate the time and effort you have dedicated to reviewing my work and offering valuable suggestions along the way. I also want to thank my examiner, Meta Berghauser Pont, for the insightful feedback and critical perspective. Your comments have helped me strengthen my arguments and enhance the clarity of my research.

To my family, thank you for your patience, encouragement, and understanding during this process. Your support has made a significant difference. I appreciate your confidence in me and your willingness to help in whatever way possible. To my friends, I am grateful for the motivation, discussions, and moments of distraction hat provided much-needed balance. Your support and perspective have made this journey more manageable and enjoyable. Completing this thesis has been both challenging and rewarding, and I appreciate everyone who has contributed to its progress and completion.

ABSTRACT

Rapid urbanisation in combination with current design and construction methods, has caused cities that are disconnected from nature, vulnerable to climate-related disasters, and detrimental to both ecosystem health and human well-being. Gothenburg is also affected by this trend: its proximity to Göta Älv and the sea makes it prone to flooding, while many residents, especially the youth, report higher stress and anxiety levels. To address these growing challenges, cities must undergo a fundamental transformation in their approach to urban planning and architecture. Biophilic design has the potential to offer a solution by reconnecting people with natural elements in the built environment, creating spaces that support climate adaptation, ecological health and human well-being.

This thesis explores biophilic park design as a strategy to enhance climate adaptation, ecosystem health and well-being in Gothenburg, with a focus on flood mitigation and mental health benefits. Using GIS analysis, literature review, comparative case studies, and research-by-design methodologies, the study examines how biophilic principles can be applied to the city's unique flood challenges, mental health stressors, and climatic context. The thesis investigates design strategies, potential challenges, and solutions at multiple scales to inform sustainable urban planning. This investigation clarifies that incorporating features such as sustainable stormwater management, layered vegetation, and sensory-rich public spaces allows biophilic design to enhance climate adaptation, ecosystem health, and well-being at Lindholmen. Thereby, the resulting park aims to reduce flood risk and support mental health, particularly among the youth, but also contributing to a healthier urban ecosystem. However, applying these principles in Gothenburg's urban fabric presents distinct challenges: the city's cold, dark winters differ significantly from those in best-practice settings, influencing both plant selection and how the park is used. Addressing these conditions in practical urban planning calls for locally adapted species, flexible design solutions, and programming that encourages year-round use. In conclusion, the thesis shows that a biophilic park in Gothenburg can promote climate adaptation, ecosystem health, and well-being while supporting flood mitigation and youth mental health in a Nordic context.

Keywords: Biophilic design I Climate adaptation I Ecosystem health I Well-being I Flood management I Mental health

TABLE OF CONTENT

ABOUT THE AUTHOR

ACKNOWLEDGEMENTS

ABSTRACT

INTRODUCTION

PURPOSE 1
RESEARCH QUESTIONS 1
DISCOURSE 3
METHOD 4
DELIMITATIONS 7

THEORY

WELL-BEING 9
CLIMATE ADAPTATION 11
ECOSYSTEM HEALTH 11
BIOPHILIC DESIGN 12
CONCLUSIONS 14

FROM THEORY TO PRACTICE

BD FRAMEWORK 15
CONCLUSIONS 21

LOCAL CHALLENGES

WELL-BEING IN THE NORDICS 23
GOTHENBURG & FLOODING 26
LINDHOLMEN 26
CONCLUSION 26

BEST PRACTICE STUDIES

GREENACRE PARK 27
BISHAN-ANG MO KIO PARK 36
CHULALONGKORN UNIVERSITY CENTENARY PARK (CUC) 42
FINDINGS FROM THE BEST PRACTICE ANALYSIS 49
CONCLUSIONS 51

IMPLEMENTATION

SITE CONTEXT 53
CONCEPT 56
BD ELEMENTS 71
OPPORTUNITIES & CHALLENGES 73
CONCLUSION 74

CONCLUSION & DISCUSSION

ADDRESSING OBJECTIVES 75
SELECTION OF FRAMEWORKS 77
SELECTION OF BEST PRACTICES 79
IMPLICATIONS 79
LIMITATIONS 79
FUTURE RESEARCH 80
CONCLUSION 80

BIBLIOGRAPHY

APPENDIX A - BD FRAMEWORK MATRICES

1. INTRODUCTION

1.1 PURPOSE

This thesis investigates how biophilic design (BD) can be applied to create a park proposal for Lindholmen, Gothenburg that enhances climate adaptation, ecosystem health, and human well-being while addressing flood mitigation and mental health concerns. As Gothenburg continues to expand and densify, the increasing risks of flooding and mental health stressors highlight the urgent need to reintegrate nature into the urban environment. By examining biophilic interventions at multiple scales, the study explores design strategies, potential challenges, and benefits of implementing biophilic parks within Gothenburg's unique environmental and social challenges, particularly in relation to flood mitigation and mental health. The findings aim to inform practical urban planning solutions that integrate biophilic principles to create a more resilient and livable city.

1.2 RESEARCH QUESTIONS

The research revolves around two central questions:

» *How can biophilic design principles be applied to create a park proposal for Lindholmen that enhances climate adaptation, ecosystem health, and well-being?*

» *What challenges and benefits arise when integrating biophilic park design principles into Gothenburg's urban fabric, considering its unique flood challenges, mental health stressors, and climatic conditions, and how can these factors be addressed in practical urban planning?*

1.2.1 OBJECTIVES

This thesis aims to develop *(1)* a design framework that provides planners with guidance on integrating BD strategies into urban environments with similar contexts as Gothenburg. The framework will serve as a practical tool for incorporating solutions into city planning that benefit climate adaptation, ecosystem health and well-being, with a particular focus on addressing flood risks and mental health challenges. Building upon the insights gained from this framework, the study will also develop *(2)* a design proposal for a biophilic park at Lindholmen. This architectural project will demonstrate how biophilic principles can be translated into a practical urban space, crea-

ting a park that enhances ecosystem health, climate adaptation and promotes well-being, with a focus on flood mitigation and mental health. Additionally, the research will *(3)* analyze the challenges and opportunities of implementing biophilic park design within Gothenburg's unique environmental, social and climatic context. By proposing scalable and adaptable BD strategies, the thesis aims to contribute to sustainable urban planning and resilient city development.

1.3 DISCOURSE

Modern cities are facing an alarming combination of environmental, social, and public health challenges (Zhong et al., 2022). Climate change is intensifying extreme weather events such as heatwaves, heavy rainfall, and flooding, while urban expansion continues to replace natural landscapes with impermeable surfaces, exacerbating these risks (Zhong et al., 2022; Egegård et al., 2024). Additionally, biodiversity loss and ecosystem degradation threaten the long-term resilience of urban areas (Lawler et al., 2013). Simultaneously, urban populations are experiencing a significant decline in mental well-being, a phenomenon associated with increasing alienation from nature (Zare et al., 2022). As cities expand and densify, natural landscapes are replaced with built environments that prioritize infrastructure over ecological balance, reinforcing the Separation between humans and nature.

As these crises intensify, cities are being forced to reconsider how they are designed and built (Cui et al., 2021). The urgent question is no longer whether urban environments need to adapt, but how they can integrate nature to ensure long-term sustainability, adaptability, and well-being.

1.3.1 THE DUAL CRISIS

Among the many environmental challenges that urban areas face, flooding stands out as one of the most destructive (Egegård et al., 2024). Over recent decades, flood events have increased due to rising global temperatures, changing weather patterns, and unsustainable land-use practices. Cities, in particular, are highly vulnerable because imperviable surfaces such as asphalt and concrete prevent natural water absorption, leading to severe surface runoff and overwhelmed drainage systems. The impacts of flooding extend beyond infrastructure damage, it also disrupt ecosystems, displace communities, and contribute to long-term environmental degradation.

At the same time, urban populations are facing a growing mental health crisis, influenced by multiple factors, including high stress levels, limited access to nature, and the overwhelming sensory stimuli of city life (Zare et al., 2022). Research indicates that prolonged separation from natural environments contributes to rising levels of anxiety, stress, and psychological distress. As urban areas expand and green spaces become increasingly scarce, many residents have reduced access to the restorative benefits of nature, which can help alleviate stress, support cognitive function, and enhance overall well-being.

1.3.2 GOTHENBURG & ITS CHALLENGES

Gothenburg exemplifies these pressing issues. Situated near the Göta River and the Sea, the city is highly vulnerable to flooding, a problem that is expected to intensify due to increased rainfall and rising sea levels (Lundqvist, 2015).

Mental health statistics in Sweden further emphasize the city's challenges. Over the past decade, self-reported mental health problems have risen across all age groups, with particularly alarming increases among young people (Fohm, 2022; Nordic Council of Ministers, 2023). These trends underscore the need for urban environments that prioritize psychological well-being, and especially for young people. Reintroducing nature seems a promising approach to tackle these challenges.

1.3.3 BD AS A SOLUTION

In response to the growing challenges facing modern cities, BD has emerged as a transformative approach to urban planning and architecture (Cui et al., 2021). Unlike conventional sustainability measures that primarily aim to reduce environmental impact, BD actively integrates natural elements into the built environment to enhance climate adaptation, ecological health, and human well-being. This reconnection with nature has long-term benefits for both ecosystems and urban residents, particularly in mitigating the effects of climate change and improving mental health (Zare et al., 2022). One of BD's most significant advantages is its ability to address flood management and mental health simultaneously. By incorporating nature-based solutions, BD enhances urban resilience by absorbing excess water, reducing flood risks, and restoring biodiversity while simultaneously creating calming and restorative spaces that support psychological well-being (Egegård et al., 2024; Ristianti et al., 2024). This holistic approach is particularly relevant as flood risks and mental health concerns become increasingly urgent (Ristianti et al., 2024).

For cities like Gothenburg, where flood mitigation strategies and mental health support are critical, BD offers a practical and scalable solution. By integrating biophilic principles into urban planning, cities can become models of resilience and well-being, ensuring long-term sustainability and improved quality of life for residents (Zare et al., 2022). Urban planners and architects can help restore ecosystem health while simultaneously strengthening climate adaptation strategies, making BD a key component of future urban development (Ristianti et al., 2024).

1.3.4 THE ROLE OF PLANNERS & ARCHITECTS

Architects and urban planners play a critical role in implementing BD strategies. The building sector alone accounts for nearly 40% of global energy consumption and carbon emissions, making it a key focus for sustainable development (Zhong et al., 2022). Research suggests that transitioning toward biophilic, climate-adaptive architecture could significantly reduce environmental impact while enhancing urban livability (Zare et al., 2022).

As cities continue to expand, innovative design solutions that integrate nature into dense urban environments will become increasingly necessary (Terrapin, 2016). Studies have shown that biophilic parks, green corridors, and nature-integrated public spaces not only improve urban climate adaptation but also provide healing and restorative benefits for city dwellers (Ristianti et al., 2024). This makes BD a powerful strategy for future urban development, balancing environmental sustainability with human well-being (Newman, 2013).

1.4 METHOD

This master's thesis uses a combined-methods approach to create a BD framework, along with a design proposal for its implementation, that helps urban planners apply biophilic principles in cities like Gothenburg. By combining theoretical research with practical insights, the study ensures that the proposed biophilic park at Lindholmen is specifically designed to address Gothenburg's climatic, environmental and social challenges, with a focus on flood prevention and mental well-being. Figure 1 visualizes the method process used, and their relationships with each other.

1.4.1 LOCAL CHALLENGES

Spatial analysis inspired by Geographic Information Systems (GIS) plays a critical role in evaluating Gothenburg's urban conditions and identifying key intervention areas. A qualitative analysis of GIS data, integrating multiple spatial datasets, informs targeted strategies for climate adaptation, ecological health, and social well-being.. This analysis will draw on datasets including:

» *Flood risk mapping:* Identifies areas prone to flooding to determine where biophilic parks are needed for flood mitigation.
» *Green space distribution:* Identifies existing parks and vegetation to determine how to connect the biophilic park via green corridors.
» *Youth-oriented spaces:* Identifies locations such as schools, to determine where a biophilic park should be placed to enhance mental health among young people.

Insights from these analysis ensure that the BD framework and biophilic park proposal are strategically placed in areas where they will have the greatest impact, maximizing their effectiveness in climate adaptation, ecosystem health and well-being.

GIS-based spatial analysis ensures that the design proposal is located where it is most needed and can make a meaningful impact. By identifying flood-prone areas, green space connectivity, and youth-oriented spaces, GIS supports evidence-based planning, ensuring that interventions effectively address flood risks and mental health challenges.

1.4.2 THEORY & FROM THEORY TO PRACTICE

A literature study will provide the theoretical foundation for understanding BD principles, their application in urban environments, and their potential benefits in addressing climate adaptation, ecosystem health, and well-being. This study will review existing research on BD, climate adaptation, ecosystem health and well-being to identify relevant strategies for the Gothenburg context. It will also contribute to the theoretical framework of the thesis and support the step of translating theory into spatial and visual examples.

LOCAL CHALLENGES

Identifies key areas for intervention and informs targeted design strategies.

GIS-BASED ANALYSIS

INFORMS

THEORY & FROM THEORY TO PRACTICE

The literature study defines key concepts and identifies strategies to inform a research-based, context-specific design approach.

LITERATURE REVIEW

GUIDES

EVALUATES

BEST PRACTICE ANALYSIS

The study draws on international examples to identify adaptable biophilic strategies. Through structured analysis, key insights are tailored to Gothenburg's context, guiding a site-specific design that addresses flood mitigation and mental well-being.

REFERENCE ANALYSIS, COMPARATIVE ADAPTATION MATRIX EVALUATION, CONTEXTUAL ASSESSMENT

INFORMS

IMPLEMENTATION

Used to iteratively develop and refine the park proposal through concept development, prototyping, and testing. Based on the GIS analysis, the literature study and best practice studies, the process ensures the design responds to Gothenburg's environmental and social needs, making it both practical and scalable.

ITERATIVE DESIGN DEVELOPMENT EVIDENCE-BASED INTEGRATION

Figure 1, Method Process

- *Well-being:* Defines well-being, explores its dimensions and relation to sustainability.
- *Climate Adaptation:* Reviewing its defenition, different forms and impact.
- *Ecosystem Health:* Understanding biodiversity restoration and ecosystem services.
- *BD Theory:* Exploring the core principles of BD and its impact on the environment and society.

The literature study ensures that the thesis is grounded in established research, guiding the methodological approach and informing the design proposal with evidence-based principles and spatial/visual interpretations of theoretical insights.

1.4.3 BEST PRACTICE ANALYSIS

Since best practice examples from cities similar to Gothenburg are scarce, this study draws inspiration from the more abundant BD strategies found in regions with different climates and urban conditions. By examining these successful cases, the research helps bridge the knowledge gap in BD for northern cities. The insights gained from these best practice studies will be analyzed to identify key principles and design strategies that can be adapted and modified within the context of Gothenburg. This process ensures that the proposed interventions at Lindholmen are not only informed by proven strategies but also tailored through site-specific assessments and feasibility analysis to effectively address the city's environmental and social challenges, particularly flood mitigation and mental well-being. Two structured analysis matrices will be used to evaluate the best practice studies, namely BD Strategies Matrix (Table 1) and Opportunities and Challenges Matrix (Table 2). The BD Elements Matrix provides a structured overview of BD strategies, illustrating how various elements contribute to climate adaptation, ecosystem health, and human well-being. By categorizing these strategies alongside their associated design elements, the matrix highlights the interconnected benefits of integrating nature into urban spaces.

The Opportunities and Challenges Matrix, helps to evaluate the opportunities and challenges associated with integrating these best practice strategies at Lindholmen, specifically in relation to climate adaptation, ecosystem health, and well-being.

The key best practice studies that will be evaluated in this thesis consists of:

- *Chulalongkorn University Centenary Park, Bangkok:* Showcases flood-adaptive biophilic strategies for urban resilience and water management.
- *Greenacre Park, New York:* Demonstrates compact biophilic interventions that enhance well-being.
- *Bishan-Ang Mo Kio Park, Singapore:* Showcases large-scale biophilic water management and urban ecological regeneration.

The comparative best practice study approach ensures that the biophilic framework and park proposal for Lindholmen are informed by tested solutions, making them adaptable and scalable within Gothenburg's urban planning context.

BD STRATEGIES	DESIGN ELEMENTS	CLIMATE ADAPTATION	ECOSYSTEM HEALTH	WELL-BEING
NATURAL ELEMENTS				
LANDSCAPE				
WEATHER				
TIME & SEASONAL CHANGE				
SPATIAL CHARACTER				
PROSPECT & REFUGE				
ENTICEMENT				
CONNECTION TO PLACE				
CONNECTION OF SPACES				
MECHANISM				

Table 1, BD Strategies Matrix

THEORY	OPPORTUNITIES	CHALLENGES
CLIMATE ADAPTATION		
ECOSYSTEM		
WELL-BEING		

Table 2, Opportunities and Challenges Matrix

1.4.4 IMPLEMENTATION

Research by design serves as a core methodology for iteratively developing and refining the biophilic park proposal. Design exploration, conceptual modeling, and prototyping enable a continuous feedback loop that integrates research findings into practical urban applications. The iterative design process follows as:

» *Phase 1 - Concept Development:* Initial proposals informed by GIS and case study findings.
» *Phase 2 - Prototyping and Testing:* Evaluated against literature and theoretical framework
» *Phase 3 - Refinement:* Iterative design adjustments based on spatial analysis and best practice analyses.

Research by design ensures that the park proposal is not only theoretical but also tested and refined to respond effectively to Gothenburg's environmental and social needs, reinforcing its viability as a scalable urban planning solution.

1.5 DELIMITATIONS

This thesis is scoped to explore the conceptual and applied adaptation of BD in Gothenburg, specifically through the development of a biophilic park at Lindholmen. The focus is on integrating BD strategies to enhance climate adaptation, ecosystem health, and human well-being, particularly in addressing flood mitigation and mental health. To maintain a clear research scope, several aspects are excluded from this study.

TEMPORAL SCOPE

The study does not assess the long-term ecological and social effectiveness of the proposed interventions. Instead, it provides a conceptual framework that can guide future implementation and evaluation.

POLICY & REGULATORY ANALYSIS

While urban policies and governance influence the feasibility of BD, this research does not conduct an analysis of Gothenburg's zoning laws, regulations, or urban governance. Rather than examining policy constraints, the study centres on practical design applications.

QUANTITATIVE IMPACT ASSESSMENT

This research prioritizes qualitative assessments of biophilic strategies, focusing on their conceptual and experiential value rather than engaging in numerical modeling, such as hydrological simulations, carbon sequestration calculations, or economic impact assessments. Instead of quantifying the direct impact of the proposed design on mental health or climate adaptation outcomes, the study relies on existing literature to identify principles that show promise in achieving these goals, rather than testing their effects afterward.

INDOOR BD

The thesis is limited to external urban spaces and does not extend to interior BD elements, such as green walls, atriums, or indoor vegetation.

STAKEHOLDER ENGAGEMENT

The study does not involve participatory design processes, such as community workshops or stakeholder engagement.

ECONOMIC CONSIDERATIONS

Instead of exploring financial feasibility or cost-benefit analyses, the research focuses on the ecological and social value created by biophilic interventions in urban planning

POLARIZATION IN URBAN PLANNING

The study does not engage in discussions of socio-political polarization related to urban green space development. Issues such as political conflicts over land use or competing public space interests fall beyond the scope of this thesis.

INFRASTRUCTURE DEVELOPMENT

Large-scale infrastructure projects, including major transportation networks, stormwater management systems, or urban redevelopment initiatives, are not examined. The research instead emphasizes the integration of biophilic elements within the existing urban fabric, rather than proposing new large-scale infrastructural interventions.

2. THEORY

This chapter provides the theoretical foundation for the thesis, explaining why concepts like well-being, climate adaptation, ecosystem health, and biophilic design are essential for creating sustainable, resilient and livable cities. By exploring these theories, the chapter helps to show how they connect and why they matter for addressing urban challenges such as flooding and mental health issues. The theories discussed here highlight the interdisciplinary nature of the topic, bringing together insights from environmental science, psychology, and urban design. This background is essential for understanding the later sections of the thesis, where real-world examples and design proposals will be presented. Ultimately, this chapter helps shape the main arguments of the thesis by providing a strong foundation for practical applications in urban planning and architecture.

2.1 WELL-BEING

Well-being is a multidimensional concept encompassing various aspects of human life, rather than a singular factor (Betley et al., 2023). The most frequently cited dimensions of well-being include environmental sustainability, physical and mental health, social and cultural identity, and economic stability. While the term is widely used in research, many studies do not explicitly define well-being, and existing definitions vary significantly depending on the field of study. As a result, well-being has evolved into a boundary object, a concept utilized across multiple disciplines without a unified definition.

One common perspective is the social and ecological systems approach, which underscores the interdependence between human well-being and environmental health (Betley et al., 2023). Another widely used framework is outcome-based, which focuses on well-being as measurable outcomes that individuals prioritize in their lives. Subjective well-being, on the other hand, highlights personal perceptions of happiness, satisfaction, and fulfillment. Additionally, Sen's (1999) capabilities approach argues that well-being should not be confined to a rigid set of parameters but should instead be adaptable to individual and cultural contexts.

2.1.1 KEY DIMENSIONS OF WELL-BEING

To fully grasp the complexity of well-being, it is essential to consider its primary dimensions, which

collectively contribute to overall life satisfaction and health (Betley et al., 2023). Physical health plays a fundamental role, as access to healthcare, proper nutrition, and a healthy living environment directly impact well-being. Equally important is mental and emotional well-being, which encompasses psychological stability, emotional resilience, happiness, and effective stress management. Social and cultural well-being also contribute significantly, as meaningful relationships, social inclusion, community support, and cultural identity help shape an individual's sense of belonging. Additionally, economic stability ensures financial security, access to essential resources, and employment opportunities, all of which enhance quality of life. Lastly, environmental well-being, defined by access to clean air, water, and sustainable ecosystems, is crucial to maintaining human health and sustainability.

2.1.2 INTERCONNECTIONS

Rather than being the result of isolated factors, well-being emerges from the interaction of multiple dimensions, demonstrating key interconnections (Betley et al., 2023). For instance, health and economic stability are closely linked, as good health fosters productivity and financial security, while economic stability, in turn, provides access to quality healthcare services. Similarly, environmental quality and physical health are interconnected, with clean air and water reducing disease prevalence and directly contributing to overall well-being. The role of social networks in mental health is also significant, as strong social connections enhance emotional resilience and support effective stress management. Furthermore, cultural and economic factors are interwoven, as economic opportunities influence cultural participation, while cultural identity fosters emotional security and a sense of belonging.

2.1.3 CHALLENGES & STRATEGIES

Recent research highlights that well-being is not merely an accumulation of these dimensions but rather a dynamic system influenced by broader environmental and equity-related factors (Betley et al., 2023). For instance, environmental well-being is increasingly impacted by natural disasters such as floods and droughts, underscoring the urgent need for sustainability within well-being frameworks.

2.2 CLIMATE ADAPTATION

Adaptation strategies refer to actions that enable human and natural systems to accommodate changes brought about by climate variability and change (Lawler et al., 2013). Adaptation refers to the process of making changes to vulnerable systems in response to current or anticipated climate-related factors, aiming to reduce negative impacts or take advantage of possible benefits.

Different forms of adaptation exist, including anticipatory (proactive) and reactive (responsive) adaptation, as well as individual and institutional, and spontaneous and deliberate responses (Lawler et al., 2013). More broadly, adaptation can also be described as modifications to human or natural systems that seek to either mitigate the adverse effects of climate change or take advantage of emerging opportunities.

Adaptation strategies serve as essential tools for helping human and natural systems respond to actual or projected climate changes (Lawler et al., 2013).

2.3 ECOSYSTEM HEALTH

Ecosystem health describes the ability of an ecological system to function effectively, maintain stability, and remain resilient to external pressures (Lu et al., 2017). It is assessed using indicators of functionality and sustainability rather than purely scientific parameters. A healthy ecosystem retains its structure and processes over time, resists stress, and recovers from disturbances.

2.3.1 UNDERSTANDING ECOSYSTEM HEALTH

The concept of ecosystem health integrates ecological function with sustainability principles (Lu et al., 2017). Several perspectives contribute to its definition:

» *Absence of Dysfunction:* Similar to human health, ecosystem health is often defined by the absence of dysfunction, meaning an ecosystem can sustain normal processes such as biodiversity conservation and nutrient cycling.
» *Vital Signs and System Integrity:* Like living organisms, ecosystems exhibit vital signs, biodiversity, productivity, and stability, that indicate their health. Resilient ecosystems can withstand stress and maintain integrity despite disturbances.
» *Sustainability and Resilience:* Sustainability is central to ecosystem health, ensuring ecological functions persist over time. Resilient ecosystems recover from disruptions such as pollution, climate change, or habitat destruction while continuing to provide essential services.
» *Social and Cultural Perspectives:* Perceptions of ecosystem health are influenced by human values and societal priorities. An ecosystem that provides clean air and water may be considered healthy in an urban setting, whereas in conservation, high biodiversity might be prioritized.
» *Normative vs. Scientific Concept:* Ecosystem health is a normative concept shaped by societal goals rather than purely scientific measures. While scientific criteria assess ecosystem function, what is deemed "healthy" depends on broader priorities such as economic sustainability, conservation, and human well-being.

2.3.2 A HEALTHY ECOSYSTEM

A healthy ecosystem is defined by three fundamental characteristics (Lu et al., 2017):

» *Organizational Structure:* Stability in species composition, ecological interactions, and ecosystem function over time.
» *Vigor of Function:* The ability to sustain productivity and key ecological processes.
» *Resilience Under Stress:* The capacity to recover from disturbances while maintaining essential functions.

Ensuring ecosystem health is vital for maintaining ecosystem services, which provide social and economic benefits (Lu et al., 2017). These services be grouped into four categories:

» *Provisioning Services:* Refer to the supply of essential resources like food, fresh water, and raw materials.
» *Regulating Services:* Involve natural processes that help control climate, purify water, reduce the risk of floods, and manage disease spread.
» *Supporting Services:* Underpin ecosystem health through functions such as soil development, nutrient recycling, and the preservation of biodiversity.
» *Cultural Services:* Encompass non-material benefits, including opportunities for recreation, spiritual connection, aesthetic enjoyment, and education. Healthy ecosystems are capable of providing these services even under environmental stress.

A well-functioning ecosystem continues to deliver these benefits despite environmental stressors (Lu et al., 2017).

2.3.3 RESILIENCE AND RESISTANCE

Resilience refers to an ecosystem's ability to recover from disturbances, while resistance describes its capacity to endure stress without significant change (Lu et al., 2017).

Key measures for resilience include (Lu et al., 2017):

» *Time Lag in Response:* Longer recovery times indicate lower resilience.
» *Ecosystem Productivity:* Systems that regain productivity quickly are more resilient.
» *Structural and Functional Recovery:* Measures the ability to restore biodiversity and nutrient cycling after a disturbance.

Key measures for resistance include (Lu et al., 2017):

» *Survival of Key Species:* Stable populations indicate a resistant ecosystem.
» *Primary Productivity:* Consistent production signals strong resistance.
» *Nutrient Cycling:* Maintains essential nutrient flows despite stress.
» *Biodiversity:* High diversity contributes to greater ecosystem resistance.
» *Symbiosis Persistence:* Maintains interdependent species relationships under stress.

2.3.4 DISTURBANCES & HUMAN INFLUENCE

Ecosystem disturbances can be classified as natural (e.g., climate variability, geological events) or anthropogenic (e.g., deforestation, pollution, urbanization) (Lu et al., 2017). Natural stressors impact ecosystems without human feedback, while human-induced disturbances create feedback loops as societies depend on ecosystem services. Addressing global environmental stressors has become an international priority, as ecosystem health directly impacts human well-being.

2.4 BIOPHILIC DESIGN

BD is founded on the principle of biophilia, which describes the inherent desire of humans to relate to and engage with the natural environment (Zare et al., 2022). Wilson (1984) described the biophilia hypothesis as the inherent affection of humans to focus on and affiliate with life and life-like processes. This idea was further developed by Fromm (1964), who defined biophilia as a fundamental love for life and living systems. As humans transitioned from natural to built environments, this inherent connection evolved into a psychological and emotional need to engage with nature (Zhong et al., 2022). Biophilic architecture and urban planning aim to reconnect people with natural elements in the built environment to enhance well-being, ecological health, and resilience (Zare et al., 2022).

2.4.1 BIOPHILIA & BD

In 1993, Kellert conceptualized BD as a direct application of biophilia within the built environment (Zare et al., 2022). This approach integrates nature into architectural and urban design, not only for aesthetic purposes but also to support human psychological and physiological well-being (Zhong et al., 2022). BD is increasingly recognized as a crucial strategy for constructing sustainable cities, as it fosters resilience by merging ecological adaptation with urban structures (Ristianti et al., 2024).

2.4.2 THEORETICAL BASE OF BD

While BD is primarily based on biophilia theory, it also draws from other psychological and environmental theories to explain human responses to natural elements in built spaces (Zhong et al., 2022). Psychological frameworks related to BD can be categorized into cognitive, affective, and evolutionary perspectives. These perspectives contribute to understanding how exposure to nature in urban environments can improve mental health, reduce stress, and enhance cognitive functions (Zare et al., 2022). Table 3 shows how different psychological theories relate to aspects of holistic health. The dots indicate which dimensions of health, physical, cognitive, emotional, social, and spiritual, each theory supports.

Zare et al. (2022) indicate that exposure to natural environments unconsciously renews attention, improving cognitive functions, memory, and problem-solving. According to Attention Restoration Theory (ART), mentally demanding tasks deplete attentional resources and cause fatigue, whereas minimal cognitive effort in nature enables attentional recovery (Zhong et al., 2022). ART also suggests that time in nature reduces stress, alleviates anxiety and sadness, and enhances creativity, vitality, and learning (Zhong et al., 2022; Zare et al., 2022).

Stress Reduction Theory (SRT) highlights nature's role in mitigating stress, leading to positive emotional responses and improved well-being (Zare et al., 2022). Specific natural elements, such as vegetation and water, contribute to this restorative process and support emotional recovery (Zhong et al., 2022). Place Attachment Theory focuses on the emotional bonds individuals form with particular environments and emphasizes how incorporating regional natural features into designs fosters identity, belonging, and social cohesion (Zare et al., 2022; Zhong et al., 2022).

Savannah Theory proposes that humans favor savannah-like landscapes due to evolutionary survival needs, a preference that persists today (Zare et al., 2022; Zhong et al., 2022). Lastly, Prospect and Refuge Theory underscores the need for spaces offering both open views (prospect) and security (refuge), allowing individuals to observe their surroundings without being easily seen, thus promoting comfort and well-being (Zare et al., 2022; Zhong et al., 2022).

2.4.3 BD & MENTAL HEALTH

Building on the psychological and physiological benefits of BD, research highlights the broader implications of human-nature interactions for overall well-being. Numerous studies emphasize that integrating natural elements into built environments enhances physical, mental, social, and spiritual health (Zare et al., 2022). The World Health Organization recognizes that engagement with nature contributes to a holistic sense of well-being, reinforcing the importance of BD in urban planning.

Beyond individual well-being, BD fosters social cohesion by creating environments that encourage interaction and trust. Studies suggest that green spaces and natural elements in urban settings enhance interpersonal relationships and reduce crime, aggression, and social isolation (Zare et al., 2022). Furthermore, access to shared natural spaces supports emotional stability by promoting relaxation and facilitating community engagement (Ristianti et al., 2024).

In densely populated urban areas, where stress and cognitive fatigue are prevalent, BD mitigates these effects by incorporating natural imagery, organic forms, and sensory-rich materials. Research indicates that even indirect exposure to nature can reduce mental strain, enhance clarity, and promote psychological recovery (Ristianti et al., 2024). Public spaces that incorporate biomorphic patterns, water features, and communal green areas provide restorative environments, addressing both cognitive and emotional needs.

2.4.4 BD & FLOOD RISK MANAGEMENT

Beyond its psychological benefits, BD contributes to urban resilience, particularly in flood risk management. Effective water management strategies integrate natural elements, such as wetlands and vegetation, to absorb excess water and reduce runoff, balancing attenuation processes with tributary inputs to mitigate flood risks (Lane, 2017). Green infrastructure solutions, including green roofs, rain gardens, and permeable surfaces, not only improve stormwater management but also support biodiversity and urban cooling (Egegård et al., 2024; Ristianti et al., 2024). Green roofs, for instance, reduce rainwater runoff while enhancing building insulation, contributing to climate adaptation efforts (Ristianti et al., 2024). Similarly, rain gardens filter pollutants and retain excess water, reducing flood peaks and improving water quality.

Water-based interventions, such as constructed wetlands and rainwater harvesting systems, further strengthen urban flood resilience by facilitating natural water retention while simultaneously enhancing ecological functions (Zhong et al., 2022). Expanding green space in urban areas supports climate adaptation efforts, as vegetation helps manage flood risks, moderate temperatures, and improve environmental quality.

By embedding BD principles into urban planning, cities can achieve multiple objectives: improving public health, fostering social connectivity, and enhancing environmental resilience. These strategies contribute to sustainable, adaptive urban environments that support long-term ecological balance and human well-being (Zare et al., 2022; Ristianti et al., 2024; Lane, 2017; Egegård et al., 2024; Zhong et al., 2022).

2.5 CONCLUSIONS

The theories discussed in this chapter show how human well-being, climate adaptation, ecosystem health, and BD are closely connected. Cities are not just collections of buildings and roads; they are living environments where people and nature interact. A key takeaway from this chapter is that improving urban spaces requires a balanced approach, one that considers both ecological sustainability and human health. The research presented here supports the idea that cities should integrate nature into their design, not only to manage climate risks like flooding but also to enhance mental well-being and social interaction. These insights provide a strong basis for the rest of the thesis, which will apply these theories to real-world challenges in Gothenburg. By linking theory to practice, this chapter plays an important role in shaping the final conclusions of the thesis, reinforcing the idea that sustainable urban development must be both environmentally responsible and people-centered. Additionally, this theoretical foundation provides essential background on climate adaptation, ecosystem health, and well-being, which is crucial for understanding and evaluating how the best practices contribute, or fail to contribute, to these outcomes.

THEORIES		HOLISTIC HEALTH DIMENSIONS				
		PHYSICAL	PSYCHOLOGY		SOCIAL	SPIRITUAL
			COGNITIVE - MENTAL	AFFECTIVE - EMOTIONAL		
COGNITIVE PSYCHOLOGY	Attention Restoration Theory	●	●	●		
AFFECTIVE PSYCHOLOGY	Stress Reduction Theory	●	●	●		
EVOLUTIONARY PSYCHOLOGY	Place Attachment Theory		●	●		
	Savannah Theory	●	●	●		
	Prospect and Refuge Theory		●	●		

Table 3, Theoretical Base of BD

3. FROM THEORY TO PRACTICE

The following chapter establishes a methodological foundation for integrating BD in urban park settings. It builds directly on the previous theoretical chapter, which explained why BD matters by exploring concepts such as well-being, climate adaptation, and ecosystem health. Here, those theoretical insights are translated into practical application. By synthesizing key frameworks, from Kellert's explorations of biophilia, to Browning & Ryan's patterns, and Zhong et al.'s optimized approach, this section shows how BD strategies can address both ecological resilience and human well-being in outdoor spaces. Rather than taking a purely theoretical stance, the frameworks highlighted here emphasize direct applicability, guiding landscape design, material selection, and spatial organization. For a context like Gothenburg, where flooding concerns and mental health challenges intersect, the framework serves as a critical guidepost, ensuring that proposed interventions are enhancing climate adaptation, ecosystem health, and well-being.

3.1 BD FRAMEWORK

BD can be systematically implemented through structured frameworks that guide its application. This thesis analyse a BD framework optimized by Zhong et al. (2022) (see appendix A, table A1), which builds upon multiple foundational sources. It integrates 4 of the 17 Sustainable Development Goals (SDGs) (see appendix A, table A2), key concepts from Kellert's BD (2008) (see appendix A, table A3), its later extension on BD Experiences and Attributes (2018) (see appendix A, table A4), and the BD Patterns developed by Browning and Ryan (2020) (see appendix A, table A5) (Zhong et al., 2022).

3.1.1 ZHONG'S OPTIMIZED FRAMEWORK

The optimized BD framework by Zhong et al. (2022) refines existing models by integrating SDGs, Kellert's frameworks (2008, 2018), and Browning and Ryan's BD Patterns (2020) to create a structured, evidence-based approach to biophilic architecture. Aligned with SDG 3 (Health), SDG 11 (Sustainable Cities), SDG 13 (Climate Action), and SDG 15 (Life on Land), the framework enhances urban livability, climate adaptation, and biodiversity conservation (Zhong et al., 2022). It builds on Kellert's principles of direct, indirect, and spatial ex-

periences of nature, refining them for practical application. Additionally, it streamlines Browning and Ryan's (2020) Biophilic Design Patterns, focusing on scientifically validated strategies (Zhong et al., 2022). By bridging theory and practice, this framework provides a clear, structured, and sustainability-driven approach to integrating nature into the built environment, enhancing both human well-being and ecosystem health and climate adaptation.

Architecture's role in advancing the UN SDGs is uneven, with studies identifying nine to eleven SDGs that benefit most from architectural and nature-based solutions (Zhong et al., 2022). However, BD extends beyond these, offering both direct and indirect sustainability benefits. Specifically, it supports SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land). A structured BD framework rooted in the SDGs is essential to maximize these benefits, encompassing tangible improvements such as flood mitigation as well as intangible enhancements like improved mental health.

The foundational works of Kellert (2008, 2018) and Browning & Ryan (2020) provide a comprehensive and progressive understanding of how BD can be systematically integrated into the built environment (Zhong et al., 2022). Each contributes essential insights that bridge the gap between theoretical principles, practical implementation, and measurable outcomes. These works form the basis for developing a structured, evidence-based approach to BD.

By consolidating these frameworks, the BD framework employed in this thesis ensures a systematic and research-driven approach to integrating biophilic strategies. It supports ecosystem health, climate adaptation, and human well-being by aligning biophilic principles with the broader objectives of the SDGs (Zhong et al., 2022).

3.1.2 SDGS

BD supports sustainability by addressing key challenges across multiple SDGs, enhancing health, climate adaptation, and ecosystem health through natural elements. For SDG 3: Good Health and Well-being, it improves air quality, thermal comfort, psychological well-being, and physical activity (Zhong et al., 2022). Key elements include plants, air, daylight, landscapes, and refuge spaces. In SDG 11: Sustainable Cities and Communities, BD fosters safety, inclusivity, and livability, reducing crime and enabling higher-density developments. Essential elements include water, air, plants, landscapes, and connections to place. Addressing SDG 13: Climate Action, it enhances resilience to extreme weather, reduces energy consumption, and mitigates the urban heat island effect using vegetation, daylight, landscapes, and climate-sensitive design. For SDG 15: Life on Land, BD supports biodiversity by protecting and restoring ecosystems through plants, animals, and ecological connections. By aligning with the SDGs, BD creates healthier, more resilient, and sustainable environments that benefit both people and nature.

3.1.3 KELLERT'S FRAMEWORK 2008

Kellert's (2008) framework is grounded in biophilia theory and biophilic values derived from evolutionary psychology (Zhong et al., 2022). It is structured around two key aspects: the categorization system and the specific elements classified within it. The framework defines BD through two dimensions, six elements, and 72 attributes.

3.1.4 KELLERT'S FRAMEWORK 2018

Kellert later revised the framework, refining its structure and focus. In the 2018 iteration, the framework was redefined based on three core experiences of BD and 25 associated attributes, providing a more streamlined and experiential approach to understanding human-nature connections in the built environment Zhong et al., 2022)

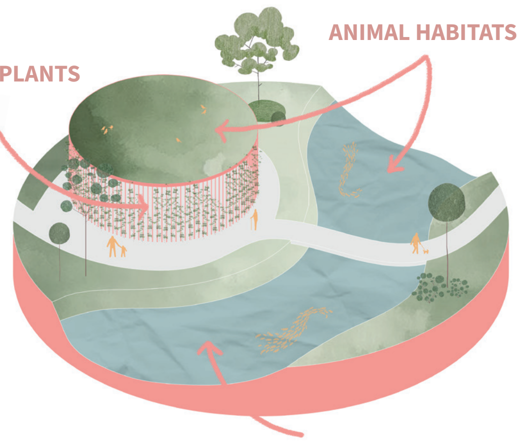
3.1.5 BROWNING & RYAN'S FRAMEWORK

In contrast to Kellert's approach, Browning and Ryan (2020) examine human-nature relationships through the lens of biological responses, focusing on psychological well-being, physiological health, and cognitive functionality and performance (Zhong et al., 2022). Their framework categorizes BD into three main categories and 15 patterns, emphasizing its impact on human health and performance.

3.1.6 BIOPHILIC PARK DESIGN FRAMEWORK

The biophilic framework developed by Zhong et al. (2022) has in this thesis, been refined to better support park design, with a streamlined structure for improved clarity and usability (see appendix A, table A6). To enhance its applicability to outdoor environments, elements primarily relevant to indoor spaces, such as images, air and daylight, have been removed. The remaining biophilic elements have been reorganized into cohesive groups, making them more accessible for understanding, study, and analysis. The revised framework now includes Natural Elements (encompassing of water, plants, animals, and air) and Spatial Character (incorporating form and shape, patterns and geometries, material, texture and color, as well as complexity and order). Additional categories include Landscape, Weather, Time and Seasonal Change, Prospect and Refuge, Enticement, Connection to Place, Connection of Spaces, and Mechanism, which remains in their groups from the original framework. These refinements enhance the framework's applicability to park design, providing a structured yet flexible approach to integrating biophilic principles into outdoor spaces.

NATURAL ELEMENTS



Design Strategies:

Construct waterscapes such as fountains, ponds, constructed wetlands, water walls, rainwater spouts, and aquariums. Provide access to natural water features like waterfalls, rivers, streams, and oceans. Integrate plants into buildings using green roofs, green walls, facades, large atria with park-like settings, and green pockets. Create spaces for animals by incorporating ponds, aquariums, and similar habitats. Design animal-friendly environments with nest boxes, gardens, green roofs, and green walls to attract wildlife.

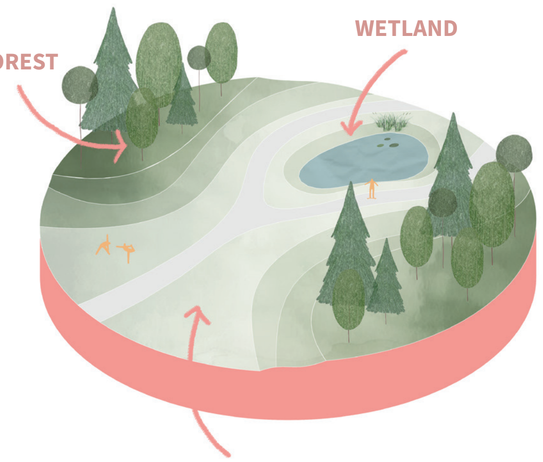
Strengths & Opportunities:

Enhance water experiences with diverse configurations and appearances. Expand water areas and prioritize fluctuating water over stagnant water. Increase green space, native plant coverage, and biodiversity. Incorporate edible plants to support urban farming. Ensure accessible green spaces for physical activity. Strengthen visual connections to nature for well-being. Improve air quality and reduce pollution. Enrich local biodiversity and ecosystem connectivity. (Zhong et al., 2022).

Weaknesses & Threats:

High-volume, turbulent water may impact acoustic quality and humidity. Biophobic reactions can arise, such as fear of deep water. Artificial water features may lead to increased energy consumption. Potential structural issues include excessive humidity, insect problems, and odors. Single plants and isolated gardens have limited ecological impact. Highly artificial designs demand significant energy and maintenance. Certain animals (e.g., snakes, spiders) or dead animals may trigger negative (biophobic) emotional responses. (Zhong et al., 2022).

LANDSCAPE



Design Strategies:

Build landscapes in the sites such as constructed wetlands, grasslands, prairies, forests, and other habitats (Zhong et al., 2022).

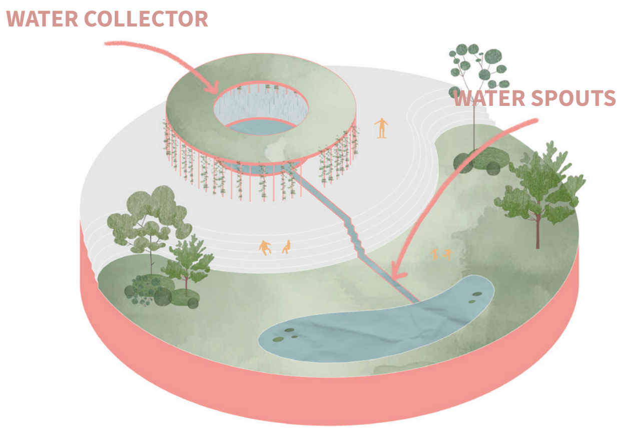
Strengths & Opportunities:

Enhance coherent and ecologically connected landscapes. Optimise the natural landscape, and minimise management requirements (Zhong et al., 2022).

Weaknesses & Threats:

Lack of participation and immersion. Lack of shelter and inappropriate distance and height to view the landscape (Zhong et al., 2022).

WEATHER



Design Strategies:

Enhance exposure to weather. Enhance awareness of meteorological conditions by using transparent roofs, rainwater collectors and spouts, etc (Zhong et al., 2022).

Strengths & Opportunities:

Allow visual access to weather and physical experiences to perceive weather. Integrate rainwater treatment systems into landscape design (Zhong et al., 2022).

Weaknesses & Threats:

Extreme weather conditions and climate change are not beneficial to human health and comfort (Zhong et al., 2022).

TIME & SEASONAL CHANGE

Design Strategies:

Present the views of the material and appearance that change after long-term exposure to nature. Provide views of seasonal changes in plants (Zhong et al., 2022).

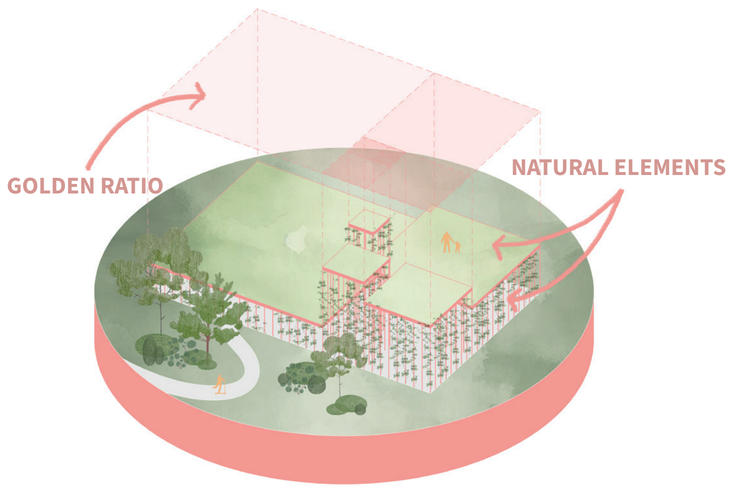
Strengths & Opportunities:

Create a sense of maturity (e.g. materials weathered over time) to resist the inauthentic and unreliable feeling of the artificial environment. Provide various sensory experiences (Zhong et al., 2022).

Weaknesses & Threats:

Building envelopes may be damaged or become dilapidated over time. Perception of seasonal changes depends on individual preferences. Differences in the visual effects of plants in different seasons cause instability (Zhong et al., 2022).

SPATIAL CHARACTER



Design Strategies:

Mimic natural contours and motifs in architecture. Use organic shapes: spirals, ovals, arches, domes, and biomorphic elements. Integrate fractal patterns and hierarchical ratios. Apply Fibonacci sequence and Golden Ratio to floor plans, sections and reliefs. Prioritize natural materials: wood, bamboo, stone, clay. Enhance sensory experiences with textures, light, color, and sound. Use natural colors: blue, green, earth tones. Arrange rich details in an orderly, harmonious way. Incorporate natural forms and patterns in structures and facades (Zhong et al., 2022).

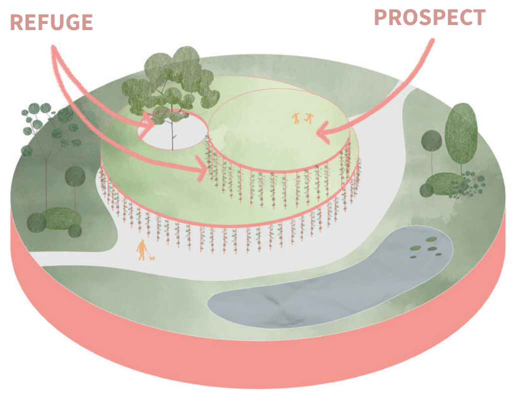
Strengths & Opportunities:

Connect culture, ecology, and design. Inspire architectural creativity. Use computers for complex shapes and materials. Enhance visual richness and natural variability. Allow rough textures for authenticity. Replace high-carbon materials for sustainability. Integrate information into design elements. Arouse visual interest. Apply algorithms for geometric precision. Strengthen environmental harmony (Zhong et al., 2022).

Weaknesses & Threats:

Overuse of forms causes visual boredom. Complex shapes increase costs. Uncertainty in green design effectiveness. Bright or clashing colors create discomfort. Disputes over natural vs. synthetic materials. Repeated fractal patterns may be dull. No consensus on visual richness (Zhong et al., 2022).

PROSPECT & REFUGE



Design Strategies:

Conceive spaces with two complementary characteristics: open views/vistas (prospect), and under shelters/safe environments (refuge) (Zhong et al., 2022).

Strengths & Opportunities:

Provide open views and a sense of closure for simultaneous pleasure and safety. Consider multi-functional prospect-refuge spaces to meet the needs of different activities. Build attractive scenes by providing prospects. Help recover from stress and mental fatigue. Effects can be enhanced by additional complexity and mystery (Zhong et al., 2022).

Weaknesses & Threats:

The balance between prospect and refuge is difficult to define. View qualities depend highly on the surrounding environments (e.g., the view of a lake is considered much more comfortable than that of a glacier) (Zhong et al., 2022).

CONNECTION TO PLACE

Design Strategies:

Provide views of prominent landmarks, landscapes, waterscapes, geological forms, etc. Use indigenous materials and native plant varieties (Zhong et al., 2022).

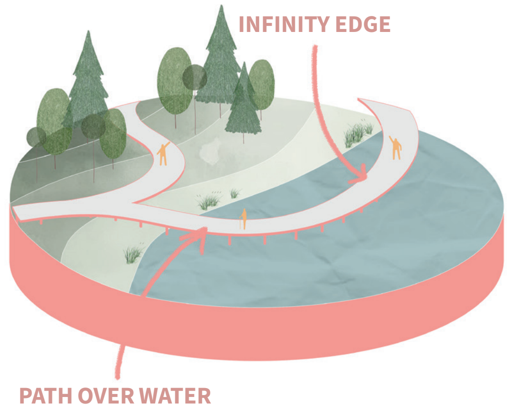
Strengths & Opportunities:

Establish connections through various dimensions (e.g., culture, history, geography, and ecology). Generate a ”sense of place” and satisfy preferences for familiar places (place attachment). Evoke a sense of belonging and support self-identity by integrating parts into the whole (nature bonding). Support relaxation and psychological comfort and security (Zhong et al., 2022).

Weaknesses & Threats:

Misunderstanding of culture and context can lead to inappropriate information or abuse (Zhong et al., 2022).

ENTICEMENT



Design Strategies:

Generate ‘peril’ using cantilevers, infinity edges, transparent facades, pathways under/over water, scenes defying gravity, etc. Create ‘mystery’ through winding paths, translucent materials, imperceptible sound sources, obscuring/curving the edges, etc. (Zhong et al., 2022).

Strengths & Opportunities:

Produce aesthetic attraction. Enhance mystery by slowly revealing spaces or create dramatic shadows. Opportunities to enrich landscapes and plants (Zhong et al., 2022).

Weaknesses & Threats:

Creating experiences of peril carries risks of physical injury. Sense of insecurity can lead to psychological discomfort. Not applicable to all users and locations. Increases maintenance costs in landscaped gardens (Zhong et al., 2022).

CONNECTION OF SPACES

Design Strategies:

Design seamless connections between outdoor spaces like patios, courtyards, pavilions, and gardens. Ensure smooth transitions between different landscapes, such as wetlands, forests, meadows, and urban green spaces. Enhance accessibility and flow in pathways, bridges, plazas, trails, and elevated walkways (Zhong et al., 2022).

Strengths & Opportunities:

Enhance spatial order and create sequential connections of spaces with clear boundaries, ideal patterns of move ment, and the overall identity. Encourage mobility (promenading) to avoid sedentary situations. Enable interaction by reaching differently designed natural scenes via paths or ramps (Zhong et al., 2022).

Weaknesses & Threats:

Transitional spaces are complex and involve multiple challenges for design, construction, and maintenance. Single-function paths can create monotony and boredom (Zhong et al., 2022).

MECHANISM

Design Strategies:

Learn from natural systems to improve durability of outdoor infrastructure to withstand extreme weather. Enhance natural water management and self-regulating landscapes. Innovate flood-adaptive designs (Zhong et al., 2022).

Strengths & Opportunities:

Enhance the efficiency of natural resources and self-regulating systems. Improve the durability of outdoor infrastructure to withstand climate impacts (Zhong et al., 2022).

Weaknesses & Threats:

Inevitable human error in mimicking nature may cause an unbalanced system and further endanger the whole larger ecosystem (Zhong et al., 2022).

3.2 CONCLUSIONS

The framework chapter demonstrates that BD is a structured and strategic approach to integrating natural elements into urban environments to support climate adaptation, ecosystem health, and well-being. By systematically analyzing and refining existing BD models, this thesis establishes a framework that is optimized for practical application in park design, particularly in Gothenburg's flood-prone and mental health-challenged urban context.

Key insights from the framework matrix highlight the strengths and limitations of various BD elements. The analysis of Kellert's (2008, 2018) and Browning & Ryan's (2020) frameworks reveals that while these foundational models provide comprehensive BD classifications, they require refinement for real-world application. Zhong et al.'s (2022) optimized framework successfully integrates these models while aligning them with the Sustainable Development Goals (SDGs), particularly SDG 3 (Health and Well-being), SDG 11 (Sustainable Cities), SDG 13 (Climate Action), and SDG 15 (Life on Land). However, the framework used in this thesis further refines Zhong et al.'s model to enhance usability, facilitate analysis of best practice studies, and make it more applicable to park design.

The matrixs also reveal the practical trade-offs of implementing BD strategies. While elements such as plants, water, air, and daylight enhance psychological restoration, biodiversity, and climate adaptation, they also present challenges such as maintenance costs, energy consumption, and potential biophobic reactions (e.g., fear of certain animals or deep water). By evaluating these opportunities and risks, the adapted framework ensures a more balanced and context-sensitive application of BD.

Ultimately, the findings from this framework confirm that BD can effectively address both climate adaptation, ecosystem health and mental well-being in urban settings. By bridging theory with practical application, the thesis provides a structured methodology for implementing BD in Gothenburg's urban parks, demonstrating how nature-based solutions can create resilient, health-supportive, and ecologically integrated public spaces.

4. LOCAL CHALLENGES

The analysis of local challenges provides an overview of two interrelated challenges; rising mental health issues among young people in Sweden and increasing flood risks in Gothenburg, that directly shape the design and planning context of this thesis. By examining current research on mental health trends and exploring the region's susceptibility to flooding events, the chapter highlights why these issues are critical for developing more resilient and supportive urban environments. In particular, Lindholmen, Gothenburg, emerges as an essential study area due to both its vulnerability to flooding and its potential to incorporate inclusive design approaches for improved well-being among young people. By detailing the scope and significance of mental health and flood-related challenges, this chapter establishes the broader context in which the thesis aims to propose integrated, BD strategies that address climate adaptation, ecosystem health and well-being.

4.1 WELL-BEING IN THE NORDICS

According to the Nordic Council of Ministers (2023), recent studies indicate an increase in mental health issues in the region. These trends highlight the pressing need for mental health interventions and policy initiatives to address this challenge (Nordic Council of Ministers, 2023).

4.1.1 MENTAL HEALTH IN SWEDEN

In Sweden, the majority of both children and adults report generally good health (Fohm, 2022). However, many individuals also experience recurring physical and mental health issues, such as headaches, low mood, and sleep difficulties. Over the past decade, self-reported nervousness and anxiety have become more prevalent among the Swedish population aged 16 to 84. The proportion of individuals experiencing these symptoms rose from 31% in 2011 to 42% in 2021, with most reporting mild symptoms. However, approximately 7% of the population described their anxiety as severe.

4.1.2 MENTAL HEALTH AMONG YOUTH

The increase in mental health issues is particularly evident among young people in Sweden (Fohm, 2022). Since the mid-1980s, self-reported mental and physical health complaints have become more common among school-aged children, especially among 13- and 15-year-old girls. Data from 2021 revealed that 20% of young women reported experiencing severe nervousness or anx-

Figure 2, Map of Gothenburg scale 1:100 000

Size:
26, 500 m²

Green network:
Lindholmen has close access to green areas like Keillers Park, Slottsberget, and the parks at Chalmers.

Blue network:
Lindholmen has direct access to blue infrastructure through its waterfront location along Göta Älv, that integrates the district with Gothenburg's broader water network.

Context:
Lindholmen's surroundings are characterized by a mix of mid-rise buildings, open public spaces, and former industrial structures. The area combines housing, education, offices, and cultural venues, creating a varied urban fabric with moderate density and a dynamic flow of people.

SCHOOL BUILDINGS: FLOOD-PRONE AREAS:

Figure 3, Map of Gothenburg scale 20 000, displaying flood-prone areas, school buildings, green spaces and the project site.

iety, compared to 9% in 2011. Among young men, the percentage increased from 5% in 2011 to 10% in 2021. Overall, mental health problems are on the rise across all age groups in Sweden, with young people, especially young women, being disproportionately affected. While most individuals experience mild symptoms, the increase in severe anxiety cases underscores the need for early intervention and improved mental health support. These findings align with broader research from the Nordic Council of Ministers (2023), which emphasises that mental ill-health is becoming more prevalent, particularly among young adults. While girls and young women are more frequently affected, mental health issues are also increasing among boys and young men. Addressing these challenges requires comprehensive strategies, including increased mental health services, prevention efforts, and policy initiatives to support psychological well-being in Sweden and the wider Nordic region (Nordic Council of Ministers, 2023). Among these, the built environment plays a crucial role; by leveraging the restorative capacity of natural elements in urban contexts, it can offer vital support for psychological health in everyday life (Zare et al., 2022).

4.2 GOTHENBURG & FLOODING

As shown in Figure 2, the Gothenburg Metropolitan Area is highly susceptible to flooding due to its geographical location along the Göta River and its tributaries, as well as its proximity to the sea (Lundqvist, 2015). The region has experienced significant flooding events in the past, such as the 2006 flood along the Mölndal River, which was caused by heavy precipitation and extreme weather conditions. In recent decades, the frequency and intensity of floods have increased, largely due to climate change and unsustainable land management practices (Egegård et al., 2024). Urban areas are particularly affected, as impermeable surfaces like concrete and asphalt limit natural water absorption, leading to a higher risk of flooding.

As floods continue to be one of the most common extreme weather events, their impact on property, infrastructure, and human safety remains a growing concern in Gothenburg (Egegård et al., 2024). The city's vulnerability highlights the need for strategies to address increasing flood risks in urban environments.

4.3 LINDHOLMEN

Lindholmen is a vibrant and diverse district in Gothenburg, where historic shipyards and industrial areas blend with cutting-edge architecture and innovation (Göteborgs Stad, n.d.). The area is home to numerous tech and mobility companies, as well as research and educational institutions. Located along the northern shore of the Göta River, Lindholmen offers scenic views of the southern waterfront and direct access to the water. Over the past years, Lindholmen has evolved significantly, and its development continues. The goal is to better connect the district to the city center across the river and to add more housing, offices, and schools. New developments like Lindholmshamnen and Karlastaden will add around 1,800 new homes and 3,500 workplaces, along with a school for approximately 500 students. These changes are shaping Lindholmen into a more dynamic urban district where businesses, education, housing, culture, and restaurants coexist. As Lindholmen is still developing, it offers an opportunity to incorporate biophilic principles early in the planning process. Its ongoing transformation makes it a suitable context for exploring how such interventions can contribute to future urban development.

Building on this overview of Lindholmen, a GIS-based spatial analysis (Figure 3) was carried out to understand the district's key vulnerabilities and assets. Three thematic layers were mapped and cross-referenced: flood-prone areas, the distribution of school buildings, and green space conductivity. **The resulting composite map indicates that the project site is exposed to flooding, hosts a high concentration of young people, and benefits from immediate access to a network of sizeable green-blue areas.**

4.4 CONCLUSIONS

In summary, local challenges demonstrates that mental health concerns, especially among young people, and recurring flood risks are significant and intertwined challenges in Gothenburg. While Sweden's youth report increasing rates of nervousness and anxiety, the city's environment also faces intensified flood hazards due to climate change and urban development patterns. Lindholmen exemplifies how a single location can be both affected by flooding and serve as a site where targeted interventions can help bolster psychological well-being, climate adaptation and ecosystem health. By underlining the urgent demand for climate-adaptive measures and mental, and ecosystem health support, the chapter reinforces the thesis aim of proposing a holistic framework that fosters social resilience and environmental sustainability.

5. BEST PRACTICE ANALYSIS

Best Practice analyses serves as a vital anchor for the thesis, illustrating how BD can be successfully implemented across various urban contexts. By examining real-world examples and analyzing their design elements, we gain a deeper understanding of how BD solutions can be integrated into public spaces to enhance climate adaptation, promote ecosystem health, and improve mental well-being. Through comparative matrices and structured best practice studies, the chapter clarifies which strategies translate effectively from one city to another, reinforcing the idea that BD is adaptable and scalable to diverse environments. Additionally, the chapter critically examines the challenges and opportunities associated with implementing these strategies and design elements within Gothenburg's unique environmental, social, and climatic context, ensuring a nuanced understanding of both the benefits and limitations of biophilic interventions.

Crucially, these best practice cases underscore the connection between sustainable urban planning and broader societal challenges, such as well-being strain, the need for climate adaptation, and ecosystem health preservation. By focusing on each project's objectives, design choices, and impacts, this chapter builds a strong foundation for the design interventions proposed in the thesis.

5.1 GREENACRE PARK

Tucked between the towering buildings of Midtown Manhattan, Greenacre Park is, as shown in Figure 4 & 5, a 557 m² retreat that offers a rare moment of quiet in the bustling city (Terrapin, 2016). Designed by Sasaki, Dawson, DeMay & Associates, this publicly accessible park was completed in 1971 and has since become a cherished space for relaxation and respite. At the heart of the park, a 7.6-meter waterfall cascades down, cooling the air and softening the noise of city traffic, creating a peaceful atmosphere. The park's three distinct levels accommodate visitors with various environmental conditions, allowing for both social interaction and solitude. Its thoughtful spatial configuration and integration of BD principles ensure a sense of tranquility, even during peak hours.

Greenacre Park serves as a restorative space, inviting city dwellers to pause for a morning coffee, lunch

Figure 4, Map of New York scale 1:100 000

Size:
557 m²

Green network:
Greenacre Park is a small, enclosed pocket park. It is not physically connected to nearby green areas like Bryant Park, the East River Esplanade, and Tudor City Greens, but functions as an independent green oasis within walking distance of other public spaces.

Blue network:
Greenacre Park is not directly connected to blue infrastructure but lies relatively close to the East River, which forms part of the area's broader waterfront and blue network.

Context:
Greenacre Park is situated within a dense urban environment, surrounded by mid-rise and high-rise buildings. The area features a structured urban layout with direct access from surrounding neighborhoods and community amenities.

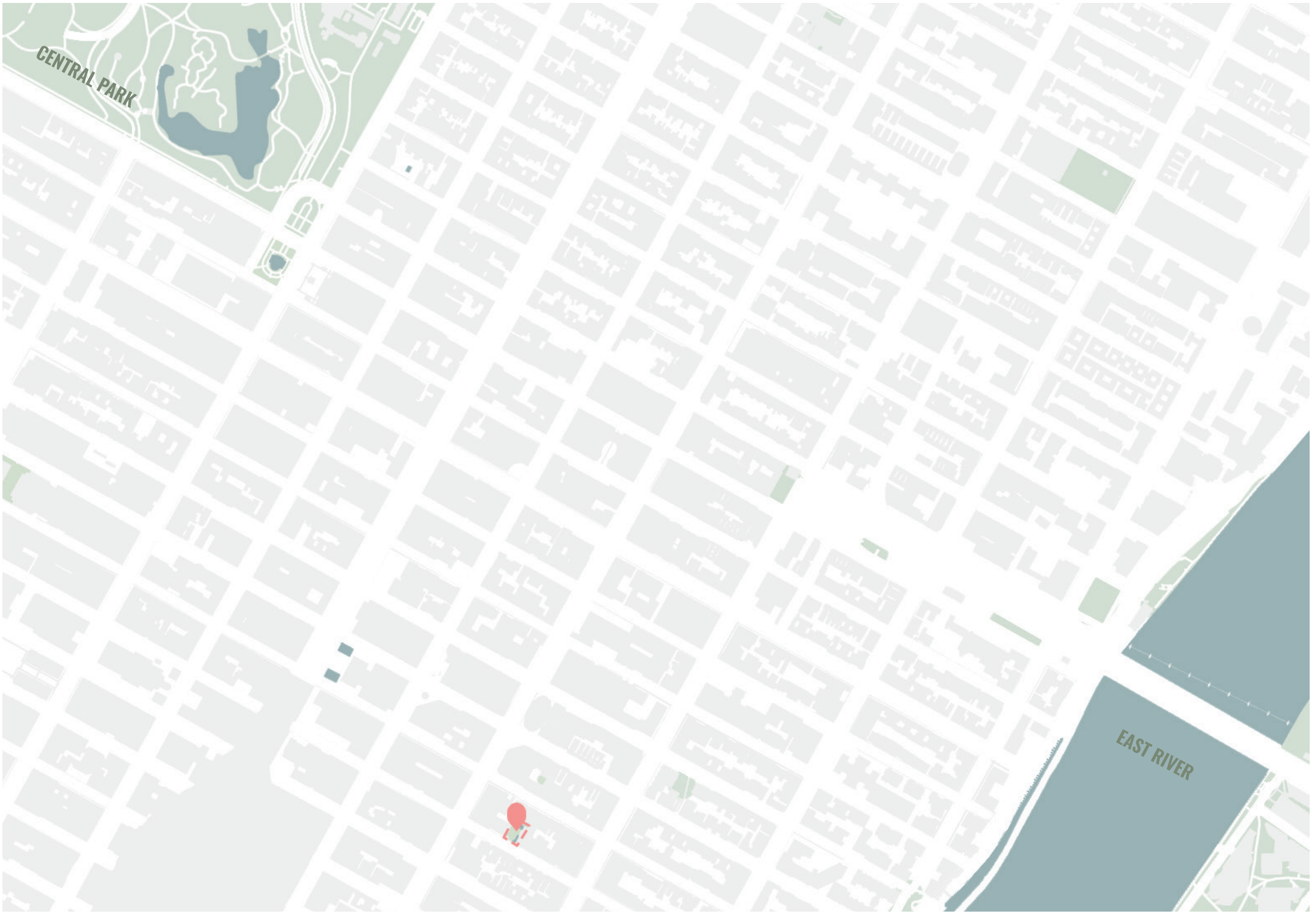


Figure 5, Map of New York scale 1:4000, displaying the location and context of Greenacre Park.

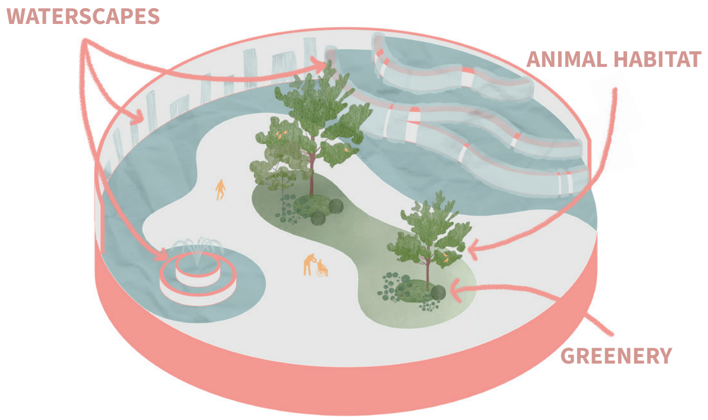
break, or an afternoon meeting (Terrapin, 2016). Recognized for its excellence in landscape design, the park has received prestigious awards, including the BSLA Merit Award (1986) and the American Association of Nurserymen Landscape Award (1972).

5.1.1 BD ELEMENTS

As shown in Table 4, for Greenacre park, natural elements, such as water, air, light, flora, and fauna, play a crucial role across all three focus areas, supporting climate adaptation, ecosystem health, and well-being. Other strategies, like time and seasonal change, spatial character, prospect and refuge, enticement, and connection of spaces primarily enhance well-being by enriching sensory experiences. Additionally, mechanisms such as natural air conditioning serve a variuos purpose, promoting well-being, climate adaptation and ecosystem health by utilizing passive cooling and ventilation strategies.

By mapping out these relationships, the matrix demonstrates the potential of BD to create more sustainable, adaptable, and livable urban environments. In the following sections, each BD element will be explored in greater detail, examining its role, implementation, and impact.

NATURAL ELEMENTS



Greenacre Park is shaped by the natural elements of water, greenery, and fauna. At the entrance, a stone sculpture guides a slow trickle of water into a pool, which then flows along a narrow runnel stretching the length of the eastern wall (Terrapin, 2016). Along this wall, a relief sculpture made of rough-hewn stones features an invisible source of water, allowing it to seep through hidden openings and trickle down the textured surface, down to the runnel. At the intersection of the northern and eastern walls, the runnel meets the fundament of a 7.6-meter tall waterfall.

Lush vegetation fills the space, with a canopy of honey locust trees filtering light and casting shifting shadows (Ibrahim & Al-Chaderchi, 2022). Shrubs and groundcover plants provide layers of greenery, while the western wall is draped in a dense covering of ivy (Terrapin, 2016). Above, the treetops provide a home for songbirds, their calls mingling with the sound of flowing water. Though the city's noise is present at ground level, the upper canopy remains a lively habitat, reinforcing the park's connection to the natural world (Ibrahim & Al-Chaderchi, 2022).

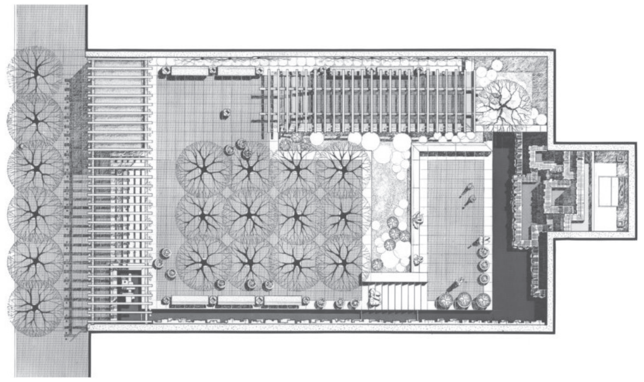
TIME & SEASONAL CHANGE

Along the ivy-covered western wall, a raised platform is shaded by a patinaed steel trellis, which evolves over time, its surface gradually deepening in texture and colour (Terrapin, 2016). The patinaed steel trellis´s weathered look over time, reinforces an authentic atmosphere, countering the artificiality of urban environments (Zhong et al., 2022).

SPATIAL CHARACTER

The natural texture and earthy scent of stone enhance Greenacre Park's sensory experience (Terrapin, 2016). Visitors engage with the space through sight, sound, and touch, immersing themselves in the gentle trickle of water, the melodic birdsong, and the rough texture of granite benches. The air, filtered through lush greenery, carries fresh, fragrant notes, while a cool breeze from the water provides a refreshing contrast to the urban surroundings. Light filters through the tree canopy at varying levels, creating a dynamic interplay of shadows and illumination. For a brief period each day, an opening in the canopy allows sunlight to cascade onto the water's surface, adding a fleeting yet mesmerizing shimmer to the space. The visual complexity of Greenacre Park's water features, natural materials, layered tree canopy, and dynamic light interplay transform its compact layout into a rich and dynamic sensory experience.

Greenacre Park. From Sasaki by Arielly, M., & Frankel, F., n.d., https://www.sasaki.com/projects/greenacre-park/



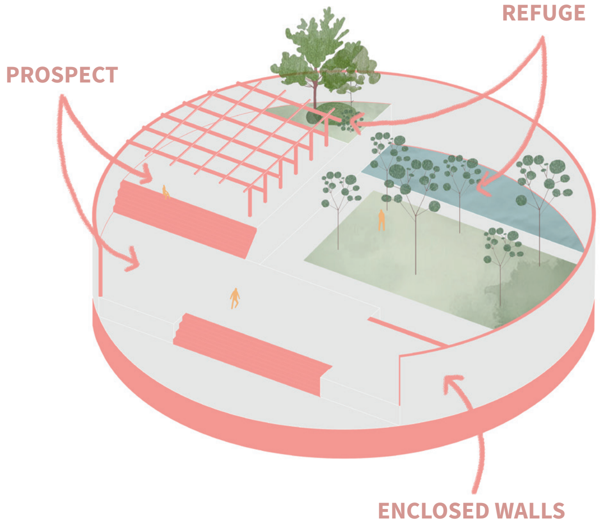
Greenacre Park Floorplan. From Sasaki by Sasaki, 1971, https://www.sasaki.com/projects/greenacre-park/

Greenacre Park Section. From Sasaki by Sasaki, 1971, https://www.sasaki.com/projects/greenacre-park/

BD STRATEGIES	DESIGN ELEMENTS	CLIMATE ADAPTATION	ECOSYSTEM HEALTH	WELL-BEING
NATURAL ELEMENTS	Water features, Air, Light, Flora and Fauna	●	●	●
LANDSCAPE				
WEATHER				
TIME & SEASONAL CHANGE	Greenery that changes depending on season and Material that ages			●
SPATIAL CHARACTER	Natural materials, textures, scents and sounds, light and shadows and visual richness.			●
PROSPECT & REFUGE	Open views and safe environments			●
ENTICEMENT	Mystery, curiosity and luring paths.			●
CONNECTION TO PLACE				
CONNECTION OF SPACES	Natural transitions between spaces and mobility in spaces.			●
MECHANISM	Natural air conditioning	●	●	●

Table 4, BD Elements Matrix

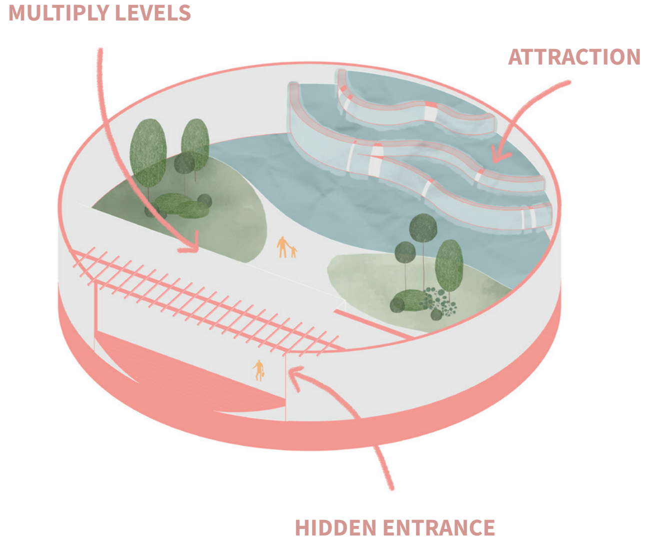
PROSPECT & REFUGE



Greenacre Park is enclosed by three walls, creating a secluded oasis filled with dense greenery, cascading water, and textured grey stone, effectively insulating it from the surrounding cityscape (Terrapin, 2016). Slightly elevated above street level, the park is further distanced from urban noise and activity. Upon ascending the stairs, visitors enter an open platform with small tables, shaded by a canopy of trees. As the largest and most social of the park's areas, this space fosters interaction while maintaining a serene atmosphere, even during peak hours.

To the park´s west, an ivy-covered wall borders a raised platform shaded by a weathered steel trellis (Terrapin, 2016). This area provides a quieter retreat from the social energy of the main level, offering an elevated vantage point that enhances both a sense of security and a balance between openness and seclusion. The filtered light and overhead covering contribute to a sense of enclosure without complete isolation, making it an ideal space for those seeking a middle ground between engagement and solitude. The lower level, partially enclosed yet open to the sky, offers the most immersive sense of refuge. Depressed several feet below ground, it obscures the street from view, replacing the urban scene with lush greenery and the soothing presence of water. The waterfall's continuous flow not only enhances the sensory experience but also muffles street noise and conversation, deepening the feeling of solitude. The contrast between open sky and surrounding walls creates an intimate yet expansive atmosphere, reinforcing the sense of being removed from the city while still maintaining a connection to natural elements. With fewer seating options than the upper levels, this space naturally encourages quiet reflection, making it a favored spot for solitary visitors seeking a moment of introspection.

ENTICEMENT



Greenacre Park's entrance is understated, blending seamlessly with the surrounding buildings (Terrapin, 2016). Without an awning extending over the sidewalk, its patinaed steel trellis and stairs align with the adjacent walls, making it easy to overlook until directly in front of the entrance. The park's design further conceals its interior from the street, with the ground level slightly elevated and the lower level recessed, limiting visibility from the sidewalk. This layering creates an element of surprise, as the lush greenery and flowing water remain hidden until visitors step inside. In contrast to the park´s inconspicuous entryway, the waterfall acts as a visual anchor, drawing attention and leading visitors toward the northern staircase. As they descend, they notice a sunken oasis bathed in sunlight and cooled by mist. A flower-lined stone bench faces the cascading water, which tumbles over multiple tiers before flowing into a runnel along the eastern wall. The park's varied elevations enhance its sense of depth, making it feel more expansive than its compact footprint suggests.

CONNECTION OF SPACES

Greenacre Park functions as an urban courtyard, naturally transitioning from the busy city into a secluded green space. Its raised entry, sunken lower level, and trellised entrance create a smooth shift from urban to natural surroundings. The park's pathways, stairs, and different elevations encourage movement, guiding visitors through multiple perspectives and experiences rather than a single, linear route.

MECHANISM

Cool air rises from the water features, while tree shading and movable furniture provide adaptable comfort, reducing the need for mechanical cooling (Ibrahim & Al-Chaderchi, 2022). This passive design strategy enhances thermal comfort and the evaporative effect of the water features further contributes to natural air conditioning, enhancing overall comfort.

5.1.2 BENEFITS OF GREENACRE PARK

Greenacre Park offers numerous benefits by fostering a strong connection between visitors and nature. The park's natural elements, including trees, shrubs, and ivy-covered walls, create a layered ecosystem that supports urban biodiversity (Terrapin, 2016). The honey locust canopy provides vital shelter for songbirds, while the park sustains various insects and small wildlife, enriching the natural balance of the city (Ibrahim & Al-Chaderchi, 2022). Additionally, interacting with these natural elements has been shown to lower systolic blood pressure, reduce stress hormones, and enhance cognitive performance, concentration, and psychological responsiveness (Terrapin, 2016). These factors contribute to improved mental well-being, tranquility, and overall health. Beyond its visual appeal, Greenacre Park offers a multi-sensory experience that stimulates curiosity while providing comfort. The dynamic interplay of natural sounds, scents, and textures fosters a deeper connection with the environment, creating a restorative atmosphere. These sensory elements enhance relaxation, strengthen social interactions, and contribute to a more efficient and pleasant urban setting for living and working.

The park's spatial design also plays a key role in its benefits. Its carefully planned layout provides a retreat from the noise, heat, and smells of Midtown Manhattan, offering a peaceful refuge where greenery and flowing water create a calming environment (Terrapin, 2016). Scenic views and natural prospects encourage relaxation, improve focus, and promote a sense of security, allowing visitors to recover from stress and mental fatigue. Additionally, the layered design, from the raised entrance to the sunken lower level, ensures smooth transitions between spaces, fostering relaxation while catering to diverse visitor preferences. The interconnected paths, stairs, and seating areas encourage physical activity and exploration, reducing sedentary behaviour while offering varied perspectives of the park.

An essential aspect of Greenacre Park is its element of enticement. The discreet entrance allows visitors to experience a moment of surprise and delight upon discovering this hidden oasis within the city (Terrapin, 2016). Moreover, the park contributes to urban sustainability by mitigating the heat island effect. The strategic placement of vegetation provides seasonal shade, fresh air circulation, and an overall cooling effect, making the park a valuable addition to the urban landscape (Ibrahim & Al-Chaderchi, 2022).

5.1.3 WEAKNESSES OF GREENACRE PARK

Despite its many benefits, Greenacre Park faces several challenges that may limit its effectiveness in urban sustainability and accessibility. One of the most resource-intensive features is the 7.6-meter waterfall, whose environmental impact is u clear due to the lack of confirmation regarding the use of r newable or recycled water (Ibrahim & Al-Chaderchi, 2022). Additionally, the absence of a sustainable energy source to power its flow further weakens the park's co servation efforts. Concerns about sustainability also extend to decorative elements, such as the inclusion of a stone sculpture. While it may enhance the park's artistic character, the use of valuable natural materials for ornamental purposes can be seen as excessive, conflicting with broader conservation priorities.

5.1.4 OPPORTUNITIES & CHALLENGES

Implementing design elements inspired by Greenacre Park in Lindholmen, Gothenburg, presents both promising opportunities and notable challenges across several aspects, including climate adaptation, ecosystem health, and well-being.

As shown in Figure 5, in Lindholmen, incorporating a water feature reminiscent of the Greenacre Park waterfall could be adapted to serve as a stormwater retention or conveyance feature, helping temporarily store and slowly release floodwaters. Such a system could be integrated with green infrastructure. Another opportunity is ecosystem health. Greenacre Park's diverse plant life supports urban biodiversity, providing shelter for birds and pollinators. In Lindholmen, a similar approach could strengthen local ecosystems by incorporating native trees and shrubs that attract wildlife.

From a well-being perspective, a Greenacre-inspired park in Lindholmen could offer an essential retreat from the fast-paced urban surroundings. Its BD emphasizing water sounds, natural materials, and shaded seating areas, can create a restorative atmosphere that reduces stress and promotes mental health. The diversity of spaces, from quiet corners for solitude to more open areas for social interaction, in several different levels, would cater to different user needs. Furthermore, the sensory engagement provided by the combination of water, stone, and greenery would enhance the overall visitor experience, encouraging relaxation and a deeper connection with nature. Finally, Greenacre Park's discreet entry reveals an unexpected oasis within a dense urban block. Translating that sense of discovery into Lindholmen's waterfront context can enrich visitors' experiences and encourage repeated visits.

However, several challenges must be considered in adapting these design principles to Lindholmen. In terms of climate adaptation, one key concern is the sustainability of water features. Greenacre Park's large waterfall, while visually striking and acoustically soothing, may be energy-intensive and require significant water resources. This excessive use of resources does not align with biophilic values.

There are also challenges related to ecosystem health. While Greenacre Park supports biodiversity in an urban setting, replicating its approach in Lindholmen would require careful selection of plant species to ensure they align with the local ecosystem and climate. Non-native species, if introduced, might disrupt existing ecological balances rather than support them.

Finally, ensuring well-being through park design presents its own set of challenges. Greenacre Park's enclosed nature creates a sense of refuge from the surrounding city, but in Lindholmen, a more open waterfront setting might make it harder to achieve the same level of tranquility. Adapting the design to balance openness with the sense of seclusion that makes Greenacre Park so inviting would require thoughtful spatial planning.

In conclusion, while a Greenacre-inspired park in Lindholmen holds immense potential for enhancing climate resilience, biodiversity, and urban well-being, its successful implementation would require a careful balance between sustainability, ecological integrity, and inclusivity. By addressing these challenges through thoughtful design and planning, Lindholmen could benefit from a unique and valuable green space that enriches both the environment and the community.

THEORY	OPPORTUNITIES	CHALLENGES
CLIMATE ADAPTATION	Water features reminiscent of the Greenacre Park waterfall could be adapted to serve as a stormwater retention or conveyance feature.	Energy-intensive features require substantial water resources.
ECOSYSTEM HEALTH	Native and diverse flora can enhance local ecosystems and creating a healthier urban environment for both humans and wildlife.	Selection of plant species that align with the local ecosystem is essential, as non-native species could disrupt ecological balance rather than support it
WELL-BEING	Sensory Engagement, fosters a calming atmosphere that reduces stress and supports mental well-being. Varied spaces, in various levels, cater to both solitude and social interaction. The park´s discreet entry ewokes a sense of discovery which enrich visitors' experiences.	Greenacre Park's enclosed nature fosters tranquility, but Lindholmen's open waterfront setting may reduce this effect. Thoughtful spatial planning is needed to balance openness with a sense of refuge.

Table 5, Opportunities and Challenges Matrix

BEST PRACTICES
BIOPHILIUS - RESULT

Figure 6, Map of Singapore scale 1:100 000

Size:
620, 000 m²

Green network:
Bishan-Ang Mo Kio Park is well connected to surrounding green areas through a series of paths, green buffers, and nearby parks. It links smoothly with spaces like Ang Mo Kio Town Gardens and Windsor Nature Park, forming part of a larger green landscape that supports ecological flow across the area.

Blue network:
Bishan-Ang Mo Kio Park is closely connected to blue infrastructure through the naturalized Kallang River, which flows through the park and links it to the wider urban water system.

Context:
Bishan-Ang Mo Kio Park is surrounded by high-density residential blocks, schools, and local roads. The area features a structured urban layout with direct access from surrounding neighborhoods and community amenities.

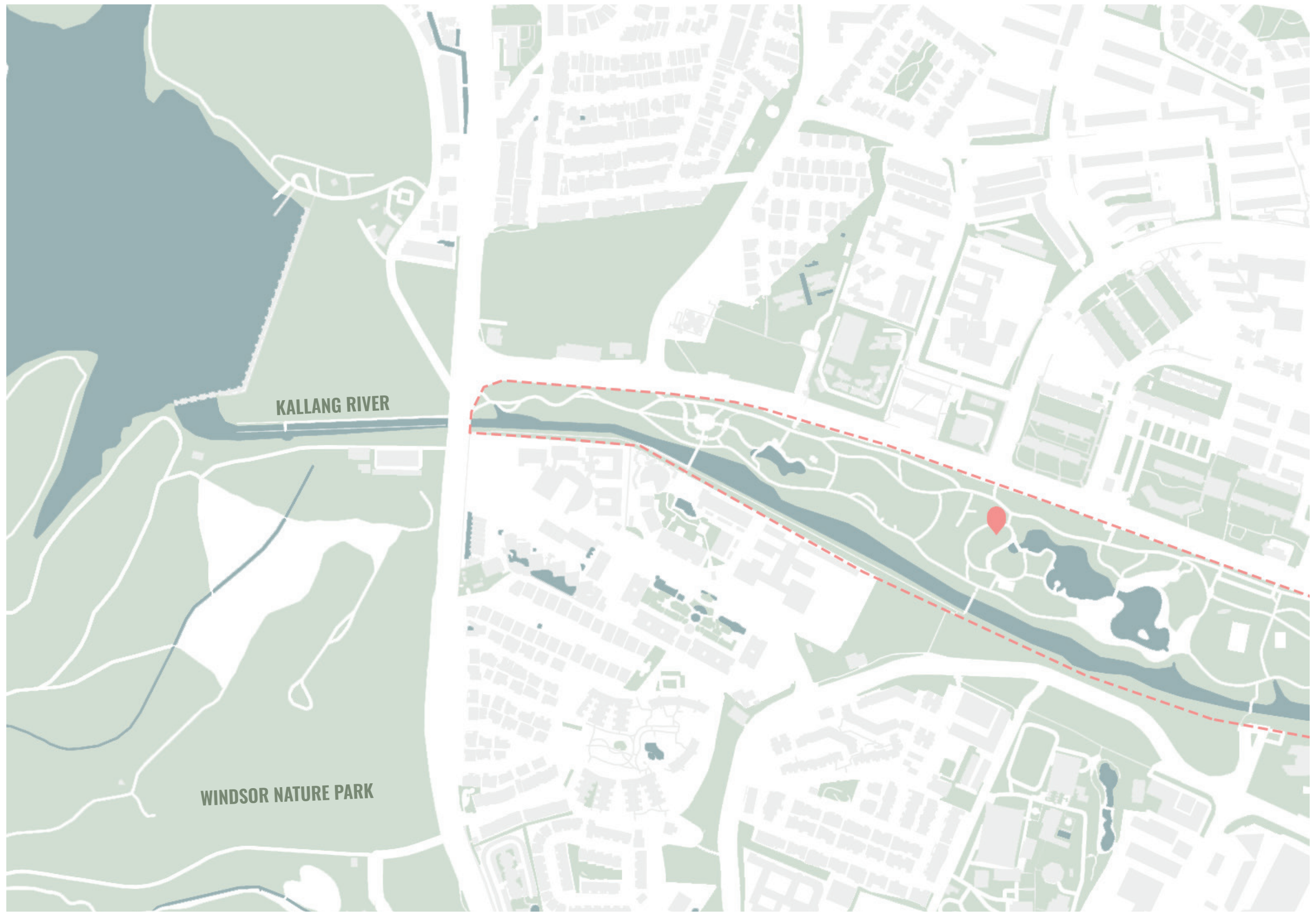


Figure 7, Map of Singapore scale 1:4000, displaying the location and context of Bish-Ang Mo Kio Park.

5.2 BISHAN-ANG MO KIO PARK

Despite being an island nation, Singapore offers few opportunities for residents to engage with water (Schaefer, 2014). One exception is Bishan-Ang Mo Kio Park, a 62-hectare green space that underwent a major transformation under the Active, Beautiful, Clean Waters (ABC Waters) Programme, launched in 2006 by the Public Utilities Board (PUB) to integrate water management, sustainability, and urban aesthetics. Historically, the Kallang River ran through the park as a 2.7-kilometer concrete canal, restricting access and creating safety risks. As shown in Figure 6 & 7, instead of expanding it with traditional concrete infrastructure, PUB and Singapore's National Parks Service (NParks) worked to naturalize the waterway, creating a meandering river with floodplains and vegetated bioswales to improve flood control, water purification, and biodiversity (Qihui, 2018; Cui et al., 2021). The redesign also helped manage intensifying rainfall events, while restoring wildlife, including vulnerable species (Cui et al., 2021). Singapore's broader strategy includes nature-based solutions for climate resilience, such as mangrove restoration and empoldering to combat sea level rise. The Bishan-Ang Mo Kio Park project exemplifies how urban water management can balance flood prevention, ecological restoration, and public engagement, contributing to Singapore's vision of a "City of Gardens and Water" (Qihui, 2018)

5.2.1 BD ELEMENTS

By analyzing Bishan-Ang Mo Kio Park, we can understand how different BD elements contribute to climate adaptation, ecosystem health, and human well-being. The BD Elements Matrix (Table 6) highlights the various strategies implemented in the park and their respective impacts across these three key sustainability dimensions.

Natural elements such as rivers, flora, and fauna play a crucial role in all three areas, supporting climate adaptation, strengthening ecosystem health, and enhancing well-being. Similarly, landscape features like biotopes, rain gardens, and vegetated bioswales provide multiple benefits, helping manage water flow, improve biodiversity, and create a more enjoyable environment for visitors.

Floodplains, as part of weather adaptation strategies, aid climate adaptation by mitigating flooding risks as well as ecosystem health and well-being. Meanwhile, prospect and refuge elements such as open views contribute significantly to human well-being by enhancing the visual experience and creating a sense of openness and refuge.

Connection to place, achieved through the use of reused site materials, education initiatives, and native plants, plays a dual role in fostering ecosystem health and strengthening well-being by promoting

NATURAL ELEMENTS

No wildlife was deliberately introduced to the park, yet a thriving and diverse fish population has taken root in its waters (Cui et al., 2021). On the same page, the restoration and greening of the waterway have also encouraged the presence of the smooth-coated otter, a species classified as "vulnerable" on the IUCN Red List of Threatened Species. On another note, once a rigid concrete canal, the naturalized Kallang River now winds gently through the landscape, inviting people closer to the water (Qihui, 2018). In 2012, the space underwent a transformation, giving rise to biotopes, rain gardens, and lush vegetated bioswales, all elements that shape the park's environment while allowing nature to flourish (Cui et al., 2021).

LANDSCAPE

The park consists of carefully designed biotopes, rain gardens, and vegetated bioswales (Cui et al., 2021). These elements were not only intended for flood regulation but also shaped the landscape into a space for recreation and a sanctuary for biodiversity. The park consists of interconnected biotopes with areas of open water and dense vegetation. Rain gardens are integrated into the landscape, collecting and channeling excess water, while vegetated bioswales create natural pathways for water movement (Schaefer, 2014). These elements are linked, forming a cohesive system where land and water interact across the site (Cui et al., 2021).

WEATHER

The river running through the center of the park was

A biophilic design. From Asla by Han, L. S., 2016
https://www.asla.org/2016awards/169669.html

Illustartive site park. From Asla by (Ramboll Studio Dreiseitl, 2016)
https://www.asla.org/2016awards/169669.html

A community park. From Asla by Han, L. S., 2016
https://www.asla.org/2016awards/169669.html

BD STRATEGIES	DESIGN ELEMENTS	CLIMATE ADAPTATION	ECOSYSTEM HEALTH	WELL-BEING
NATURAL ELEMENTS	River, Flora and Fauna	●	●	●
LANDSCAPE	Biotopes, Rain gardens and Vegetated bioswales	●	●	●
WEATHER	Flood plains	●	●	●
TIME & SEASONAL CHANGE				
SPATIAL CHARACTER				
PROSPECT & REFUGE	Open views			●
ENTICEMENT				
CONNECTION TO PLACE	Reused site material, Education, Native plants		●	●
CONNECTION OF SPACES				
MECHANISM	Sustainable drainage systems	●	●	●

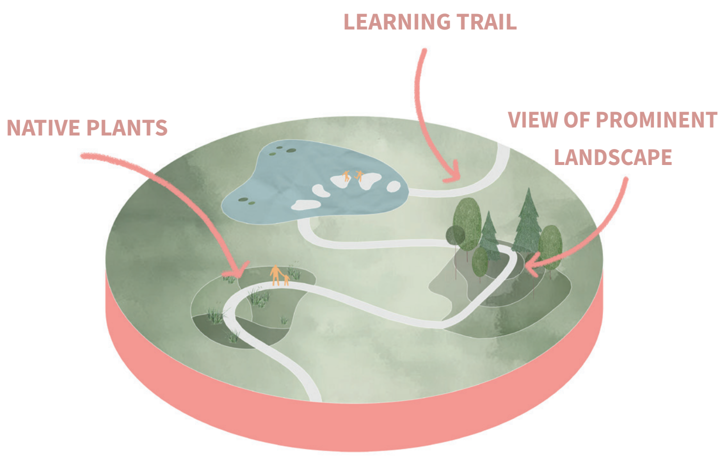
Table 6, BD Elements Matrix

redesigned using a floodplain concept, reconnecting it to the Kallang River. Previously a concrete stormwater drainage channel, it has now been naturalized, integrating with the surrounding parkland (Cui et al., 2021). Instead of a rigid, 24-meter-wide concrete channel, the landscape was shaped to allow the park itself to function as a floodplain (Schaefer, 2014). When water levels are low, the vegetated and grassy riverbanks become open spaces for recreation. When heavy rain fills the river, the surrounding parkland absorbs the excess water, temporarily transforming into flood zones Visitors experience the changing conditions of the landscape throughout the seasons. The open parkland shifts with the weather, from dry and accessible to submerged and flowing with water. The riverbanks, covered in vegetation, provide a space that changes with the elements, allowing visitors to interact with the natural rhythms of water and land.

PROSPECT & REFUGE

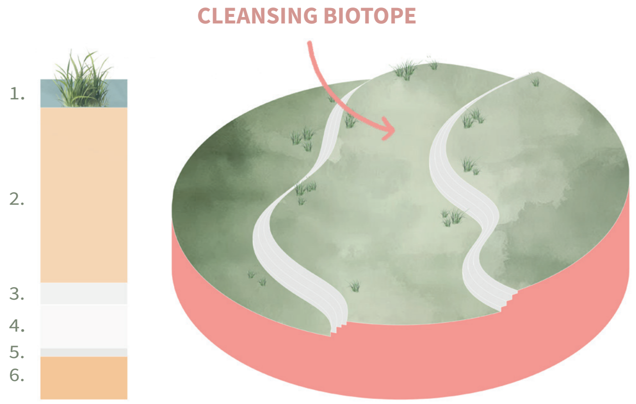
Concrete from the previous structure along the river was reused to construct an elevated landform known as Recycle Hill (Schaefer, 2014). This hill stands as a vantage point, offering an elevated perspective of the park and with a design that balances open spaces with sheltered areas. From the heights of Recycle Hill, visitors can take in wide views of the surrounding landscape.

CONNECTION TO PLACE



Beyond Recycle Hill, repurposed concrete from the former water structure was utilized to create steps and pathways that wind through the park, incorporated into the design of several park buildings (Schaefer, 2014). The park is also a setting for education, serving as an outdoor classroom for nearby schools and students. The ABC Waters Learning Trails Program, developed by PUB Singapore, guides students through the landscape, encouraging exploration and hands-on learning at various sites within the park. Alongside this institutional program, local schools have established their own trails, integrating subjects such as science, geography, and even mathematics into lessons conducted within the park. The park's connection to place is reinforced through its landscape. Native plants shape its natural identity, blending with the flowing river and vegetated banks. Pathways follow the contours of the terrain, linking open spaces with shaded pockets of greenery. The park's features are interwoven with the surrounding environment, forming a space that reflects both natural and built elements of Singapore's landscape.

MECHANISM



1. Plants, 2. Filter Substrate, 3. Riverwash Gravel 4. Round Gravel, 5. Multi-Layered Liner, 6. Soil

The transformation of the Kallang River at Bishan-Ang Mo Kio Park incorporated sustainable drainage systems (SUDS) to enhance flood mitigation and water filtration (Qihui, 2018). SUDS is an umbrella term for water management practices, designed to coordinate modern drainage infrastructure with natural hydrological processes. These systems consists of structures and strategies that efficiently manage surface water drainage in a sustainable manner (Cui et al., 2021). SUDS frequently utilize engineered elements that replicate natural features to facilitate flood reduction through attenuation and infiltration. In turn this enhances water quality, and support biodiversity by creating habitats for wildlife and plants. This approach shifts the focus from traditional flood risk management, which treats surface runoff as a problem, to a more sustainable philosophy that considers surface water a valuable resource to be managed for optimal environmental benefit. One of the strategies employed in the park is the transformation of the original 2.7 km concrete drainage channel into a 3 km naturalized river (Qihui, 2018). The riverbanks were reinforced with bioengineered edges, incorporating soil bioengineering techniques to prevent erosion. As shown in Figure 8, various stabilization methods, including riprap with fresh cuttings, gabions filled with rock and soil, and brush mattresses made from native plant species, were tested to ensure resilience against flooding (Schaefer, 2014). Additional measures such as fascines, geotextile-wrapped soil lifts, and reed rolls provided further reinforcement, promoting a riparian environment that integrates natural vegetation. Another integral component of the park's SUDS framework is the integration of vegetated biotopes, which function as natural water filtration zones (Qihui, 2018). These biotopes help cleanse rainwater runoff and river water, utilizing wetland vegetation to absorb and filter contaminants (Schaefer, 2014). The largest purification system within the park is the cleansing biotope, a constructed wetland consisting of 15 cells and four terraces. The substrates used in these wetland cells are nutrient-poor and support plant species selected for their ability to remove pollutants such as phosphorus, nitrogen, and heavy metals from surface runoff. Additionally, an ultraviolet treatment system is employed to eliminate bacteria before the treated water is reintroduced into the river or directed to recreational areas.

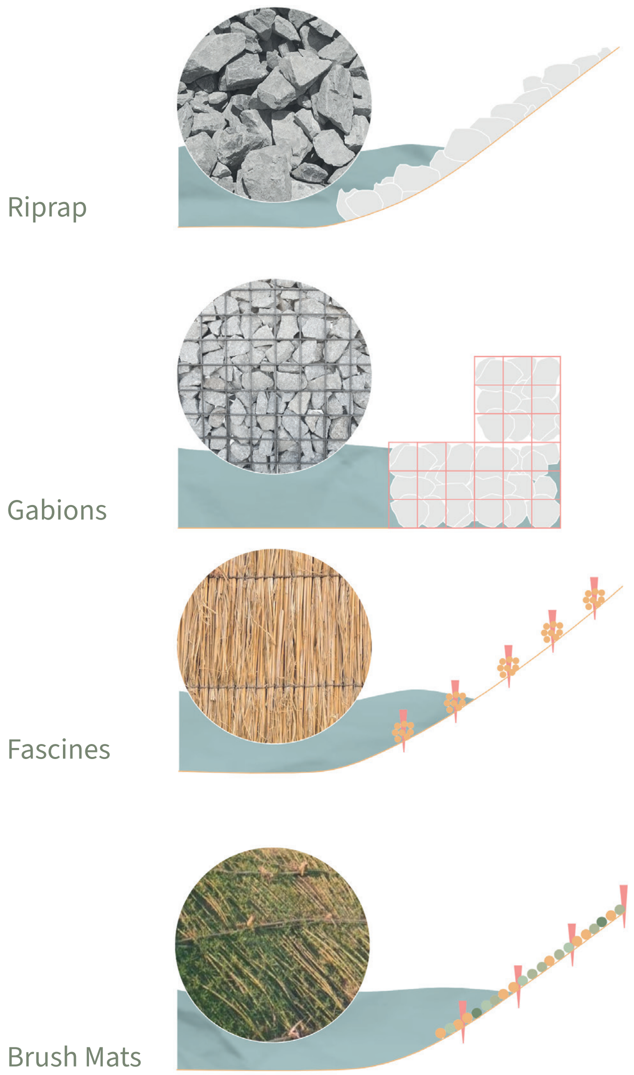


Figure 8, Bioengineered edges

Vegetated bioswales serve as another crucial element in the park's water management strategy (Schaefer, 2014). Positioned along mild slopes, these bioswales are lined with plants and rocks to slow the flow of water, capture sediments, and filter runoff before it reaches the main river system. While bioswales alone may not meet all stormwater treatment objectives, they serve as an essential pre-treatment step for downstream systems such as wetlands. The bioswales in Bishan-Ang Mo Kio Park contain plant species like Bacopa monnieri, which assists in filtering cadmium and lead, and Cymbopogon citratus, which helps control mosquito populations.

5.2.2 BENEFITS OF BISH-ANG MO KIO

Bishan-Ang Mo Kio Park has become a popular destination for both local residents and visitors from across Singapore (Cui et al., 2021). The transformation of the park has replaced the former concrete canal with a naturalized river, providing a scenic and inviting environment for the community (Qihui, 2018). This revitalized space allows for various outdoor recreational activities, promoting physical and mental well-being among visitors. Furthermore, the redesigned river offers a safe and interactive environment where individuals can engage with water-based activities (Schaefer, 2014).

Wetlands are recognized as nature-based solutions that provide essential ecosystem services, including carbon sequestration, water quality improvement, flood mitigation, and biodiversity support (Cui et al., 2021). Research highlights that wetlands effectively reduce flood risks, combat water pollution, and enhance purification processes. The park's redesign has contributed to a 30% increase in biodiversity, with frequent sightings of otters, egrets, and other wildlife (Qihui, 2018). Moreover, the transformation from a rigid canal to a meandering river has created a more aesthetically pleasing and ecologically rich landscape, fostering deeper interactions between people and nature (Schaefer, 2014). The project exemplifies how urban planning can accommodate both human and ecological needs, supporting Singapore's aspirations for a balanced coexistence of biodiversity and urban life (Schaefer, 2014). The park integrates Sustainable Urban Drainage Systems (SUDS), which mimic natural hydrological processes to reduce flooding, improve water quality, and enhance biodiversity (Cui et al., 2021). By leveraging natural filtration and conveyance processes, the park supports Singapore's objective of sustainable rainwater management (Schaefer, 2014). Additionally, the biodiversity of the park has flourished, with over 60 wildflower species, 50 bird species, and 20 dragonfly species, some of which are rare outside nature reserves. This transformation not only integrates the river within the urban landscape but also fosters greater human engagement with nature.

5.2.3 WEAKNESSES BISH-ANG MO KIO

Despite these benefits, concerns over water safety emerged during the planning process, particularly regarding whether to incorporate protective barriers along the river (Schaefer, 2014). According to Schaefer, (2014), a key challenge was overcoming public fear of water. Instead of erecting fences, designers collaborated with government authorities to develop a monitoring and alert system. This system includes red markers indicating safe zones, loudspeakers, flashing lights, and multilingual warning signs to ensure safety during periods of rising water levels.

While increased biodiversity is a positive outcome, interactions between humans and wildlife can pose safety risks. An incident involving a wild boar from Lower Pierce natural area highlights the challenges of managing human-wildlife interactions in urban parks (Schaefer, 2014). Although no severe injuries were reported, such encounters underscore the need for educational initiatives to promote coexistence. Rather than isolating wildlife from human spaces, parks with a more natural design can serve as platforms for fostering awareness about responsible interactions with urban fauna.

One challenge associated with the park's design is its reliance on dynamic water levels. When water flow is low, the vegetated riverbanks serve as recreational spaces; however, during periods of high water levels, these areas become flood zones (Schaefer, 2014). While most visitors are unlikely to use the park during heavy rainfall, the temporary loss of parkland may be perceived as a limitation. Nevertheless, this adaptive use of space aligns with the park's role in flood mitigation and urban resilience planning.

5.2.4 OPPORTUNITIES & CHALLENGES

The transformation of Bishan-Ang Mo Kio Park turned a rigid concrete canal into a naturalized, meandering river with floodplains and vegetated bioswales. This innovative approach has significantly improved water management, biodiversity, and climate adaptation. A similar strategy could be implemented in Lindholmen, where designers could integrate hybrid solutions such as sustainable drainage systems (SUDS) to manage intense rainfall. By reducing surface runoff these solutions could play a crucial role in climate adaptation.

One of the key elements in Singapore's approach is the use of wetlands and natural water filtration systems to improve water quality while strengthening urban resilience against climate change. These systems offer multifunctional benefits, not only do they mitigate flooding, but they also support local biodiversity. Bishan-Ang Mo Kio Park successfully increased biodiversity by 30% through the restoration of natural habitats and the integration of native flora and fauna. A similar approach in Lindholmen could establish ecological corridors, enhance water quality, and provide better conditions for native species, contributing to a healthier urban ecosystem. Additionally, implementing multi-functional wetlands, could create natural water treatment zones while promoting habitat diversity.

Beyond ecological functions, Bishan-Ang Mo Kio Park's naturalized, interactive landscape, with its open water and lush vegetation has been shown to positively impact mental health. Similar designs in Lindholmen could create urban sanctuaries, alleviating stress and promoting social interaction. Bishan-Ang Mo Kio Park extensively use for educational programs, including the education trails and outdoor classrooms, is an effective strategy to engage youth. Lindholmen could incorporate similar trails to attract the areas students. Finally, the park´s water features and green spaces encourage outdoor activities, which are linked to reduced stress levels and improved well-being.

While Singapore's design is optimized for tropical rainfall, Gothenburg faces a combination of coastal, fluvial, and pluvial flooding, exacerbated by prolonged rainfall and seasonal snowmelt. This means that adapting the floodplain concept and SUDS from Bishan-Ang Mo Kio Park would require modifications suited to different hydrological conditions. Likewise, biodiversity strategies that thrive in a tropical climate may need adjustments to accommodate colder winters and shorter growing seasons in Lindholmen. The selection of plant species and habitat structures must take these seasonal variations into account to maintain year-round ecosystem functionality. Furthermore, unlike Singapore's consistently warm climate, Gothenburg's colder winters and shorter daylight hours might limit year-round outdoor engagement, potentially reducing some of the direct mental health benefits associated with regular exposure to nature. Ultimately, the park cannot be used during floods, making its benefits to well-being unreliable.

THEORY	OPPORTUNITIES	CHALLENGES
CLIMATE ADAPTATION	The transformation from a concrete canal into a naturalized river with floodplains and bioswales has enhanced water management, biodiversity, and climate adaptation, a strategy that could be adapted in Lindholmen.	Adapting Bishan-Ang Mo Kio Park's floodplain concept and SUDS to Gothenburg would require modifications to address its diverse flooding challenges and seasonal snowmelt.
ECOSYSTEM HEALTH	The park's use of natural filtration systems improves water quality, mitigates flooding, and supports biodiversity, a model Lindholmen could adopt to enhance ecosystem health.	Biodiversity strategies from tropical climates must be adapted in Lindholmen to withstand colder winters and shorter growing seasons, ensuring year-round ecosystem functionality.
WELL-BEING	Bishan-Ang Mo Kio Park's naturalized landscape enhances mental well-being, a concept Lindholmen could adopt to create stress-relieving urban sanctuaries with adaptable green spaces. Lindholmen could incorporate similar education trails to attract the areas students.	Gothenburg's colder winters and shorter daylight hours may limit year-round outdoor engagement, reducing some mental health benefits of nature exposure. The park cannot be used during floods, making its benefits to well-being unreliable.

Table 7, Opportunities and Challenges Matrix

5.3 CHULALONGKORN UNIVERSITY CENTENARY PARK (CUC)

Bangkok, situated on soft marine clay, faces significant environmental challenges due to its low-lying topography (See, 2021). With an average elevation of 1.5 meters above sea level and some areas even below sea level, the city is predicted to experience annual flooding by 2030 Urban expansion has further intensified these challenges, as Bangkok's green spaces have declined from 40% to less than 10% over the past two decades. This reduction in permeable ground surfaces has accelerated stormwater runoff, compounding the city's vulnerability to flooding. In response, Chulalongkorn University Centenary Park was developed to expand the university's green corridor westward, strengthen urban connectivity, and counteract Bangkok's trend toward hardscape development. Opened in 2017, this 40 000 m² public park was designed to collect, filter, and store stormwater runoff, offering a flood mitigation solution while creating a valuable green space in the city.

Beyond its environmental role, the park has redefined Bangkok's relationship with water, encouraging new ways of integrating flood mitigation into urban life (See, 2021). As shown in Figure 9 & 10, positioned between key commercial, educational, and governmental institutions, it supports both public recreation and ecological sustainability. With an estimated 1,000 daily visitors, the park has earned significant recognition, including the World Landscape Architecture 2019 Award of Excellence. Its success has also inspired broader projects, such as the Green Bangkok 2030 initiative, which seeks to increase urban green space per resident. While no single park can fully resolve the city's flood risks, Chulalongkorn University Centenary Park demonstrates the potential of landscape architecture to drive innovation and climate adaptation in the face of climate change and rapid urbanization.

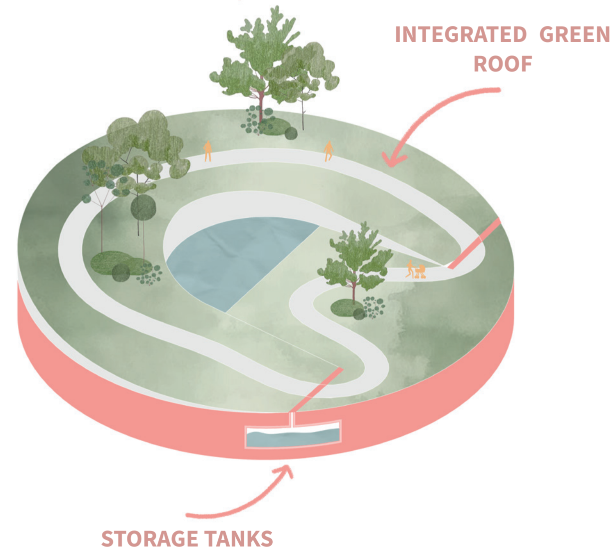
5.3.1 BD ELEMENTS

Through research on biodiversity-driven urban planning, the BD Elements Matrix (Table 8) showcases how various design elements contribute to climate adaptation, ecosystem health, and well-being. The matrix reveals that natural elements such as green roofs, ponds, fauna, and flora provide benefits across all three dimensions, climate adaptation, ecosystem health, and well-being. Similarly, landscape features like constructed wetlands, meadows, and diverse biomes help manage water, support biodiversity, and promote human well-being. Floodplains, as part of weather adaptation, primarily aid climate adaptation while also benefiting ecosystems and public health.

In terms of prospect and refuge, open views and safe environments contribute significantly to well-being by enhancing psychological comfort and social interactions. Connection to place, achieved through native plants, locally sourced materials, and educational opportunities, plays a role in ecosystem health and well-being, fostering a deeper environmental connection among people. Additionally, seamless transitions between buildings and landscapes and interactive pathways enhance the connection of spaces, promoting engagement and well-being. Mechanisms such as natural water filtration offer multifunctional benefits by improving water quality, strengthening ecosystems, and contributing to human health.

This matrix emphasizes how thoughtful biodiversity design can create sustainable, adaptable environments that support both ecological balance and community well-being. The following sections will explore each BD element in greater detail, illustrating its role in shaping resilient urban landscapes.

NATURAL ELEMENTS



A 5,200 m² green roof crowns the west side of the park, seamlessly integrating with the landscape through a gentle 3-degree incline (See, 2021). This green infrastructure channels rainwater to storage tanks and through a network of wetlands before reaching the

Figure 9, Map of Bangkok scale 1:100 000

Size:
40, 000 m²

Green network:
The park connects to nearby green areas via green corridors and landscaped pedestrian routes. A key feature is the transformed central road that now acts as a green link, improving walkability and ecological flow between the park and surrounding neighborhoods.

Blue network:
The park captures stormwater from surrounding areas via its rain gardens. The system filters and stores water for reuse, supporting irrigation and reducing flood risk locally and in adjacent zones.

Context:
Situated in Bangkok's dense urban core, the park is surrounded by commercial, educational, and residential developments. Its design serves as a green oasis, providing open space and ecological functions within a highly built-up area.

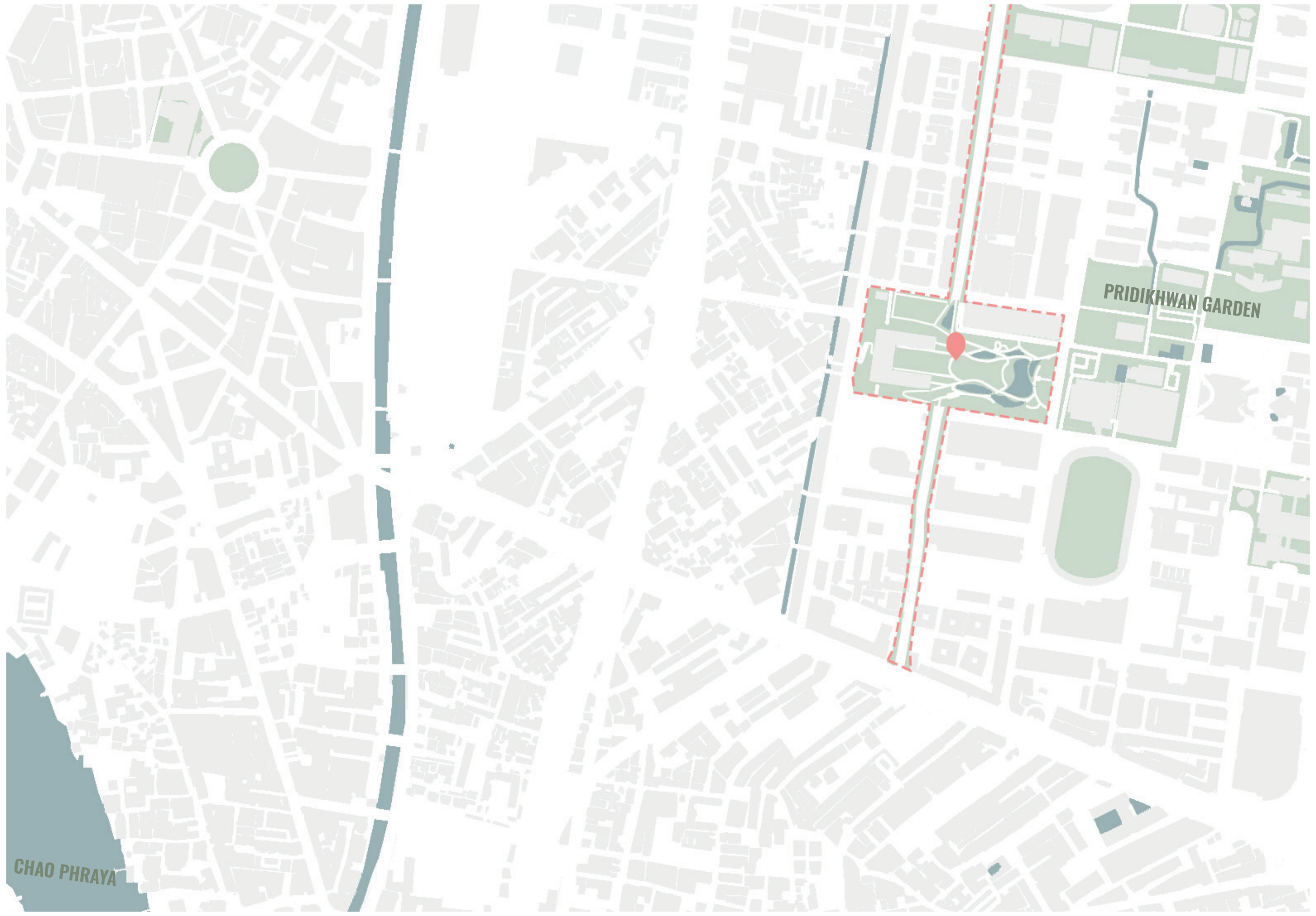


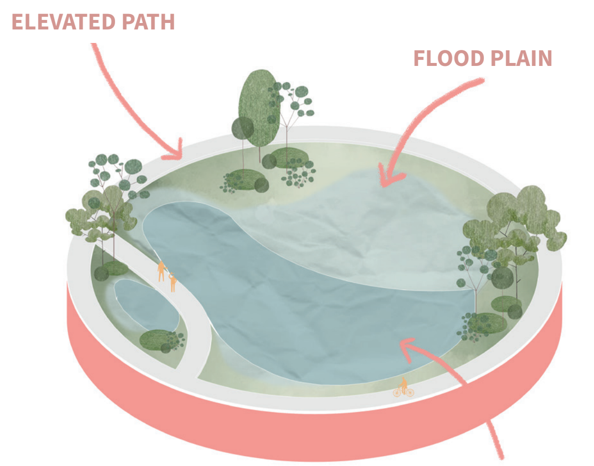
Figure 10, Map of Bangkok scale 1:4000, displaying the location and context of CUC Park.

retention pond on the east side of the park . Along the pond's edge, stationary water bikes are installed to support aeration and water flow, encouraging public engagement with the blue infrastructure. Lastly, the park features over 300 varieties of trees and plants, creating diverse and inviting habitats for birds and insects (Landezine International Landscape Award, n.d.).

LANDSCAPE

The park is designed not only as a green space for collecting, treating and holding stormwater runoff but also as a place for discovery and learning. Scattered along both sides of the main lawn, eight distinct landscape outdoor classrooms showcase a variety of biomes, each offering a unique sensory experience and function (LILA, n.d.). Visitors can explore the Herb Room, where fragrant plants engage the senses, or step into the Gravel Room, where rough textures and shifting stones create a grounded, tactile experience. The Bamboo Room stands tall and serene, its slender stalks swaying gently with the breeze. The Earth Room, shaped like an amphitheater, uses the natural contours of the land as a gathering space. In the Vine Room, climbing greenery forms a living, shaded enclosure, while the Forest Room offers a cool retreat beneath a dense canopy of trees. The Stone Room contrasts with its rugged surfaces, a space defined by raw, elemental materials. Finally, the Sand Room invites movement and play, its soft terrain designed for interaction and activity. These spaces serve as more than just gardens, they become places to gather, reflect, and engage with the landscape, each shaped by the natural materials that define them.

WEATHER



Shaped by ecological design, the park invites the city to engage with water as a natural presence rather than a threat (LILA, n.d.). Open spaces and gently sloping terrain create a diverse landscape that responds to changing weather, allowing rain to move freely through wetlands before gathering in a central retention pond. The pond shifts with the weather and swell beyond its boundaries in severe floods, merging with the main lawn and doubling in size as the park temporarily becomes part of the water's path. By embracing rather than resisting the forces of nature, the park introduces Bangkok to a new way of living with water, one that encourages interaction, adaptation, and coexistence, even in an era of climate uncertainty.

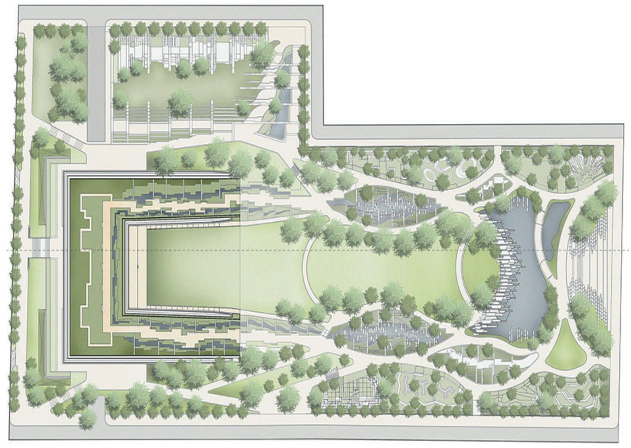
PROSPECT & REFUGE

At the park's highest point, a rare view unfolds of Bangkok's skyline, stretching into the distance, framed by open skies and a vast expanse of green (LILA, n.d.). Here, atop Thailand's largest green,

Stationary water bikes. From World Landscape Architect, by Holmes, D., 2019 https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Green Corridors. From World Landscape Architect, by Holmes, D., 2019 https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Chulalongkorn University Centenary Park. From World Landscape Architect, by Holmes, D., 2019, https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af



Masterplan. From World Landscape Architect, by Holmes, D., 2019, https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Section. From World Landscape Architect, by Holmes, D., 2019, https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

BD STRATEGIES	DESIGN ELEMENTS	CLIMATE ADAPTATION	ECOSYSTEM HEALTH	WELL-BEING
NATURAL ELEMENTS	Green roof, Ponds, Fauna and Flora	●	●	●
LANDSCAPE	Constructed wetlands, Meadows and Eight biomes	●	●	●
WEATHER	Flood plains	●	●	●
TIME & SEASONAL CHANGE				
SPATIAL CHARACTER				
PROSPECT & REFUGE	Open views and safe environments			●
ENTICEMENT				
CONNECTION TO PLACE	Native Plants, Locally sourced Materials, Views of prominent landmarks and Education		●	●
CONNECTION OF SPACES	Seamless transition from building to landscape Interactive path through different settings			●
MECHANISM	Natural water filtration	●	●	●

Table 8, BD Elements Matrix

visitors find a space that offers both refuge and perspective, where nature and the city exist in balance. Beneath this elevated landscape, a museum and parking space remain hidden, seamlessly integrated into the design, allowing the rooftop to serve as a quiet retreat above the urban rush.

CONNECTION TO PLACE

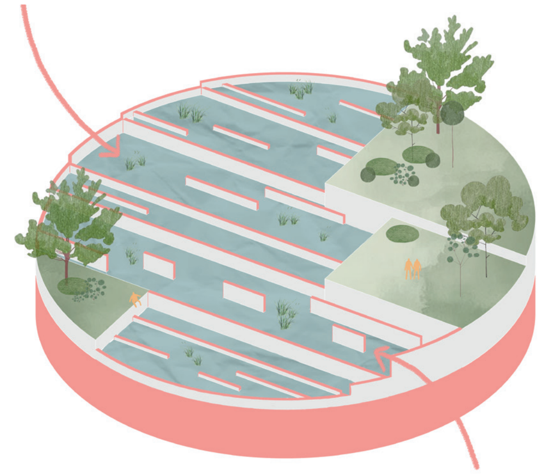
Every element of the park is thoughtfully designed to reflect its surroundings, from the use of locally sourced materials to the selection of porous components that blend seamlessly with the landscape (LILA, n.d.). The outdoor classrooms are shaped to complement the park's natural systems, reinforcing its connection to the environment. On top of the green roof, the park opens to a sweeping view of Bangkok's skyline, grounding it within the city's identity. The landscape, covered in native grasses and wild plants, becomes a habitat of its own, drawing local birds and insects, ensuring that the park remains not just a space for people, but a thriving part of the local ecosystem. Apart from this, the Park educates visitors on sustainable water management through outdoor classrooms, facilities, and interactive features. The park demonstrates how cities can coexist with water, fostering awareness of flood resilience and sustainability (See, 2021; Fullerton, 2018).

CONNECTION OF SPACE

Chulalongkorn University Centenary Park creates a seamless transition between built structures and the natural landscape through its gradual 3-degree incline. The 5,200 m² green roof atop the park's highest point extends into wetlands, cascading weirs, and a retention pond, forming a continuous ecological system that integrates urban and natural environments. An interactive pathway guides visitors through diverse settings, including eight landscape outdoor classrooms, each designed with distinct biomes (LILA, n.d.). These classrooms provide opportunities for education, recreation, and biodiversity, immersing visitors in different natural environments as they move through the park. The pathway also leads through open lawns and water features, showcasing how ecological design can support both public engagement and sustainable water management in an urban setting (See, 2021).

Originally, a roadway ran through the centre of the site, connecting two major streets in Bangkok (Holmes, 2019). As part of the park's design, the road was rerouted around the park's perimeter, slowing vehicular traffic and reducing four lanes to two while simultaneously prioritising wider pedestrian walkways and bike lanes. To further integrate the park with its surroundings, linear rain gardens filled with native plant species were introduced along the roadway, enhancing stormwater absorption and extending the park's ecological benefits into the neighbourhood. The redesigned road now serves as a pedestrian- and bicycle-friendly green corridor, seamlessly linking major streets with the park's pathways.

MECHANISM



CUC Park is designed to work with nature, creating a self-sustaining water management system that maximizes the collection, filtration, and reuse of water (See, 2021; LILA, n.d.; Holmes, 2019). At its highest point, a 5,200-square-meter green roof, sloping gently at 3 degrees, channels rainwater into three underground storage tanks before gradually releasing it into the landscape (See, 2021). Guided by gravity, the water then flows toward four constructed wetlands, two on either side of the park, retention ponds slow its pace, allowing time for natural absorption and aeration (LILA, n.d.). Native grasses, weeds, and aquatic plants thrive in these wetlands, filtering and cleansing the water as it travels toward the lowest point of the site.

A large retention pond expands and contracts based on rainfall, capable of doubling in size during severe flooding by spilling onto the main lawn (See, 2021). To prevent stagnation, water is pumped back to the wetlands, ensuring circulation and supporting further filtration by aquatic plants (Holmes, 2019). Beyond managing rain, the park also collects wastewater from surrounding neighborhoods, filtering it through an internal system before returning it, cleaned, to the local supply (LILA, n.d.). Acting as a large-scale detention area, the park ensures zero water discharge by capturing, storing, and redistributing water through storage tanks, rain gardens, and wetlands (Holmes, 2019). During dry seasons, stored water irrigates the green roof, preserving vegetation health while reducing reliance on external sources.

Originally, a roadway crossed the center of the site, connecting two major streets in Bangkok (Holmes, 2019). As part of the park's redesign, the road was rerouted around the park's perimeter and reduced from four lanes to two, allowing for wider pedestrian walkways and bike lanes. Linear rain gardens filled with native plants were introduced along this new route, improving stormwater absorption and extending the park's ecological impact into the surrounding neighborhood. Today, the redesigned road functions as a pedestrian- and bicycle-friendly green corridor, seamlessly linking major streets with the park's pathways.

5.3.2 BENEFITS OF CUC

Chulalongkorn Centenary Park is a multifunctional green space that enhances climate adaptation, ecosystem health, and human well-being. By integrating a green roof, interconnected ponds, and diverse plant life, the park supports biodiversity while providing ecological and social benefits (See, 2021). The native grasses and plants require minimal maintenance and create essential habitats for local species in an increasingly urbanized landscape (LILA, n.d.). Additionally, the park's retention pond and wetland system play a crucial role in stormwater management, reducing flood risks and sustaining a healthy ecosystem (See, 2021). Beyond environmental sustainability, the park promotes mental and physical well-being. Studies show that exposure to green spaces reduces stress, improves mood, and enhances mental health (Zhong et al., 2022). Features such as shaded pathways, open lawns, and water elements provide tranquil areas for relaxation, while interactive spaces, including cycling paths and water bikes, encourage physical activity, benefiting overall health and productivity (LILA, n.d.).

The park's landscape design further supports urban ecology and community engagement. Featuring constructed wetlands, meadows, and eight biomes, it offers a variety of sensory experiences while serving as an outdoor classroom for environmental education (LILA, n.d.). Spaces such as the Herb Garden and Bamboo Room provide areas for reflection, while the Earth Amphitheater and Sand Room encourage social interaction. The park's gradual incline and interconnected pathways create a seamless spatial flow, guiding visitors through different ecological zones and enhancing accessibility. Another key contribution of the park is its role in climate adaptation. By integrating sustainable water management systems, including a retention pond, wetlands, and a green roof, it mitigates urban flooding while demonstrating how cities can coexist with water. Its flood management design, which accounts for long-term climate projections, reduces urban inundation risks and supports sustainable water use (See, 2021). Additionally, at its highest point, the park offers panoramic views of Bangkok's skyline, balancing openness and refuge, which contributes to both urban aesthetics and visitor experience (Zhong et al., 2020).

5.3.3 WEAKNESSES OF CUC

Despite its ecological and social benefits, Chulalongkorn Centenary Park faces challenges in perception, maintenance, and long-term effectiveness. While the park's low-maintenance design supports biodiversity and water filtration, some visitors perceive its natural aesthetic as unkempt, describing certain areas as messy or poorly maintained (Suksawang, 2020). Public appreciation of ecological landscapes remains a challenge, as some prefer manicured green spaces over wild, native vegetation. Accessibility concerns have also been raised, particularly regarding the park's sloped pathways, which are designed for stormwater control but may be difficult for some visitors to navigate. Another limitation is the park's scale in addressing Bangkok's broader flooding challenges. While its integrated water management system efficiently collects, filters, and redistributes rainwater, its impact remains localized (Fullerton, 2018). Parks like CUC Park serve as valuable models for sustainable urban design but are only part of the solution to the city's wider flood risks.

5.3.4 OPPORTUNITIES & CHALLENGES

CUC Park in Bangkok is a pioneering example of climate-adaptive urban design, integrating stormwater management, biodiversity enhancement, and public well-being into a multifunctional green space. The following explores key opportunities and challenges in climate adaptation, ecosystem health, and well-being, and is summarized in Table 9.

CUC Park employs green roofs, underground storage tanks, constructed wetlands, flood plains, and retention ponds to manage stormwater and mitigate urban flooding. In Lindholmen, adopting these features could help capture and filter increased precipitation, reducing flood risks and calm stormwater pressure on local infrastructure. Further, a dynamic water retention system, where ponds temporarily expand during heavy rain, could bolster resilience to more frequent and intense rainfall events.

The park's diverse vegetation (over 300 plant varieties) and series of "outdoor classrooms" (biomes) serve as thriving habitats for birds, insects, and other wildlife. Replicating this approach in Lindholmen could enrich urban biodiversity, increase habitat connectivity, and foster ecological awareness among residents. Moreover, integrating native plant species would support local ecosystems, reduce maintenance needs, and create educational opportunities for community engagement with nature.

CUC's design prioritizes public recreation, mental relaxation, and social engagement through open lawns, shaded pathways, water

THEORY	OPPORTUNITIES	CHALLENGES
CLIMATE ADAPTATION	Chulalongkorn Centenary Park's stormwater features, green roofs, wetlands, and retention ponds, could help Lindholmen manage floods. Additionally expandable ponds would enhance resilience to heavy rainfall.	Bangkok's monsoon-adapted water system may need modifications for Lindholmen's colder climate. Winter conditions require engineering adjustments to ensure systems remain functional and safe year-round.
ECOSYSTEM HEALTH	Chulalongkorn Centenary Park's diverse vegetation and outdoor classrooms enhance biodiversity and habitat connectivity. Adopting this in Lindholmen with native plants could support ecosystems health.	Transplanting Bangkok's species or designs to Gothenburg may disrupt local ecosystems. Using native Nordic species is crucial for balance, but perceptions of "wild" landscapes as untidy could pose challenges in maintenance and public acceptance.
WELL-BEING	CUC's design fosters recreation, relaxation, and social engagement through open lawns, shaded paths, and interactive water features. Applying these elements in Lindholmen could promote well-being, social interaction, and a stronger community identity.	CUC's design supports well-being, but Gothenburg's climate requires adaptations. Sloped pathways may become slippery in winter, necessitating safety adjustments for year-round accessibility.

Table 9, Opportunities and Challenges Matrix elements, and interactive features like water bikes. Transposing these design elements to Lindholmen could provide similar benefits by creating inviting communal spaces that encourage physical activity, social interaction, and restorative contact with nature. Such spaces have been shown to improve mental health, reduce stress, and strengthen community identity. Finally, an elevated park, inspired by CUC's design principles, could enhance Lindholmen by creating a dynamic social hub overlooking the waterfront and city skyline. Open views and higher vantage points are linked to stress relief and a sense of refuge, offering a private or contemplative retreat. Additionally, incorporating elevated areas ensures the park remains accessible during flooding, making its well-being benefits reliable even in changing climate conditions. Implementing these features in Lindholmen would strengthen its resilience while supporting social and mental well-being.

Bangkok's tropical, low-lying context differs markedly from Gothenburg's cooler, northern climate. While a gravity-driven water system with wetlands and retention ponds is effective in monsoon-prone environments, Lindholmen's winter conditions may require modified engineering solutions. Ensuring that wetlands and green roofs function year-round, and remain safe and accessible even in icy conditions, poses a logistical challenge.

Directly transplanting species or design typologies from Bangkok to Gothenburg risks a mismatch with local flora and fauna. Native Nordic species and appropriate landscaping methods must be used to maintain ecological balance.

While CUC's design promotes well-being, adaptations are necessary to align with Gothenburg's cultural context and seasonal changes.

5.4 FINDINGS FROM THE BEST PRACTICE ANALYSIS

The thesis' "Opportunities and Challenges Matrix" shows how each BD strategy impacts three key areas: climate adaptation, ecosystem health and human well-being, when integrated into Gothenburg´s urban fabric. By comparing best practices to Lindholmen's specific conditions, the matrix highlights barriers and enablers. The result is a list of challenges and opportunities to guide design strategies that supports flood risk management and fosters mental health, espacially among the youth, at Lindholmen.

5.4.1 OPPORTUNITIES

Integrating BD into Lindholmen offers a chance to turn essential climate-adaptation measures into assets that also nurture ecosystem health and well-being. Experience from the best practice studies demonstrates how BD strategies can simultaneously benefit the city, local ecosystems and the people who live and work there. Greenacre Park's waterfall, water wall and runnel shows that an elegant water feature can double as a storm-water management system. Re-imagining a similar cascade in Lindholmen as part of a SUDs would let it store downfall flows and release them slowly to the larger blue network. Bishan-Ang Mo Kio Park provides an even larger lesson: its conversion of a straight concrete canal into a meandering river flanked by floodplains and bioswales turned a liability into an amenity (Cui et al., 2021). A comparable bioengineered edges treatment along Lindholmen's quay could widen the flood buffer and create inviting public space at the same time. CUC Park goes further by linking green roofs, constructed wetlands, underground storage tanks, retention ponds and flood plains that together absorb millions of litres during a single storm (LILA, n.d.). If Lindholmen adopted the same logic it could relieve pressure on Gothenburg's drainage network and future-proof the district against more intense rainfall.

Moreover, BD is benefecial for ecosystem health. Selecting a palette of native shrubs, trees and flowering perennials in Lindholmen would create new habitat niches while keeping maintenance low. Bishan-Ang Mo Kio Park boosted local species richness by roughly thirty percent by restoring a naturalised river (Cui et al., 2021). Lindholmen can achieve similar gains by shaping a continuous, richly vegetated park that spreads habitat across the whole site. Rain gardens from CUC Park, demonstrate how green infrastructure can support more than just water management. These rain gardens capture and filter stormwater while forming planted corridors that connect the park to nearby green spaces, enhancing habitat continuity (Holmes, 2019). Lindholmen can apply a similar strategy by integrating rain gardens along adjacent streets. These planted strips have the potential to help manage surface runoff, reduce pressure on the drainage system, and link the park to surrounding greenery. In doing so, they could act as green corridors that support pollinators, birds and other wildlife, contributing to a healthier, more resilient urban ecosystem.

Implementing BD strategies in Lindholmen presents a opportunity to support well-being and foster a deeper connection to nature, especially among the area's youth. A Greenacre-inspired space in Lindholmen could serve as a calming retreat from the fast-paced city environment . With features such as gentle water sounds, natural materials, and shaded seating areas, the park could offer a soothing, restorative atmosphere that helps reduce stress and supports mental clarity (Zare et al., 2022). Carefully layered spaces, ranging from quiet nooks for reflection to open areas for gathering, could accommodate diverse needs and activities. A discreet entrance, echoing the hidden oasis quality of Greenacre Park, could create a sense of discovery and intimacy that encourages repeated visits and personal connection. Similarly, the naturalized, interactive landscape of Bishan-Ang Mo Kio Park highlights the value of open water and lush vegetation in promoting mental wellness. Its design shows how sensory-rich environments can improve mood and alleviate stress while also inviting social interaction. Importantly, this park's extensive use for educational activities, such as nature trails and outdoor classrooms, demonstrates how green spaces can be a platform for youth engagement and learning. Incorporating similar features in Lindholmen could make the park a dynamic setting for students, offering not only relaxation but also inspiration and a sense of belonging. CUC further exemplifies how thoughtful BD can promote social cohesion and personal well-being. Its open lawns, shaded pathways, interactive water elements, and playful features like water bikes create inviting communal spaces that support physical activity, leisure, and meaningful encounters (LILA, n.d.). Adapting these elements to Lindholmen could encourage healthier lifestyles and help build a stronger sense of community identity. An elevated park, inspired by CUC's design, could also serve as a unique social hub with expansive views of the waterfront and city skyline. Such vantage points are known to reduce stress and offer a sense of refuge (Zare et al., 2022; Zhong et al., 2022), while also ensuring accessibility and function during flooding events, adding climate resilience to the park's benefits.

5.4.2 CHALLENGES

Apart from the opportunities, adapting BD strategies from established best-practice examples to Lindholmen, Gothenburg presents several challenges, in relation to climate adaptation, ecosystem health, and well-being. One major issue in climate adaptation is the sustainability of water features. While elements such as the dramatic waterfall in Greenacre Park offer visual appeal and sensory benefits, they can be highly resource-intensive, consuming energy and water at levels that may not align with the sustainable goals of BD.

Furthermore, strategies developed in tropical climates, such as Singapore's flood-resilient Bishan-Ang Mo Kio Park, must be significantly rethought for Gothenburg's northern conditions. The city faces complex hydrological challenges, exacerbated by prolonged rain and snowmelt. While Singapore's floodplain concepts and SUDs work well in a tropical context, transferring these ideas to Gothenburg could require careful modification to function under a colder, more variable climate.

In terms of ecosystem health, tropical biodiversity strategies cannot be directly applied to Lindholmen without adaptation. Species selected for Singapore's and Bangkok´s year-round growing season may not survive Gothenburg's colder winters and shorter daylight hours.

Promoting well-being through biophilic spaces also poses site-specific challenges. In Singapore, outdoor environments can be used year-round, supporting frequent nature interaction and associated mental health benefits. In contrast, Gothenburg's harsh winters and limited daylight may reduce opportunities for outdoor use, making the health benefits of biophilic spaces less consis-

BIOPHILIUS - RESULT
BEST PRACTICES

tent. Additionally, areas like Lindholmen's open waterfront setting differ from the enclosed calm of Greenacre Park, which creates a strong sense of refuge. Replicating this psychological comfort in a more exposed urban context will require innovative spatial design to balance openness with seclusion.

5.4.3 SOLUTIONS

To address the challenges of implementing BD in Lindholmen, several adaptive strategies can be considered. Instead of relying on resource-intensive water features, designs can incorporate passive, climate-responsive elements such as rain-activated installations, seasonal wetlands, and rain gardens that reflect natural hydrological cycles without excessive energy or water use. Renewable energy sources like solar panels, along with human-powered solutions, such as energy-generating bikes seen in CUC Park, can support the park's functionality in a sustainable way. In flood-prone zones, structures can be elevated and partially enclosed to remain usable even during high water events, offering both refuge and visual interest. The principles of "refuge" and "mystery" can be translated into the open landscape of Lindholmen through thoughtful spatial design, using planting, topography, and subtle transitions to create moments of seclusion and curiosity without compromising the openness of the waterfront. Biodiversity strategies should be tailored to Gothenburg's climate by focusing on native and resilient species, and drawing from Swedish ecosystems such as wetlands, bioswales, and biotopes to support local ecological health. Given the city's cold winters and limited daylight, promoting year-round use will require the integration of sheltered spaces like greenhouses, pergolas, and weather-protected pavilions that maintain a connection to nature while offering comfort in harsher conditions. Ultimately, designing for seasonal change, rather than against it, can create dynamic, multifunctional spaces that respond to the rhythms of Gothenburg's environment while supporting climate adaptation, ecosystem health, and human well-being.

5.5 CONCLUSIONS

In comparing the best practice matrices, several key conclusions and patterns emerge that highlight the ways biophilic projects align and differ across multiple design strategies. These patterns also illustrate how such projects address climate adaptation, ecological integrity, and human well-being.

Water emerges as a multifunctional element beyond aesthetics. In projects like Bishan-Ang Mo Kio and CUC Park, water features manage stormwater, mitigate floods, and enhance water quality while serving as community amenities. Even in smaller interventions like Greenacre Park, water cools microclimates and promotes relaxation, reinforcing its dual role in environmental and mental well-being.

Layered vegetation enhances biodiversity and visitor experience. Projects incorporate trees, shrubs, groundcover, and vertical planting to create varied habitats and immersive green spaces. Adaptive landforms and flexible floodplains, as seen in Bishan-Ang Mo Kio and CUC Park, replace rigid infrastructure with dynamic, flood-tolerant recreational areas.

Seamless spatial transitions enhance urban parks. Greenacre Park uses elevation changes and gateways to create a tranquil retreat from city noise, while larger parks like Bishan-Ang Mo Kio employ meandering pathways and interconnected floodplains for a continuous green space.

Education and community engagement are central. Bishan-Ang Mo Kio's wetlands serve as outdoor classrooms, and CUC Park integrates sustainability into daily campus life, fostering ecological stewardship. Sustainable materials reinforce environmental responsibility, as seen in the use of recycled concrete in Bishan-Ang Mo Kio and CUC Park and natural stone in Greenacre Park.

These projects balance recreation with habitat conservation. Floodplains serve as play areas in dry seasons and water retention zones during heavy rain.

Challenges remain, such as energy-intensive water features and balancing between spaces designed for human well-being and those that support ecosystem health and climate adaptation. However, long-term benefits include reduced flood damage and enhanced well-being.

Ultimately, these findings reinforce that BD is not merely an abstract ideal but a tangible, adaptable framework capable of transforming urban landscapes into healthier, more resilient ecosystems for both people and wildlife.

6. IMPLEMENTATION

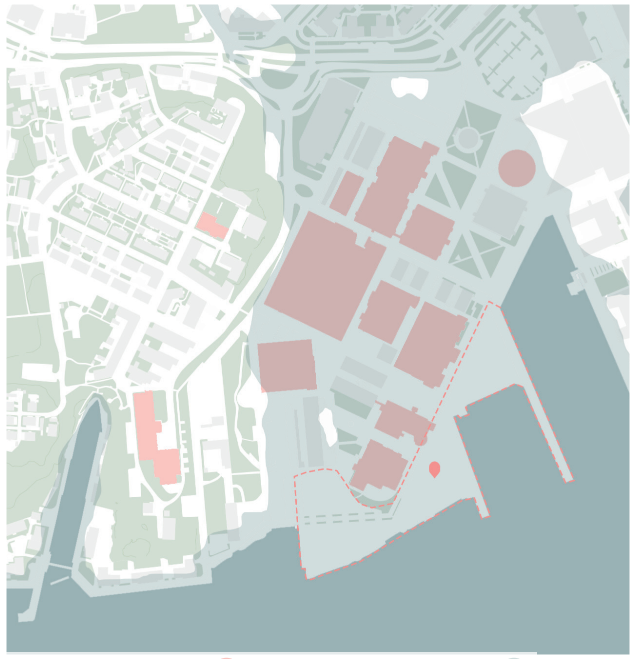
This chapter demonstrates how the theories, frameworks, and best practices introduced earlier can be brought together and applied in a concrete design task. Drawing directly on the Opportunities and Challenges Matrix and the optimized biophilic framework, this chapter systematically evaluates how BD strategies can be adapted to Gothenburg's climatic, ecological, and social conditions. The chapter distils lessons from best-practice precedents, into site-specific opportunities, challenges, and responsive solutions, ensuring that each design decision supports flood resilience, ecosystem health, and youth well-being. Futhermore, the chapter contextualises these strategies within Lindholmen's unique urban fabric, integrating GIS-based findings on flood risk, existing green corridors, and concentration of educational institutions to pinpoint optimal intervention zones. Finally, it presents the park concept itself, layered network of water-sensitive landscapes, sensory-rich gathering spaces, inclusive social pavilions, and all with BD-values, demonstrating how the theoretical constructs and analytical tools introduced earlier consolidate into an actionable, site-responsive design.

6.1 SITE CONTEXT

Set within Gothenburg's unique urban fabric, the proposed biophilic park, as shown in Figure 11, addresses both environmental and social needs by leveraging Lindholmen's existing strengths and challenges. Lindholmen benefits significantly from its riverside location along the Göta River, offering visual and physical access to water, an element strongly associated with psychological restoration and stress reduction (Zhong et al., 2022). The presence of water not only supports biophilic experiences but also provides an ideal canvas for incorporating water-based design elements like wetlands and flood plains.

However, Lindholmen's low elevation near the river makes it highly susceptible to flooding, particularly as climate change increases the frequency and intensity of rainfall events (Lundqvist, 2015). Impermeable surfaces in the built environment exacerbate flooding risks by overwhelming drainage systems and causing surface water accumulation (Egegård et al., 2024). Therefore, integrating BD solutions such as continuous green corridors could help enhance ecological resilience, manage stormwater effectively, and improve biodiversity.

Although Lindholmen's existing network of green-



SCHOOL BUILDINGS: FLOOD-PRONE AREAS:

Figure 11, Map of Gothenburg scale 1:40 000

blue spaces provides an ecological foundation, these spaces are sometimes fragmented or disconnected due to surrounding infrastructure. The current lack of continuous and accessible green pathways limits both ecological connectivity and the residents' everyday interactions with nature, interactions that are especially beneficial for youth mental health.

Socially, Lindholmen is characterized by a high concentration of schools, universities, and innovation hubs, leading to a demographic rich in young people and students. This demographic is particularly vulnerable to rising mental health concerns, including increased anxiety and stress, especially among young women (Fohm, 2022). The area thus represents an important site for design interventions that explicitly support mental wellness through biophilic spaces. Finally, Lindholmen's built environment reflects its industrial heritage and ongoing urban development, resulting in a diverse mix of residential, educational, and commercial functions. While this density and diversity support a multifunctional park that can serve various community needs, the limited availability of open space poses challenges for creating larger integrated green areas. Nonetheless, Lindholmen's waterfront location, planned expansions, and spatial variety clearly offer valuable opportunities to weave nature more effectively into the urban fabric, promoting both ecological and social resilience.

PUBLIC TRANSPORTATION STOPS: FLOWCHART PEOPLE: H L RAIN CORRIDORS: CONNECTED HARD SURFACES: CONNECTED GREEN SPACES:

Figure 12, Connection to adjacent parks and school buildings

6.2 CONCEPT

At the heart of the Lindholmen proposal lies Biophilius, a holistic vision that fuses Flood Resilience and Mental Health through BD principles. Biophilius builds upon insights from literature reviews and best practice studies to address climate adaptation, ecosystem health, and youth well-being.

Located along the Göta River, and as shown in the Biophilius masterplan (Figure 13), the design transforms flooding from a challenge into a functional part of the landscape. Inspired by successful implementations like Bishan-Ang Mo Kio Park and CUC Park, the design integrates SUDs such as green roofs, retention ponds, floodplains, constructed wetlands, bioengineered edges and underground storage systems to manage water sustainably. Elevated pathways and raised social structures are strategically integrated into the park's layout to maintain accessibility and usability during flood events. These elements not only allow safe circulation when lower areas are inundated, but also serve as vantage points from which visitors can observe the dynamic transformation of the landscape. By lifting key routes and gathering spaces above flood-prone zones, the design ensures continuity of movement, social interaction, and engagement with the environment, even in extreme weather conditions. This approach transforms flooding from a disruptive force into a visible, natural phenomenon that is both accommodated and appriciated within the park experience.

Ecologically, the park enhances the local environment by converting previously impermeable surfaces into diverse green spaces. It introduces multiple habitats such as ponds, trees, green roofs, native plantings, and rain gardens, all carefully selected to thrive in Gothenburg's climate. As shown in Figure 12, rain corridors connect the park to adjacent green areas and urban spaces, helping manage stormwater runoff while fostering habitat continuity for wildlife.

Focused on improving mental health, particularly for Lindholmen's youth, the park applies BD principles to create sensory-rich environments that engage all senses. Carefully designed structures with varying heights offer prospect and refuge, creating spaces that provide both openness and intimacy. Inspired features from CUC Park such as study areas, outdoor classrooms, casual gathering spots, and interactive activity centers encourage relaxation, social interaction, education, and play. Sheltered spaces and a greenhouse provide year-round usability, while green roofs and climbing plant–covered vertical elements offer habitats for local wildlife and a calming visual backdrop. These socially oriented spaces are aimed at drawing people to the park, especially the area's youth, as shown in Figure 12. With its accessible and multifunctional design, the park becomes an extension of nearby schools and universities. Students are attracted by the opportunity to study outdoors, join informal lessons, or simply gather and socialize in a natural setting. The layered programming invites both spontaneous use and organized activities, making the park a regular and meaningful part of daily life for the area's visitors.

Located in Lindholmen, a district that currently hosts around 25,000 people each day, thanks to its concentration of offices and universities (Lindholmen, 2020), the park is designed to be easily accessible. As the area continues to grow, with its population density expected to double in the next five years, connectivity becomes increasingly important. Rain corridors, designed as green fingers, link the park to nearby ferry terminals and bus stops such as Lindholmskajen and Lindholmen Busshållplats. These transit hubs provide direct access to central Gothenburg and other university campuses, making the park a natural stop along daily routes through the city. The corridors also help manage stormwater while creating welcoming promenades that guide visitors through a sequence of landscaped spaces, gradually transitioning from the urban edge into the heart of the park. They connect directly to nearby schools and universities, reinforcing the park's integration into the educational and urban fabric of Lindholmen.

Overall, this biophilic park offers a holistic and sustainable response to Lindholmen's unique challenges. It merges flood mitigation, biodiversity enhancement, and youth mental health support into a dynamic, engaging landscape that strengthens the community's connection to nature.

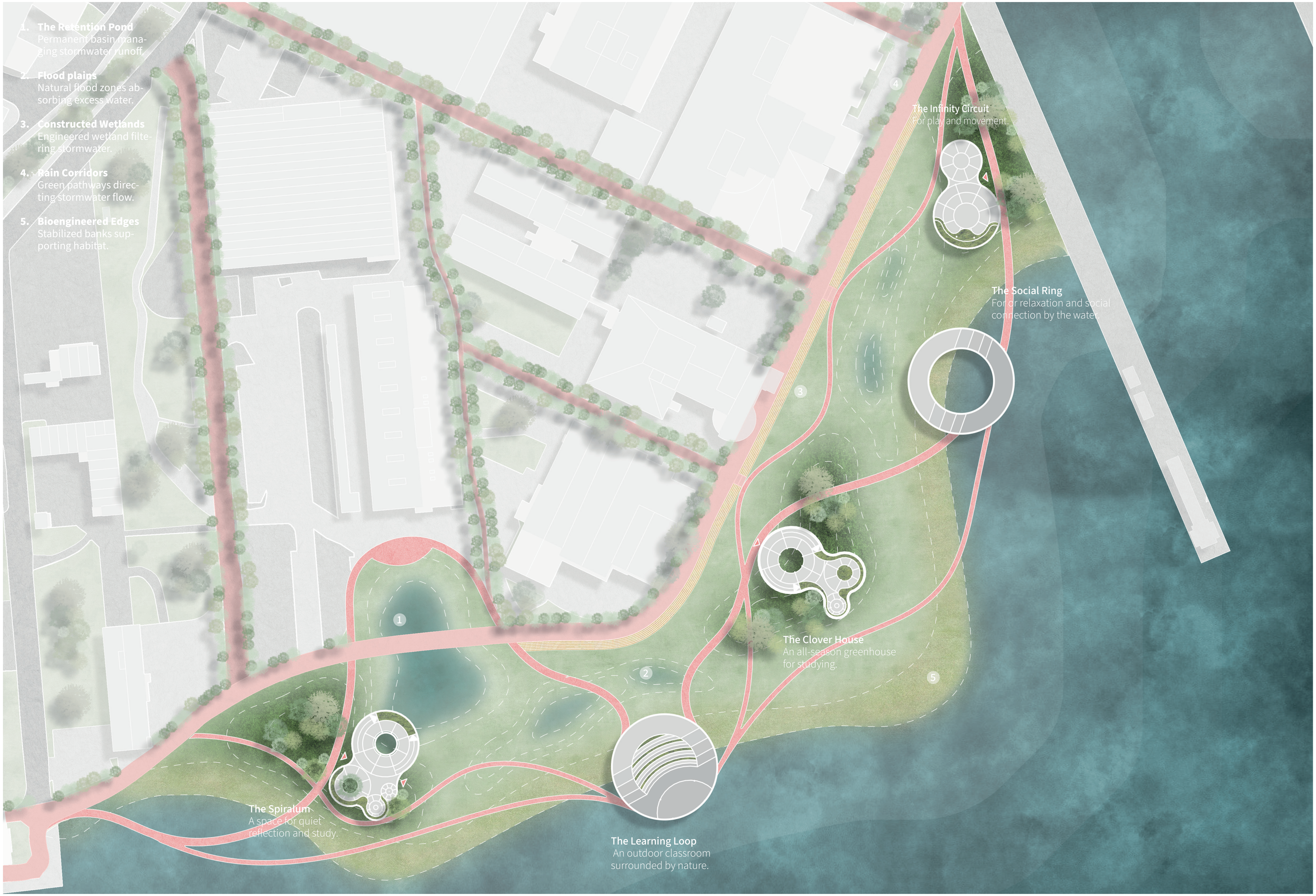
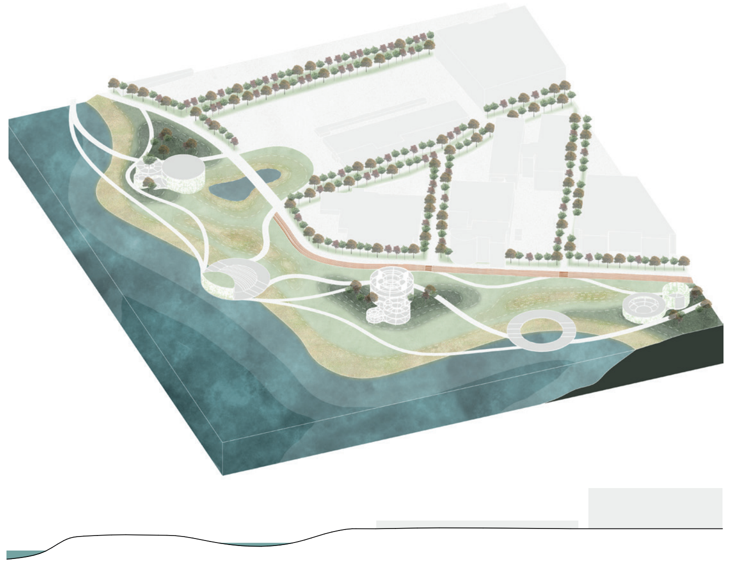


Figure 13, Masterplan scale 1:1000

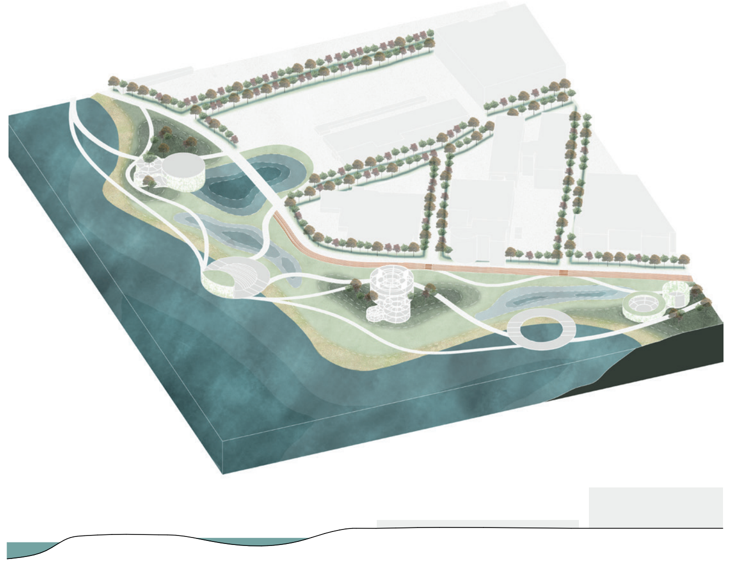
Dry Weather:

During dry conditions, the entire park is fully accessible, inviting guests to wander freely across its varied topography. Gentle slopes and winding paths connect the different levels, allowing for a seamless exploration of the landscape. Visitors can stroll from the shaded understory to the sunny grasslands, crossing water channels, stepping onto mossy stones, and pausing in sheltered clearings. Each habitat reveals something new and the park becomes a living classroom, where guests of all ages can observe, interact, and learn from the layered ecosystems around them.



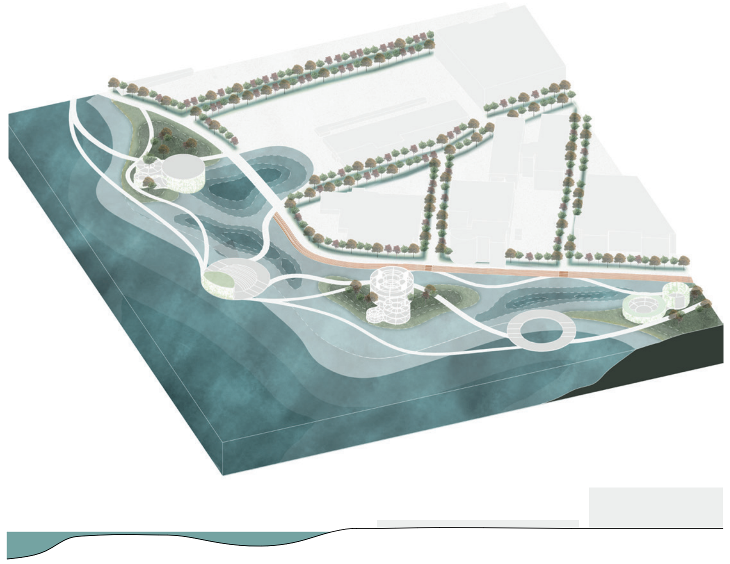
Minor Flooding:

During a minor flood, the park transforms into a dynamic, living landscape. The floodplains and retention pond gradually fill with water, giving rise to temporary wetland habitats. The constructed wetland comes alive, channeling the rising water into a cascading waterfall effect that draws both curiosity and calm. As the water flows gently into the runner, visitors can follow its journey, watching it meander through the landscape. While some low-lying paths may be submerged, most of the park remains accessible, inviting guests to experience this altered state of nature.



Severe Flooding:

During a severe flood, the park plays a critical role in managing and softening the impact of excess water. Underground storage tanks fill first, followed by the full inundation of the floodplains. The park's SUDs dampen and slow the floodwaters, reducing pressure on surrounding areas through rain corridors that help divert and relieve overflow. Despite the high water, key social functions, such as roads, pathways, and gathering spaces, remain usable, allowing the park to continue supporting both people and the urban system in the midst of the storm.



6.2.1 TERRAIN

The park designed for Lindholmen embodies an innovative flood management strategy integrated seamlessly with its biophilic principles, creating a resilient and nature-connected environment. As shown in Figure 14, central to the design is a main road for bicycles and pedestrians, carefully elevated approximately 1.5 meters above the park's lowest point to ensure usability even during flood events. The road is kept as straight as possible to ensure an effective flow and transportation through the park. Alongside this road runs a strategically placed rain garden, extending beyond the park boundaries to efficiently manage surface runoff and mitigate urban flooding. Adjacent to the rain garden and the main road are constructed wetlands positioned, to further enhance flood resilience. These constructed wetlands play a crucial role by slowing down water flow through native aquatic plantings and terraced steps, before water enters a water runnel system. This system channels the water towards underground storage tanks, minimizing flood risks and providing a sustainable water resource. As shown in Figure 15, complementing the constructed wetlands, the design features a retention pond, linked directly to floodplains throughout the park. These floodplains are thoughtfully designed with lowered areas, featuring characteristics typical of natural wetlands, further argumenting the park's water-holding capacity during peak flooding events. Such integration creates dynamic waterscapes, enriching the biodiversity of the site and promoting habitats for native wildlife. As shown in Figure 16, along the shorelines, additional wetlands provide multifunctional flood protection by moderating water flow both from urban runoff towards Göta Älv and vice versa. This two-way moderation enhances the ecological stability of the shoreline, protecting it through bioengineered edges that utilize soil bioengineering techniques to prevent erosion. Accessibility during flooding events is maintained through a series of elevated pathways branching off the main elevated road. These pathways provide continuous connectivity, leading directly to elevated entrances of social structures strategically positioned within raised topographical areas. This not only ensures operational continuity

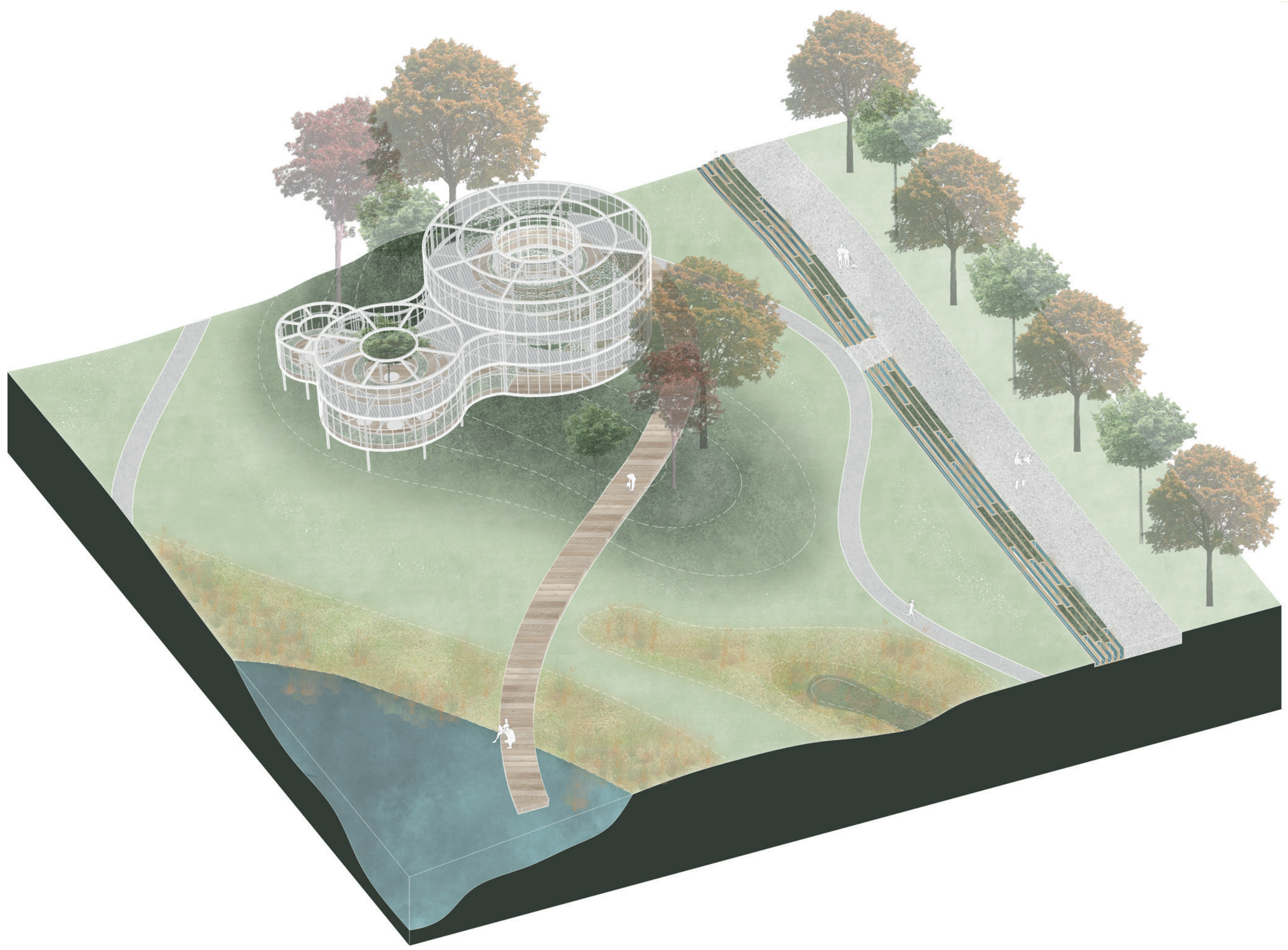


Figure 14, Axonometry of a portion of the park, displaying the parks different strategies and functions

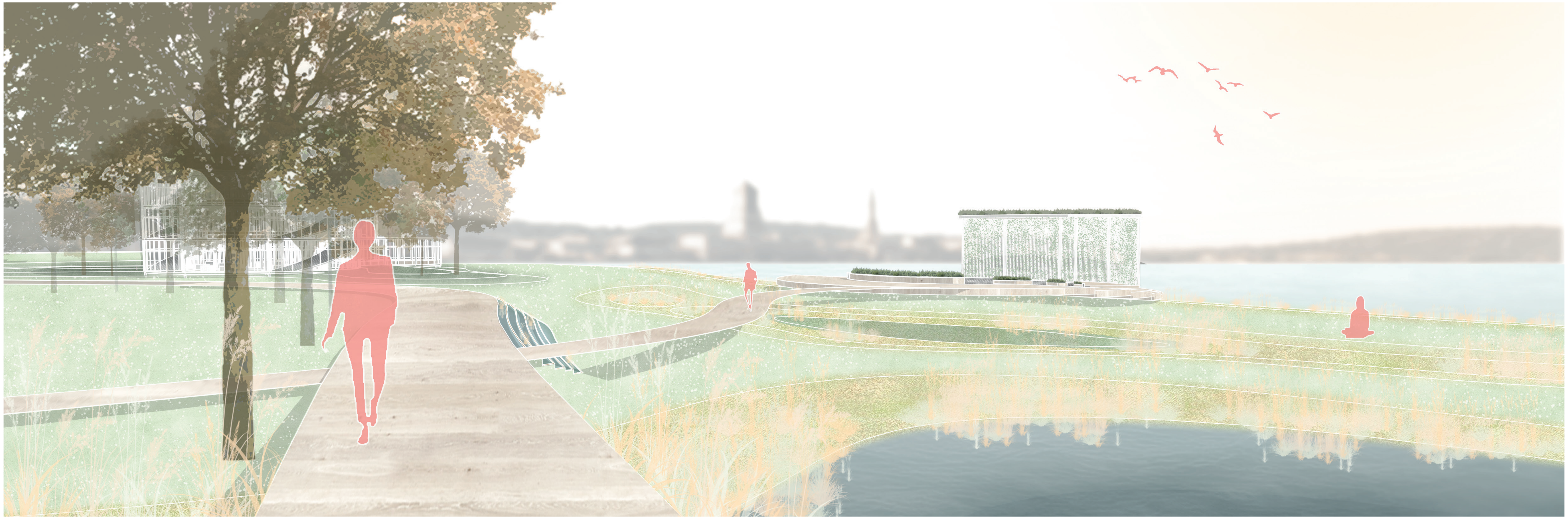


Figure 15, Perspective of the retention pond and flood plains

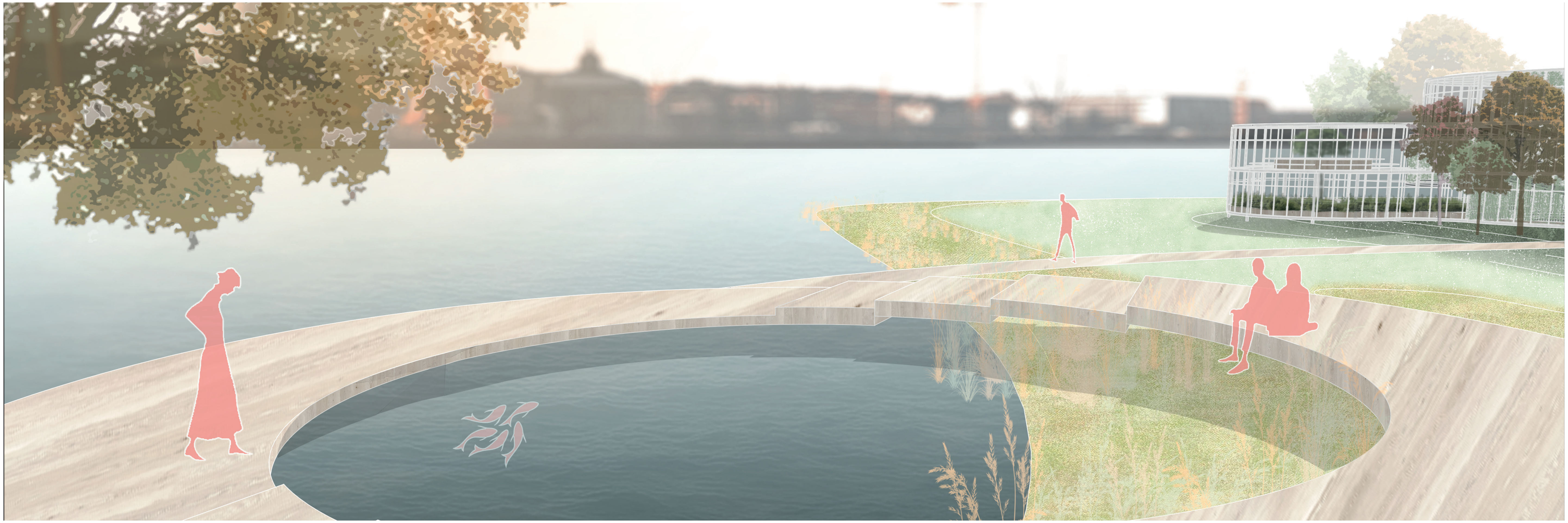


Figure 16, Perspective of the park´s shoreline

IMPLEMENTATION

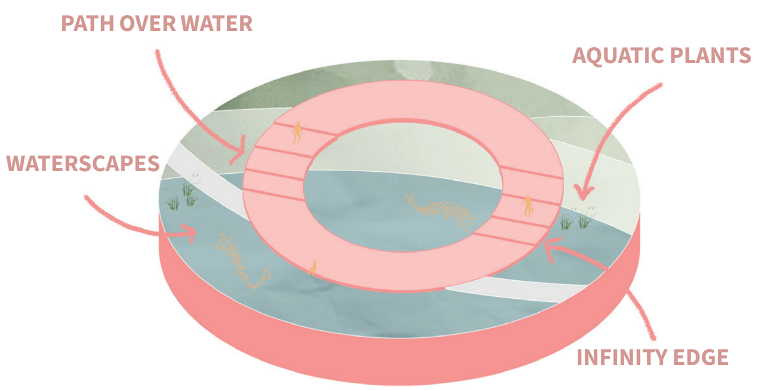
BIOPHILIUS - RESULT

during flooding but also enriches the park with varied habitats and ecosystems, reinforcing the biophilic approach. Complementary non-elevated paths offer immersive experiences, allowing closer interactions with the park's natural elements. While these paths might be temporarily inaccessible during floods, they encourage exploration and sensory engagement during normal conditions, contributing significantly to the park's biophilic attributes. Overall, this integrated flood concept employs SUDS, embodying modern drainage practices harmoniously blended with natural hydrological processes. Elements such as constructed wetlands, rain gardens, and bioengineered edges align with the biophilic strategies, enhancing climate adaptation, ecological health, and human well-being. Through careful planning, the park not only manages stormwater sustainably but also provides diverse, sensory-rich natural environments that encourage wildlife habitats, offer visual and physical connectivity to water, and heighten awareness of seasonal and meteorological variations. Ultimately, the park design transforms flood management into an opportunity for ecosystem health, climate adaptation, and enhanced well-being.

6.2.2 SOCIAL FUNCTIONS

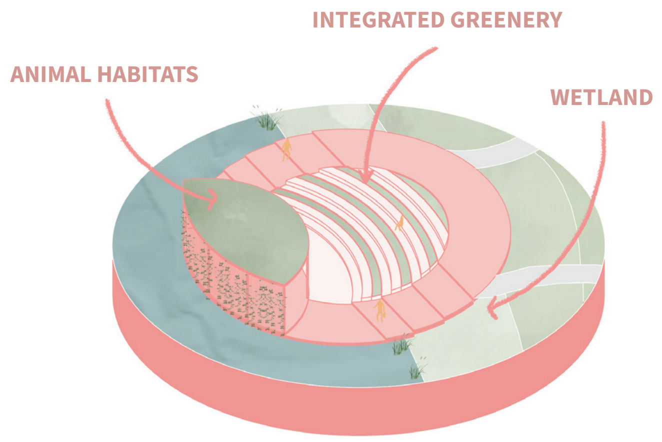
Central to Lindholmen's biophilic park are five structures: The Social Ring, The Learning Loop, The Infinity Circuit, The Clover House, and The Spiralum. The structures are intentionally designed to enhance mental health, particularly for the area's youth, while promoting climate adaptation and ecosystem health. The design concept is grounded in biophilic spatial characteristics, including fractal patterns and the golden ratio, and enables meaningful interactions with nature while accommodating flood resilience.

THE SOCIAL RING



The Social Ring features a terraced deck providing direct access to the water of Göta Älv, allowing visitors to relax on the steps or enjoy panoramic views. The deck offers visual connections to seasonal plant changes. Infinity edges and pathways over water introduce playful moments of excitement, while panoramic vistas of the river and city landmarks foster a sense of place (Zhong et al., 2022). By blending informal gathering spots with interactive paths, the Social Ring encourages peer connection, improvised study groups, and restorative moments beside the water which are beneficial for youth stress relief and social well-being.

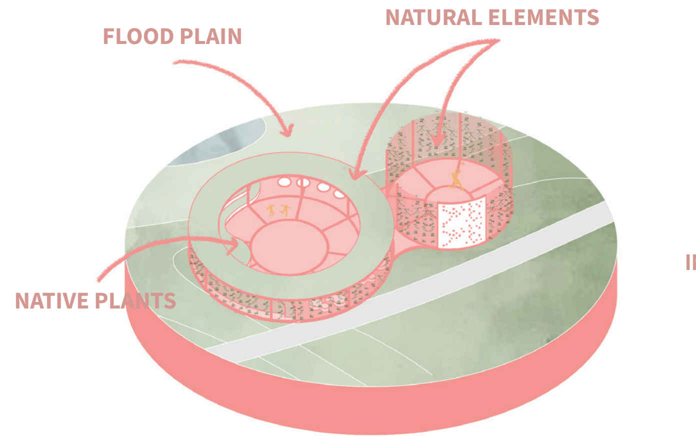
THE LEARNING LOOP



The Learning Loop features terraced seating integrated with lush greenery, creating an immersive backdrop for lessons, workshops, or group discussions. The speaker area is comfortably sheltered by a green roof, while audiences enjoy scenery views complemented by bird songs and water sounds that enhance focus and memory retention. The space incorporates wetlands and animal-friendly habitats like green roofs and green walls, reinforcing biodiversity and ecological engagement. Infinity edges and paths over water contribute to a sense of adventure and discovery, enhancing the educational experience. By situating youth learning directly within nature, the The Learning Loop supports hands-on education, peer collaboration, and emotional restoration, strengthening resilience and academic engagement.

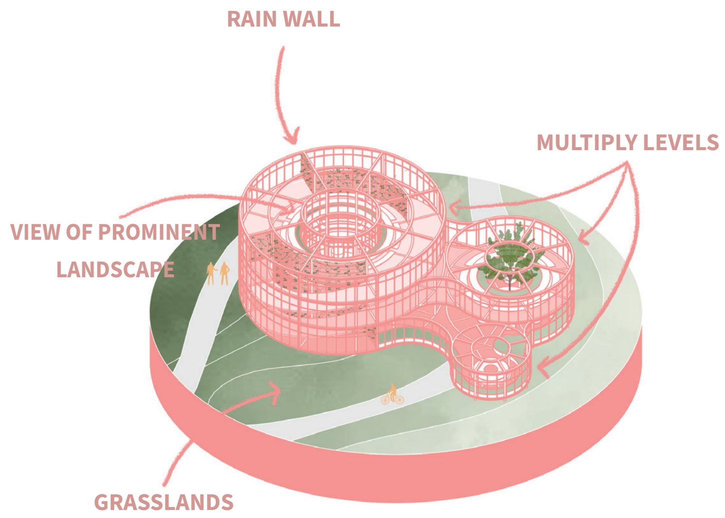
THE INFINITE CIRCUIT

The Infinity Circuit is a multifunctional space accommodating diverse activities such as dance, sports and community events. Covered by a green roof, it features seating, swings, and a climbing wall that combine physical challenge with elements of prospect and refuge, as well as peril and mys-



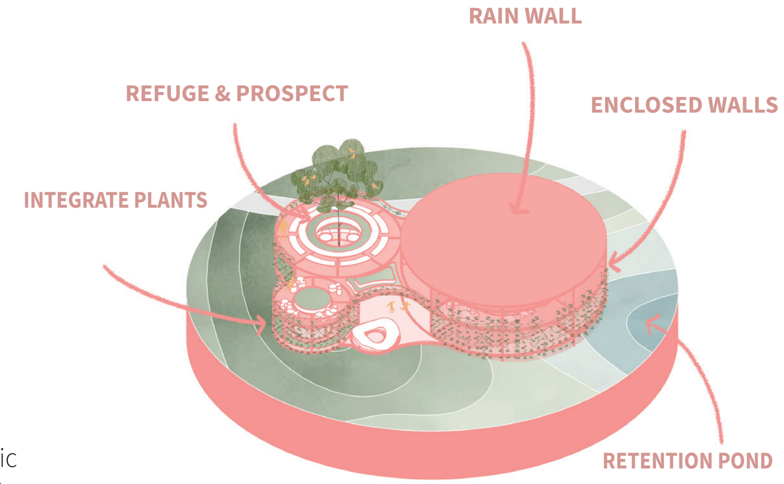
tery. Native plants and climbing greenery create dynamic visual effects and ecological niches, enriching local biodiversity and providing calming visual and sensory stimulation through interplay of light and shadow. The Center encourages active lifestyles, team-building activities, and stress-releasing movement, all while showcasing habitat-friendly green walls and roofs that support local wildlife.

THE CLOVER HOUSE



The Clover House offers year-round interaction with nature, especially beneficial during Gothenburg's colder months. A roof opening creates a soothing rain wall on the glass exterior during rain, enhancing weather awareness without extra energy use. Flexible seating zones and group study tables invite students to work, meet, or relax among climbing vines and an interior tree that spans floors. The temperate microclimate supports year-round bird and butterfly visitors, adding soft natural sounds that aid concentration and reduce isolation, important for youth mental health in winter months.

THE SPIRALUM



The Spiralum is designed around an internal tree, visible from various seating arrangements, creating an intriguing visual focus and promoting contemplation. A rain wall generated by passive weather-responsive design flows along a central stone feature, connecting visually and functionally with a retention pond. Semi-transparent walls covered in climbing plants offer privacy and mystery, enhancing the sense of refuge while providing clear views of the surrounding landscape. This enclosure creates a secure "refuge" for youth to decompress, while the seasonal plantings maintain a bond to nature. Animal-friendly habitats and seasonal plant views further enrich ecological interaction. The pod's design encourages quiet reflection, peer mentoring, and creative brainstorming in a biophilic setting.

Collectively, these five structures form a cohesive network tailored to youth needs. By integrating biophilic elements, Natural Elements, Landscapes, Weather, Time and Seasonal Change, Spatial Chatacter, Prospect and Refuge, Enticement, Connection to Place, Connection of Spaces and Mechanism, the park offers restorative environments that bolster social bonds, support active and collaborative learning, and foster overall mental health.

6.2.3 ZOOMIN IN ON THE SPIRALUM

As shown in Figure 17 and 18, Spiralum is a gently spiraling, two-storey pavilion built around two natural focal points: a mature tree and a vertical rain wall in stone. These twin elements physically and symbolically anchor the space, intertwining living nature and flowing water into the architectural core. Designed with biophilic spatial character in mind, including fractal geometry and golden ratio align-

Figure 17, Ground Floor scale 1:200

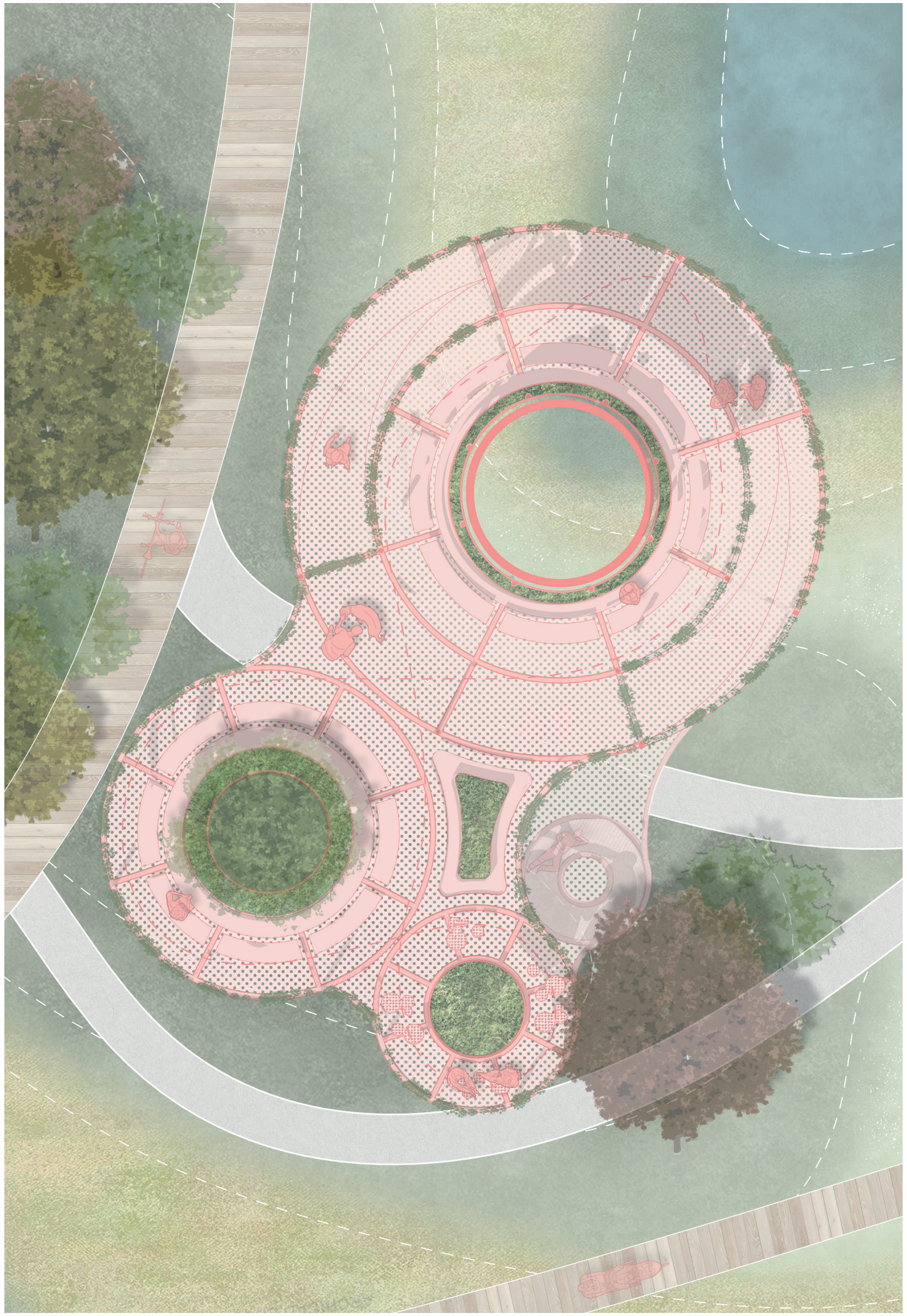


Figure 18, First Floor scale 1:200

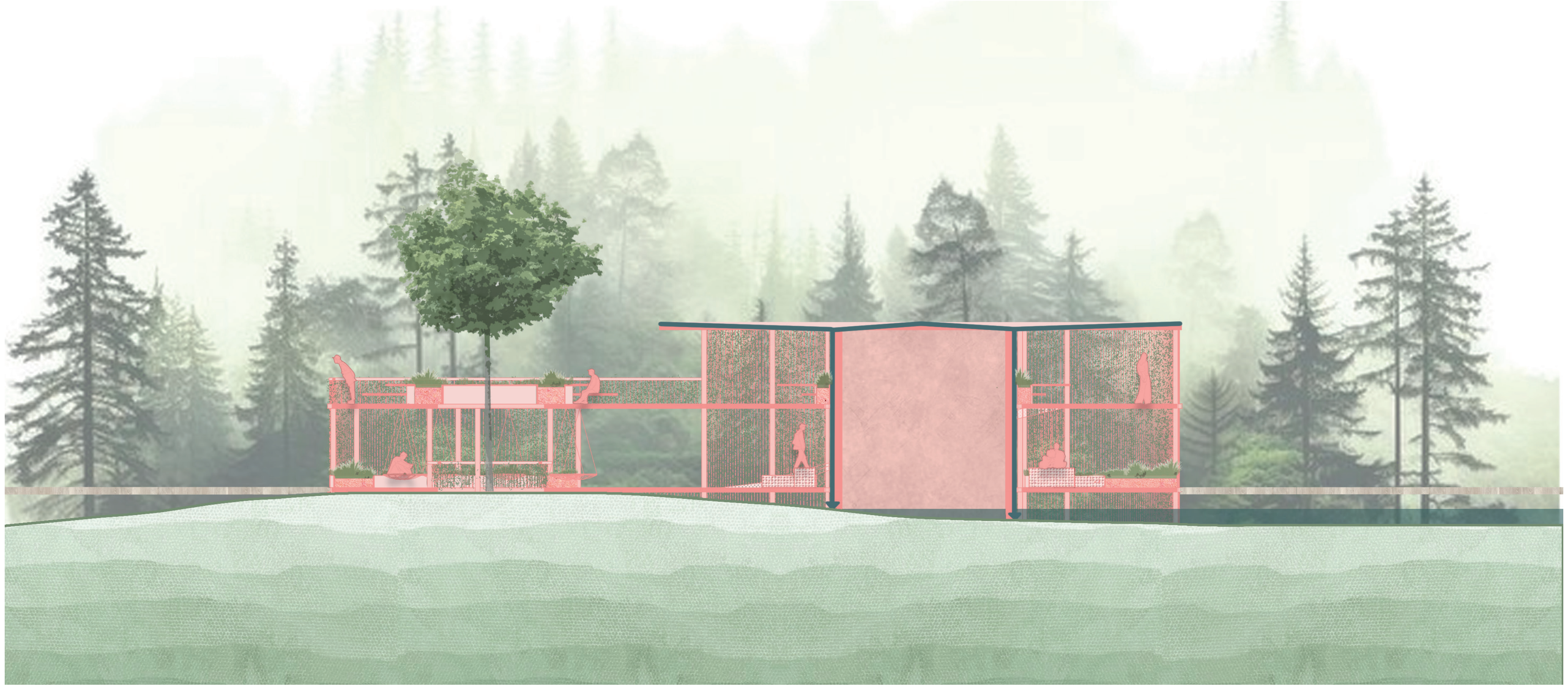


Figure 19, Section A scale 1:200

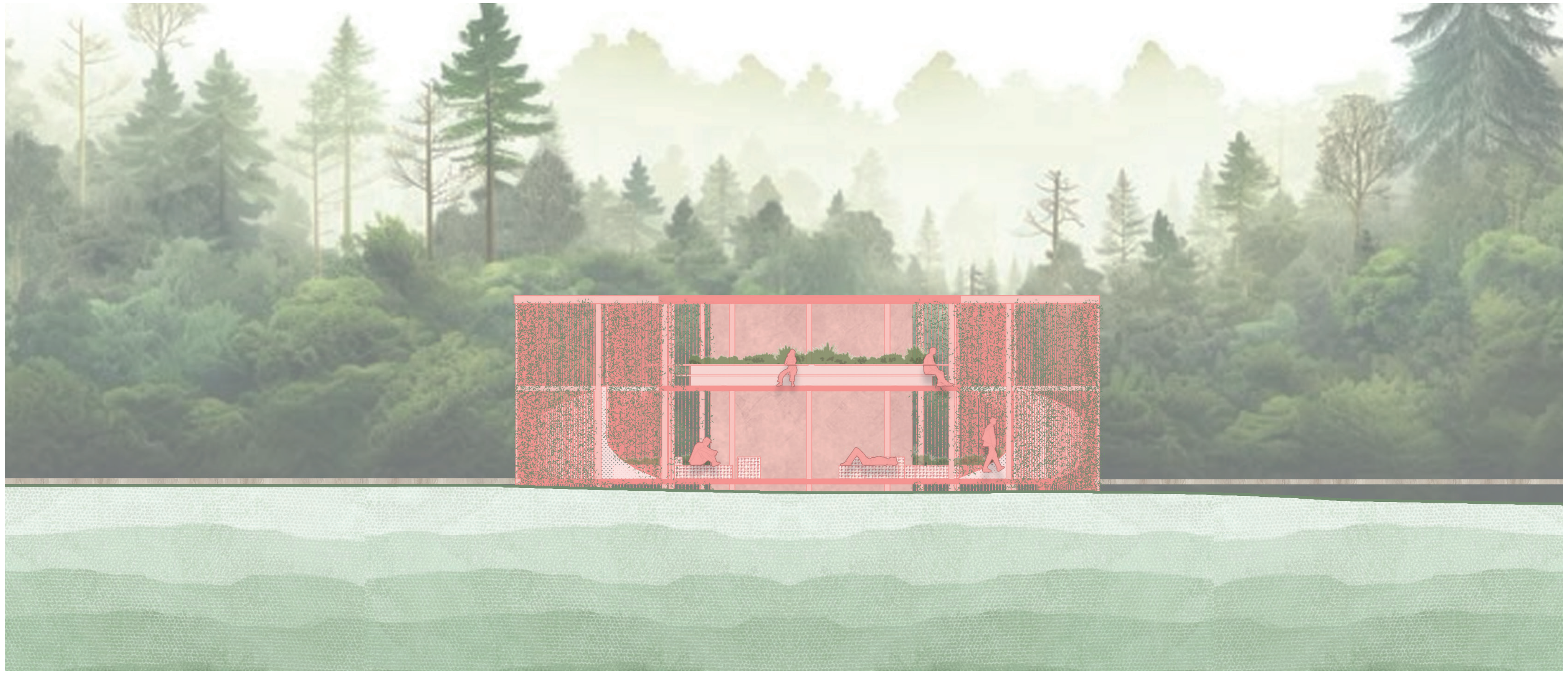


Figure 20, Section B scale 1:200

ments, the structure encourages sensory engagement, reflection, and a deeper connection to nature. From the moment visitors step inside, they are immersed in an environment where structure and landscape merge, and where the tree is not just a backdrop but a central protagonist.

As shown in Figure 19, the tree rises through an opening in the roof, its bark, branches, and shifting canopy visible from every level. As it grows, it marks the seasons, soft greens in spring, rich golds in autumn, reinforcing the passage of time and cycles of renewal. Surrounding it, layered seating areas and platforms allow young people to linger, gather or study. As shown in Figure 21, the openness of the upper decks offers sweeping views of Göta Älv and the surrounding cityscape, fostering a sense of prospect, while the more enclosed areas inside the network of green wires and under the tree crown, provide refuge and privacy. This rhythm of openness and shelter has been shown to reduce stress and enhance comfort, particularly important for youth navigating the pressures of academic and social life.

At the core of the structure, a vertical stone wall transforms rainfall into a subtle, sensory experience. As shown in Figure 19, when it rains, water is gathered by the drainage system in the center of the roof. This water is then released through small openings directly above the stone surface, creating a controlled, gentle flow down the wall. The result is a soft cascade that visually marks the rainfall and enhances the surrounding atmosphere. The soothing sound of trickling water helps mask urban noise, creating a calming, acoustically comfortable environment ideal for reflection and focus. The rainwater then continues into a nearby retention pond, contributing to the site's flood mitigation strategy by temporarily storing runoff during storm events. This elegant cycle turns a functional drainage system into an emotional and educational experience.

As shown in Figure 20, the semi-transparent wire facades are covered in climbing plants that filter light, blur the boundary between inside and out, and provide food and shelter for pollinators and birds. The veiled walls create a sense of mystery, just enough to make the structure feel hidden and special, especially for teens seeking a space that feels like

Figure 21, Perspective from the ground floor of Spiralum

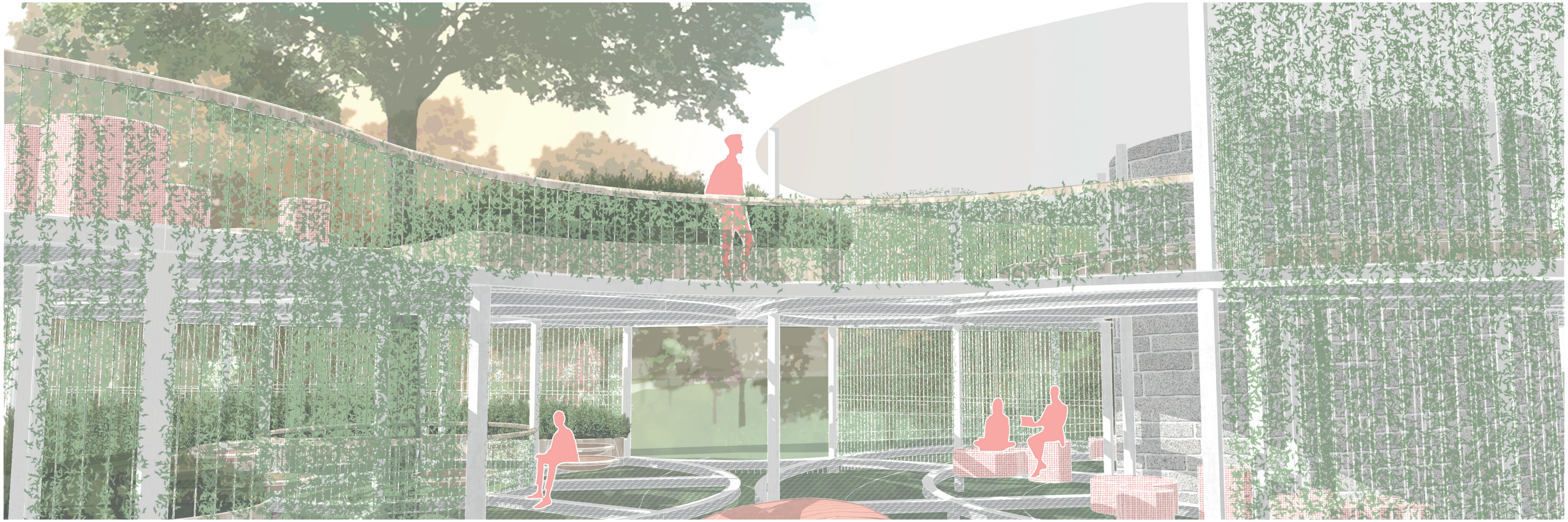


Figure 22, Perspective from the second floor of Spiralum

IMPLEMENTATION

BIOPHILIUS - RESULT

their own. As shown in Figure 22, on the ground level, hammocks and informal seating zones invite quiet conversations or solitary moments, while the mid-level is equipped for study and group work.

The structure's entrances align with the height of the park's elevated paths, ensuring continued accessibility even during flood events. The floors throughout Spiralum are made from perforated metal sheets, allowing light and air to pass through while maintaining a clear visual and sensory connection to the nature below. The surrounding landscape is also subtly lifted, forming a micro-habitat that contrasts with the lower-lying, flood-tolerant wetlands and floodplains, offering ecological diversity within the park's overall design. Green facades enhance biodiversity by providing vertical habitats, meeting targets for pollinator support outlined in the thesis.

Spiralum is a sanctuary and a stage, a place where learning, weather, and emotion assemble. For Gothenburg's youth, it offers a space that doesn't just accommodate nature but celebrates it. Here, architecture teaches resilience not through signage, but through experience. It reminds young visitors that weather can be beautiful, that stillness has value, and that even in the midst of a flood, it's possible to find peace.

6.3 BD ELEMENTS

As shown in Table 10, the proposed park design builds on the biophilic framework established earlier in this thesis, translating abstract principles into tangible, spatial strategies that respond to both human and ecological needs. Informed by site-specific challenges and inspired by global best practices, this section explores how each BD element has been integrated into the Lindholmen proposal.

NATURAL ELEMENTS

The project creates accessible green spaces that support physical activity, visual contact with nature, and thriving ecosystems. Wetlands, grasslands, and densely plant-covered hills, introduce layered, diverse habitats for birds, insects, and aquatic life, enriching local biodiversity and ecological connectivity. Nature is woven into the park's architectural structures. Perforated metal floors allow users to see greenery below their feet and sky above, creating a full vertical visual connection to nature. Flower boxes and metal wires support climbing plants, while trees growing through roofs blur the boundaries between structure and landscape. Green roofs and greenhouses serve as microhabitats, attracting pollinators and small wildlife, and further embedding ecology into built forms. The sensory experience is rich and immersive. Birdsong filters through the trees, the scent of blossoms drifts through open walls, and rainwater cascades gently along stone surfaces. Pathways hover above shallow water, bringing visitors close to the sound and shimmer of moving streams. These design choices invite touch, sight, scent, and sound, offering a calming, engaging, and biophilic environment that supports both physical movement and mental restoration.

LANDSCAPE

The design enhances coherent, ecologically connected landscapes through native grasslands, floodplains, and constructed wetlands. Low-maintenance, climate-adapted plantings create a seamless natural network that functions year-round with minimal intervention.

WEATHER

Weather is not just observed but felt throughout the park. Transparent roofs, semi-transparent walls, rain walls, and water runnels bring atmospheric conditions into the visitor experience, engaging the senses with shifting light, soft acoustics, and the texture of falling rain. In response to heavy rainfall, designed floodplains and retention ponds temporarily fill, safely transforming lower park areas into reflective waterscapes. While these zones are not accessible during flooding, elevated paths, sculpted hills, and raised social structures ensure continuous movement and engagement. Weather becomes a dynamic feature of the park, something to experience, observe, and acknowledge as part of nature's rhythm.

TIME & SEASONAL CHANGE

Natural materials and vegetation evolve gracefully over time. Shifts in plant texture, scent, and form offer subtle sensory cues that promote awareness of environmental rhythms. Materials like wood and stone age naturally, enhancing authenticity and connection to place.

SPATIAL CHARACTER

Fractal geometry and the golden ratio inform the layout and form of key structures, enhancing visual harmony and cultural resonance. The result is a spatial experience that bridges design, ecology, and user engagement.

PROSPECT & REFUGE

The park offers a rich blend of openness and enclosure that supports both exploration and retreat. Elevated decks, terraces, and viewing platforms create clear sightlines over the Göta River and surrounding landscape, fostering a strong sense of prospect and visual connection to the broader environment. These expansive views offer psychological relief, promote orientation, and invite casual observation of the park's activity. In contrast, more sheltered areas, such as green-covered structures, shaded seating arrangements, and intimate study zones, provide quiet, comfortable spaces where visitors can pause, reflect,

BD STRATEGIES	DESIGN ELEMENTS	CLIMATE ADAPTATION	ECOSYSTEM HEALTH	WELL-BEING
NATURAL ELEMENTS	Accessible green spaces, sensory-rich environments and wildlife-supporting structures	●	●	●
LANDSCAPE	Ecological landscape networks and native, low-maintenance plants	●	●	●
WEATHER	Rain-responsive features and elevated, flood-safe paths	●	●	●
TIME & SEASONAL CHANGE	Natural material aging and seasonal changing plants		●	●
SPATIAL CHARACTER	Fractal-informed layouts and harmonious spatial rhythm			●
PROSPECT & REFUGE	Open viewing platforms and Sheltered restful zones			●
ENTICEMENT	Winding, mysterious paths and semi-transparent enclosures			●
CONNECTION TO PLACE	Local materials used and landmark views framed		●	●
CONNECTION OF SPACES	Blurred indoor-outdoor boundaries and seamless spatial transitions			●
MECHANISM	Rain gardens, wetlands, retention ponds, underground storage tanks and floodplains	●	●	●

Table 10, BD Elements Matrix

or engage with others. These spatial contrasts are intentionally designed to support both active engagement and moments of calm, allowing users to shift fluidly between social interaction and personal restoration depending on their needs.

ENTICEMENT

Infinity edges, bridges over water, and winding paths introduce mystery and aesthetic appeal. These design elements encourage movement through the park by sparking curiosity. Social structures contribute to this sense of intrigue, some are wrapped in semi-transparent walls that reveal shadows and silhouettes, hinting at interior activity without fully disclosing it. This subtle veiling invites exploration and builds a sense of discovery. Together, these strategies heighten visual interest and enrich the overall experience of the landscape.

CONNECTION TO PLACE

Views of Gothenburg's landmarks and prominent landscapes, native vegetation, and local materials create cultural, ecological, and emotional grounding. These choices foster place attachment and a strong sense of belonging.

CONNECTION OF SPACE

Clear, walkable routes connect varied environments, wetlands, dense hills and meadows, via bridges and ramps. These connections encourage exploration and movement, enhancing accessibility and social interaction. Inside and outside blend fluidly through architectural features such as semi-transparent walls, open roof structures, and interior atriums filled with greenery. Plants growing through buildings and visual links across floors foster a continuous spatial dialogue between built and natural elements. This seamless transition supports a coherent, layered experience that invites users to navigate, pause, and interact with the landscape from multiple perspectives.

MECHANISM

Flood mitigation in the park is achieved through a comprehensive SUDS, integrating various elements that collectively manage and adapt to rainfall events. Rain gardens are strategically placed along paths and edges to capture and filter surface runoff, using vegetation and soil layers to naturally slow its flow. Constructed wetlands further this process on a larger scale, offering both ecological habitat and effective water treatment. Retention ponds are designed to temporarily hold stormwater, reducing peak flow and minimizing pressure on the city's drainage system. These ponds not only store excess water but also contribute to the park's biodiversity and visual richness. Underground storage tanks add a hidden yet powerful layer of resilience, safely storing large volumes of stormwater below the surface for controlled release. Floodplains are shaped into the topography to receive overflow during intense rainfall. These areas are allowed to flood intentionally, buffering the rest of the park from water accumulation. While inaccessible when inundated, they are an essential safety mechanism that transforms flooding into a controlled, ecological event. Wetlands woven throughout the site support biodiversity and filtration while holding excess water during storms. Together, these components form a layered and adaptive flood management strategy that enhances both resilience and ecological value.

6.4 OPPORTUNITIES & CHALLENGES

As shown in Table 11, integrating BD into Lindholmen offers a unique chance to combine climate adaptation with ecosystem health and well-being. Drawing inspiration from the best practices cases, Lindholmen could adopt features such as wetlands, rain gardens, green roofs, and floodplains to manage stormwater, boost biodiversity, and create inviting public spaces. These green interventions can enhance ecosystem health, reduce stress, and foster youth engagement and social connection, turning infrastructure into vibrant, restorative environments.

Translating global BD models to Gothenburg poses several hurdles. Resource-intensive water features may not align with sustainability goals. Climate differences, especially Gothenburg's colder winters, variable daylight, and complex flooding risks, limit direct transfer of tropical SUDS designs. Natural-based strategies also need to account for local species resilience. Furthermore, promoting mental well-being through outdoor BDn is more difficult in a city with long winters and exposed waterfronts, requiring a different spatial approach than in warmer, enclosed settings.

To meet these challenges, Lindholmen can prioritize passive, climate-responsive systems like rain gardens, seasonal wetlands, and rain-activated features. Designs should rely on native vegetation and Swedish ecosystem models, ensuring ecological compatibility. For comfort year-round, features like greenhouses, covered pavilions, and wind-protected seating areas can extend outdoor use. Elevating structures and integrating solar or human-powered elements can enhance resilience and sustainability. Smart spatial design that balances openness with refuge will help make the area both inviting and climate-adapted.

6.5 CONCLUSIONS

The Implementation chapter visualize that BD can be operationalised in Lindholmen by aligning BD Frameworks and global best-practice strategies with local conditions. The Opportunities and Challenges Matrix has been instrumental in this process, it surfaces a wide range of possibilities, flags context-specific risks, and points toward adaptive solutions that balance climate adaptation, ecosystem health, and well-being. The park concept itself weaves together two scales of intervention. At the terrain scale, flood-resilient landscapes, manage stormwater on-site while creating new habitats and connective blue-green corridors. At the social scale, structures like the Social Ring, Learning Loop, Infinity Circuit, Clover House, and Spiralum act as sensory-rich refuges tailored to youth mental health, providing places for study, play, and quiet reflection. Together, these elements form a unified park that concurrently advances climate adaptation, bolsters ecosystem health, and nurtures well-being. By tracing a clear path from the BD framework through matrix-driven strategy selection to a site-responsive concept, the chapter demonstrates that a methodical, evidence-based approach can deliver a multifunctional, resilient, and restorative biophilic park, offering a replicable model for integrating nature, infrastructure, and social needs in urban landscapes.

THEORY	OPPORTUNITIES	CHALLENGES
CLIMATE ADAPTATION	Adoption of wetlands, rain gardens, green roofs, and floodplains can help manage stormwater and enhance resilience to climate events.	Tropical SUDS designs will in some cases have to be transfer to Gothenburg's colder climate and flooding risks.
ECOSYSTEM HEALTH	Green infrastructure can boost biodiversity using native vegetation and Swedish ecosystem models, creating ecologically integrated urban spaces.	Strategies must account for the resilience of local species; global BD models may not fit local ecological and climatic conditions.
WELL-BEING	Restorative environments like inviting public spaces, youth engagement, and social connection through nature enhance mental health and community bonds. Covered, wind-protected, and seasonally adaptable areas can extend usability in cold seasons.identity.	Outdoor well-being initiatives are harder in cold, dark winters and exposed settings like waterfronts, requiring thoughtful design to encourage year-round engagement.

Table 11, Opportunities and Challenges Matrix

7. CONCLUSION & DISCUSSION

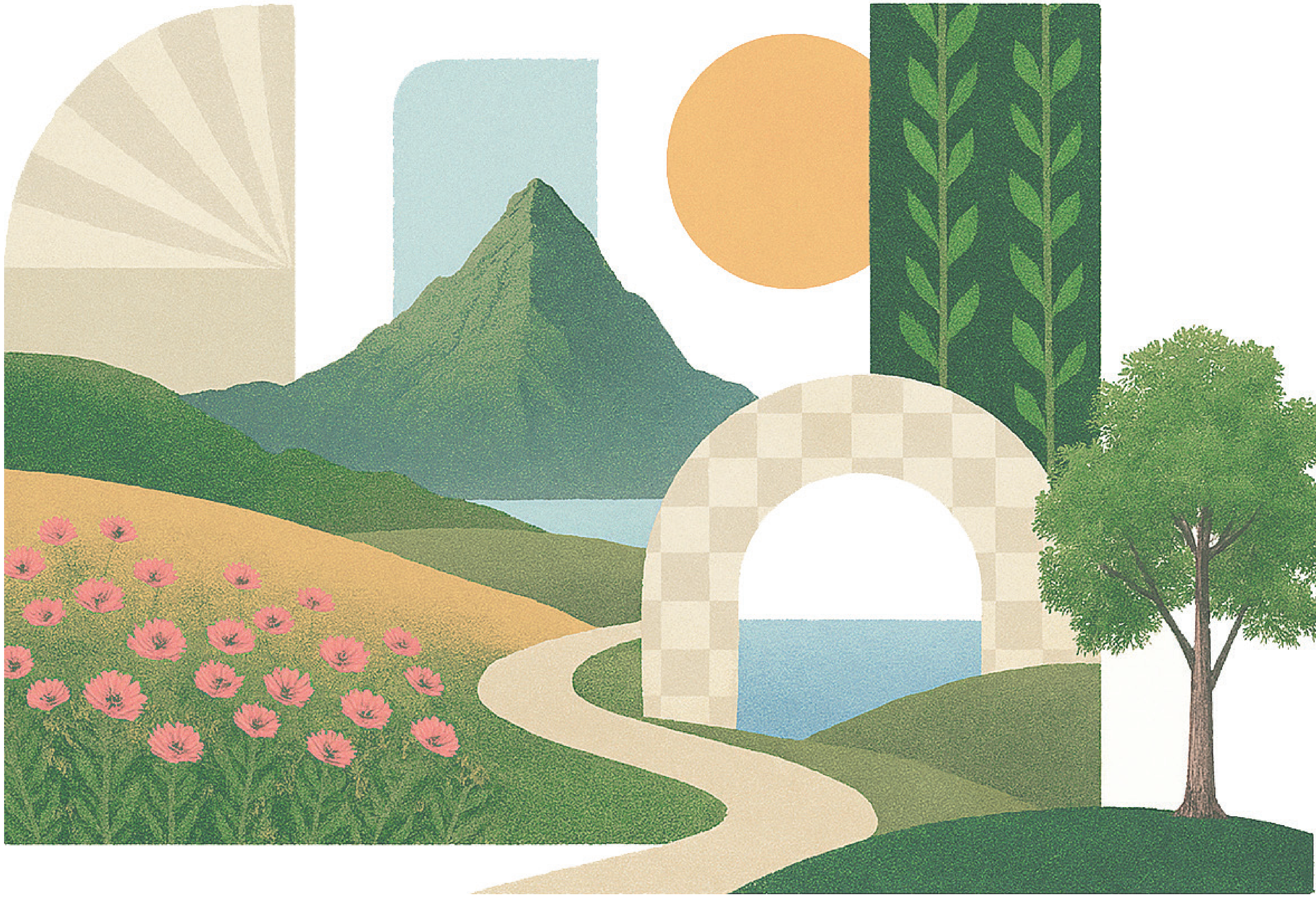
This final chapter synthesize the findings, reflections, and insights that have emerged throughout the thesis. Building upon the theoretical grounding, contextual challenges, and design experimentation discussed in earlier sections, this chapter evaluates how BD has been spatially and contextually applied to the Lindholmen park proposal. It examines the interplay between the BD elements and the core themes of climate adaptation, ecosystem health, and well-being, serving as a bridge between theory and practice. Here, the abstract principles of BD are interpreted through site-responsive strategies, illuminating how global frameworks can be localized to respond meaningfully to Gothenburg's climate, topography, and social needs. This discussion not only reflects on the findings, but also critically addresses the nuances, trade-offs, and new potentials revealed by integrating biophilia into complex urban resilience design.

7.1 ADDRESSING OBJECTIVES

Building on the park design's translation of the biophilic framework into spatial interventions, and adaptation of the best practices cases to Gothenburg´s unique context and needs, the following discussion evaluate how the BD elemen has been applied architecturally to meet Lindholmen's climate adaptation, ecosystem health, and well-being objectives. By examining recurring patterns, relationships, and unexpected effects, it assess how these design strategies answer the question "How can biophilic design principles be applied to create a park proposal for Lindholmen that enhances climate adaptation, ecosystem health, and well-being?" and uncover insights for future refinement. The application of the BD framework to the Lindholmen park proposal reveals that these principles, when thoughtfully adapted, can serve as useful tools to enhance climate adaptation, ecosystem health, and human well-being. The design outcomes suggest that BD is more than a conceptual model; it is a spatial and experiential language capable of responding to both environmental systems and human needs in urban contexts.

A key insight is that translating BD from theoretical texts and global best practices into a site-specific design is not a linear process of replication, but one of interpretation. The BD Element Matrix provided a structured lens through which abstract principles were distilled into meaningful spatial strategies. This enabled a synthesis of multiple BD attributes into layered interventions, for example, where stormwater wetlands double as sensory-rich environments, or green corridors serve both ecological connectivity and restorative human experiences.

Patterns emerged showing how BD elements rarely act



in isolation. Instead, they often intersect across all three focus areas of the research question. Elements introduced to enhance ecosystem health also play crucial roles in stormwater management and in offering sensory stimulation that supports psychological well-being. This overlap shows that BD naturally creates synergy, enhancing ecosystems and enriching human experiences at the same time, rather than treating them as separate goals. At the same time, this layering of functions raises questions about clarity of purpose. When design elements are expected to do too much, it becomes harder to evaluate which goals are actually being met, and for whom. In some cases, ecological value and user preferences may even come into quiet conflict, a tension that merits further exploration.

Another finding is the role of spatial atmosphere, especially those informed by BD categories like ”prospect and refuge,” ”connection to place,” and ”seasonal change”, in reinforcing well-being outcomes. When layered into the park design, these qualities create a cohesive environment that feels both safe and stimulating, contributing to users' sense of comfort and engagement with nature.

What also becomes evident is that even within a single site, BD can be scaled across multiple experiential levels, from immersive landscape zones to subtle material choices and path curvatures. This multiscalar application broadens the potential of BD, affirming that the principles can be adapted across different types and intensities of intervention.

In sum, the findings affirm the core premise of the research question: BD principles can be effectively applied to a park proposal in Lindholmen to enhance climate adaptation, ecosystem health, and well-being. This is achieved not by literal replication of best practice models, but through a locally attuned design logic that weaves natural systems and human experiences into an integrated urban landscape. The result is a spatial strategy that is both ecologically grounded and emotionally resonant, a key hallmark of successful BD.

7.1.1 OPPORTUNITIES & CHALLENGES

Building on the comparative analysis between best-practice studies and the Lindholmen park proposal, the following section evaluates how these insights answer the question “What challenges and benefits arise when integrating biophilic park design principles into Gothenburg's urban fabric, considering its unique flood challenges, mental health stressors, and climatic conditions, and how can these factors be addressed in practical urban planning?” The comparative analysis between the best practice studies and the Lindholmen park proposal highlights a nuanced set of challenges and opportunities that emerge when adapting BD principles to Gothenburg's specific context. These findings confirm that while BD offers promising solutions for climate adaptation, ecosystem health, and well-being, its integration into the Nordic urban fabric is far from straightforward.

A key pattern that emerged across all the Opportunities & Challenges Matrices is that success in one context does not guarantee effectiveness in another. Strategies such as immersive wetlands or dynamic water features, celebrated in tropical or temperate climates, posed operational and experiential challenges in Gothenburg's colder, darker environment. This disconnect underscores the importance of translating, not transplanting, design solutions. What works in Bangkok or Singapore may need significant modification to function in Gothenburg, especially when long winters and limited daylight affect both plant vitality and public space usage.

Another insight lies in the overlap between challenges and opportunities, especially around flood mitigation and mental health. The Lindholmen matrix shows that several strategies serve dual purposes, for instance, rain gardens that manage stormwater while offering sensory engagement and seasonal interest. However, this dual functionality is also where tensions emerge. The demand for multi-functional design can lead to trade-offs: for instance, balancing flood resilience with the aesthetic and experiential needs of youth-oriented public space.

In practical urban planning, these findings suggest that BD can work in Gothenburg when its principles are adapted through a local lens and supported by flexible frameworks. The matrices demonstrate the value of structured, iterative evaluation, what begins as an opportunity in theory may reveal hidden challenges in implementation, and vice versa. Importantly, the Lindholmen case shows that even under climatic and social constraints, BD can generate layered benefits, if approached with critical creativity.

In conclusion, the findings affirm that while integrating BD into Gothenburg's urban landscape presents distinct challenges, especially in terms of climate and mental health, these very constraints can catalyze design innovation. The process of mapping, comparing, and adapting global strategies has proven crucial, not just for creating a site-specific proposal, but for identifying how BD can inform a broader shift in urban planning practice, one that is both ecologically sound and emotionally intelligent.

7.2 SELECTION OF FRAMEWORKS

The selection of foundational frameworks in this thesis was driven by their academic rigor, interdisciplinary relevance, and ability to address the multifaceted challenges facing urban environments like Gothenburg. Each framework was chosen for its distinct theoretical contribution and its potential to be integrated into a cohesive, actionable model for biophilic park design.

The SDGs were incorporated as a strategic anchor to align the framework with globally endorsed priorities for sustainable development. Academically, the SDGs provide a comprehensive structure for addressing interconnected ecological and social. By focusing on SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land), the thesis ensures its relevance to both urban planning theory and global policy discourse. Their inclusion reinforces the framework's normative legitimacy and its potential influence in shaping sustainability-oriented urban design.

Kellert's biophilic frameworks (2008, 2018) were chosen for their foundational role in articulating the philosophical and evolutionary basis of BD. Kellert's work has been instrumental in establishing a scientifically grounded definition of biophilia within the built environment, emphasizing the importance of direct, indirect, and spatial experiences of nature. His dual frameworks bring academic depth by bridging environmental psychology, evolutionary biology, and design theory, making them essential for exploring how urban nature affects cognitive and emotional well-being. This makes them particularly relevant in addressing mental health, a core focus of the thesis.

Browning and Ryan's 15 patterns of BD were selected for their methodological clarity and evidence-based structure. Their contribution lies in translating abstract biophilic principles into specific, actionable design strategies validated through research in environmental psychology, human behavior, and workplace productivity. This practical orientation complements the thesis's design-by-research approach and provides a robust typology of interventions suitable for evaluating and adapting to Gothenburg's urban morphology and climate.

Zhong et al.'s optimized framework (2022) was selected as the primary structural model for its academic innovation and integrative capacity. Building upon Kellert and Browning & Ryan, Zhong's framework synthesizes prior theoretical contributions into a streamlined, SDG-aligned system optimized for urban resilience. Its methodological value lies in bridging theory and application through structured matrices, making it especially suitable for comparative analysis and performance assessment. In this thesis, Zhong's model was refined to remove indoor-centric components and tailor its use for outdoor park environments, demonstrating its flexibility and suitability for localized adaptation.

7.2.1 ADDITIONAL BD FRAMEWORKS

Had this thesis adopted other BD frameworks, its direction and outcomes would likely have shifted in notable or less notable ways. While each framework presents valuable academic and practical insights, their scope, focus, and application vary, and may not have aligned as effectively with the thesis objectives of flood mitigation and youth mental health support.

The Practice of Biophilic Design (Kellert & Calabrese, 2015) builds directly on Kellert's earlier work by synthesizing 25 attributes into three experiential categories to reflect the practice of BD (Wijesooriya et al., 2023). Given its structural and conceptual similarity to Kellert's 2008 framework, which already underpins the Zhong et al. optimized model used in this thesis, adopting this framework independently would likely not have significantly changed the thesis outcome. However, while it offers a refined categorization of biophilic experiences, it does not explicitly integrate broader sustainability targets such as the UN SDGs or emphasize measurable outcomes related to urban climate resilience, both of which are critical to addressing the challenges of Lindholmen.

The Biophilic and Innovative-Conducive University Campus Framework (Abdelaal 2019) is a research-informed model designed specifically to guide the application of BD principles in academic campus environments (Wijesooriya et al., 2023). While it presents a robust academic foundation, its design assumptions—focused on semi-private, institutional settings—are less suited to the open, multifunctional nature of urban public parks. The spatial configurations and user dynamics it targets differ significantly from those found in diverse, socially active areas like Lindholmen. As a result, applying this framework might have led to a design less responsive to the broader social inclusivity, seasonal usability, and ecological adaptability required in Gothenburg's public realm.

The Biophilic Framework for Sustainable Design (Xue et al. 2019) strongly emphasizes integration with environmental sustainability (Wijesooriya et al., 2023). While this would have enhanced the environmental performance angle of the design, it may have deprioritized experiential and emotional dimensions of human-nature interaction, which are essential for supporting psychological well-being.

The Biophilic Water Criteria Framework (Wijesooriya et al. 2021) introduces a valuable methodology for linking BD with water-sensitive design (Wijesooriya et al., 2023). While promising for flood management, its narrow functional focus on hydrology may have restricted the broader scope of the thesis, which also targets biodiversity and social inclusion. Using this framework might have skewed the project toward technical resilience at the expense of social or sensory richness.

By instead integrating the SDGs, Kellert's biophilic framework, Browning and Ryan's 15 Patterns and Zhong et al.'s optimized, flexible, and outcome-oriented framework, this thesis constructs a design model that is both academically grounded and contextually adaptable. This approach allowed for the creation of a framework that meets Gothenburg's specific environmental and social needs while remaining scalable for future application in similar Nordic contexts.

7.3 SELECTION OF BEST PRACTICES

The selection of best practice studies was driven by their proven ability to integrate BD with challenges similar to those in Gothenburg. Each case offers distinct strengths: Greenacre emphasizes sensory well-being in compact urban spaces, Bishan showcases large-scale flood adaptation and youth programming, and CUC Park demonstrates multifunctional stormwater solutions paired with educational design for youth mental health.

The Lindholmen park design draws from each: it mimics Greenacre's spatial richness for mental restoration, incorporates Bishan's ecological flood strategies and youth-oriented trails, and adopts CUC Park's climate-adaptive landscape systems. While not as advanced in large-scale flood mitigation strategies as the latter two, Lindholmen's design is more tailored to Nordic conditions, and scores high on mental health and youth inclusion according to the Opportunities and Challenges Matrix.

7.3.1 ADDITIONAL BEST PRACTICES

Alternatively, if the Lindholmen design had drawn on a Gothenburg best-practice study, e.g. Slottsskogen, it would have built on planting palettes suited to Nordic seasons, and familiar park-use behaviors. This could have resulted in a design comfortably aligned with local expectations. However, it may have missed some of the more experimental flood-mitigation strategies and interactive educational features seen in the international examples. While Slottsskogen's public familiarity and ecological framework provide a practical baseline, its biophilic elements and water-sensitive solutions are more subtle, potentially leading to a park proposal that feels familiar and reliable but offers fewer novel or exploratory experiences.

7.4 IMPLICATIONS

The implications of this research span several areas, including theory, practice, policy, and future research. Theoretically, the study contributes to the ongoing development of BD by examining how existing frameworks can be adapted and applied in a Northern European urban setting. This highlights their potential relevance in colder climates and socially varied environments. On a practical level, the thesis presents a framework and design proposal that may support urban planners and architects in integrating BD strategies to improve urban conditions. From a policy perspective, the research underlines the potential benefits of incorporating climate adaptation, ecosystem health, and well-being considerations into spatial planning, which could inform future local development initiatives. The refined framework also offers a foundation for continued exploration in related contexts, particularly in Nordic or flood-prone cities where similar environmental and social challenges exist. In terms of application, the use of biophilic strategies in areas such as Lindholmen may help manage flood risks, enhance biodiversity, and support the creation of inclusive, nature-rich public spaces. These strategies may be particularly beneficial for younger populations, who are often more affected by mental health concerns and may gain from improved access to restorative outdoor environments. Additionally, by introducing a spatial component through the use of sketches, the framework enhances its practical applicability. This visual approach provides a clearer and more accessible way for others to apply the principles, moving beyond a purely textual description.

7.5 LIMITATIONS

This study acknowledges several limitations that help define the scope and applicability of its findings. Firstly, the research focuses on a single implementation area which may limit the transferability of the results to other urban settings with different environmental or social conditions. Methodologically, the study does not include participatory processes or direct stakeholder engagement; while not essential to the framework development, involving local youth could have provided valuable insights into their specific needs and preferences, enhancing the contextual relevance and inclusivity of the design. It also operates within a conceptual timeframe, proposing strategies without assessing their long-term ecological or social outcomes. In terms of analysis, the thesis primarily adopts a qualitative approach supported by literature and theoretical frameworks. While the flood risk assessment is based on established and credible sources, more advanced, site-specific hydrological modeling could have enhanced the accuracy of the analysis and potentially influenced certain aspects of the design proposal. Another limitation is the number of best practice studies used which, while carefully selected, may not fully capture the breadth of BD strategies applicable across diverse contexts. Despite these constraints, the study maintains academic transparency and offers a clear foundation for future research and continued refinement.

7.6 FUTURE RESEARCH

The research highlights several areas for further exploration, particularly in addressing questions that remain beyond the scope of the current research. One important direction involves investigating the long-term effects of BD on both mental health and flood mitigation to better understand the sustained impact of such interventions. Further research could also explore how specific biophilic features influence youth mental health during the darker winter months, when access to restorative outdoor environments may be limited. Seasonal variation more broadly presents a valuable area of inquiry, especially in terms of how it shapes public interaction with biophilic parks in northern climates. Incorporating participatory design processes involving youth, residents, and planners could also provide deeper insights into local needs and preferences, enhancing the contextual relevance of future frameworks. Comparative studies across diverse urban settings, both within and outside the Nordic region, may help assess how adaptable and scalable the framework is in different social and environmental conditions. Additionally, biodiversity assessments could provide empirical data on ecological outcomes following implementation, offering a more comprehensive understanding of BD's role in urban ecosystems.

7.7 CONCLUSION

This thesis explored how BD principles can be applied to develop a park proposal for Lindholmen that supports climate adaptation, ecosystem health, and human well-being. Central to this inquiry was the question of how such principles could translate into practical design strategies within the specific environmental and social context of Gothenburg. In addition, the research examined the challenges and benefits that emerge when integrating biophilic park design into the city's urban fabric, particularly in relation to local flood risks, youth mental health stressors, and climatic conditions and considered how these factors might be addressed through adaptable and context-sensitive urban planning approaches.

The findings indicate that BD can function as more than a conceptual or aesthetic framework. When tailored to local environmental conditions and social needs, it becomes a practical strategy for developing urban spaces that support ecological resilience and psychological restoration. The Lindholmen proposal demonstrates how globally informed biophilic frameworks can be translated into spatial and sensory experiences that respond to Gothenburg's specific climate and urban fabric. Key insights suggest that BD is most effective when approached as a layered and adaptable process, one that engages with local climate, cultural identity, and user experience. Design interventions such as rain gardens, green roofs, wetlands, and sensory landscapes were found to simultaneously address stormwater management, biodiversity, and mental well-being. However, the dual role of many biophilic elements also introduces complexity, particularly in balancing functional, ecological, and social expectations across seasons. The project also revealed that while Gothenburg's cold climate and long, dark winters may limit the direct transferability of biophilic best practices from warmer regions, these conditions present unique design opportunities. Rather than acting as barriers, seasonal constraints can inform creative spatial responses that enhance usability and comfort throughout the year. Adaptive features such as wind-protected seating areas, covered structures, seasonal planting schemes, and the inclusion of greenhouses can extend the functionality of outdoor spaces, providing warmth, shelter, and sensory engagement even in colder months.

In conclusion, this thesis affirms that BD principles can be meaningfully applied to support climate adaptation, ecosystem health, and well-being in Gothenburg. However, success depends on a careful process of contextualization rather than replication. The Lindholmen park proposal illustrates how biophilic strategies can be integrated into urban planning as a flexible design language, one that is grounded in both ecological processes and human experiences, and capable of addressing contemporary urban challenges in a holistic, site-specific manner.

DISCUSSION
BIOPHILIUS - SYNTHESIS

BIBLIOGRAPHY

LIST OF REFERENCES

A

Abdelaal, M, S. (2019). Biophilic campus: An emerging planning approach for a sustainable innovation-conducive university. Journal of Cleaner Production, 215, 1445-1456. https://doi.org/10.1016/j.jclepro.2019.01.185

B

Betley, E. C., Sigouin, A., Pascua, P., Cheng, S. H., MacDonald, K. I., Arengo, F., Aumeeruddy-Thomas, Y., Caillon, S., Isaac, M. E., Jupiter, S. D., Mawyer, A., Mejia, M., Moore, A. C., Renard, D., Sébastien, L., Gazit, N., & Sterling, E. J. (2023). Assessing human well-being constructs with environmental and equity aspects: A review of the landscape. People and Nature, 5(6), 1756–1773. https://doi.org/10.1002/pan3.10293

Browning, W.D., & Ryan, C.O. (2020). Nature Inside: A biophilic design guide (1st ed.). https://doi.org/10.4324/9781003033011

C

Cui, M., Ferreira, F., Fung, T. K., & Matos, J. S. (2021). Tale of Two Cities: How Nature-Based Solutions Help Create Adaptive and Resilient Urban Water Management Practices in Singapore and Lisbon. Sustainability, 13(18), 10427. https://doi.org/10.3390/su131810427

E

Egegård, C. H., Lindborg, M., Gren, Å., Marcus, L., Pont, M. B., & Colding, J. (2024). Climate Proofing Cities by Navigating Nature-Based Solutions in a Multi-Scale, Social–Ecological Urban Planning Context: A Case Study of Flood Protection in the City of Gothenburg, Sweden. Land, 13(2), 1-16.
https://doi.org/10.3390/land13020143

F

Folkhälsomyndigheten. (2022). Mental health.
https://www.folkhalsomyndigheten.se/the-public-health-agency-of-sweden/living-conditions-and-life-style/mental-health/

Fromm, E. (1964). The Heart of Man: Its Genius for Good and Evil. Harper & Row Publishers.

Fullerton, J. (2018). As Bangkok sinks, could this anti-flood park be the answer?. The Guardian.
https://www.theguardian.com/cities/2018/oct/03/as-bangkok-sinks-could-this-anti-flood-park-be-the-answer

G

Gur, T. (n.d) The single raindrop never feels responsible for the flood. The Elevate society.
https://elevatesociety.com/the-single-raindrop-never-feels/

H

Holmes, D. (2019), Chulalongkorn University Centenary Park – green infrastructure for the city of BangkokChulalongkorn University Centenary Park – green infrastructure for the city of Bangkok. World Landscape Architects.
https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=b870c45f9584

I

Ibrahim, I., & Al-Chaderchi, B. M. (2022). Contribution of the biophilic design approaches to the UN sustainable development goals. Eco-Architecture IX, 210, 115-125.
https://doi.org/10.2495/ARC220101

K

Kellert, s. R., & Calabrese, E. (2015). The Pr acTice of BioPhilic Design University of Minnesota Twin Cities.

Kellert, S. R. (2008). Dimensions, elements, and attributes of biophilic design. John Wiley & Sons, Inc.

Kellert, S. R. (2018). Nature by Design: The Practice of Biophilic Design. https://doi.org/10.12987/9780300235432

Kellert, S. R. (1993) The Biological Basis for Human Values of Nature. Island Press.

L

Landezine International Landscape Award. (n.d.). Chulalongkorn University Centenary Park. Landezine Award. https://landezine-award.com/chulalongkorn-university-centenary-park/

Lane, S. N. (2017). Natural flood management. WIREs Water, 4(3), 1-12.
https://doi.org/10.1002/wat2.1211

Lawler, J. J., Spencer, B., Olden, J. D., Kim, S. H., Lowe, C., Bolton, S., Beamon, B. M., Thompson, L., & Voss, J. G. (2013). Mitigation and Adaptation Strategies to Reduce Climate Vulnerabilities and Maintain Ecosystem Services. Climate Vulnerability, 315–335. https://doi.org/10.1016/B978-0-12-384703-4.00436-6

Lindholmen. (2020). Lindholmen Open Days – Global nytta för detta decennium. Lindholmen Science Park. https://www.lindholmen.se/sv/nyheter/lindholmen-open-days-global-nytta-detta-decennium

Lu, Y., Wang, R., Zhang, Y., Su, H., Wang, P., Jenkins, A., Ferrier, R. C., Bailey, M., & Squire, G. (2017). Ecosystem health towards sustainability. Ecosystem health towards sustainability, 1(1), 1-15 https://doi.org/10.1890/EHS14-0013.1

Lundqvist, L. J. (2015). Planning for Climate Change Adaptation in a Multi-level Context: The Gothenburg Metropolitan Area. European Planning Studies, 24(1), 1–20. https://doi.org/10.1080/09654313.2015.1056774

N

Newman, P. (2013). Biophilic urbanism: a case study on Singapore. Australian Planner, 51(1), 47–65. https://doi.org/10.1080/07293682.2013.790832

Nordic Council of Ministers. (2023). Young men's mental ill-health in the Nordics (TemaNord 2023:549). https://pub.norden.org/temanord2023-549/

Q

Qihui, H. (2018). Singapore: Bio-Engineering Works at Bishan-Ang Mo Kio Park to Prevent Urban Flooding. C40.
https://www.c40.org/case-studies/singapore-bio-engineering-works-at-bishan-ang-mo-kio-park-to-prevent-urban-flooding/

R

Ristianti, N., Dewi, S., Susanti, R., Kurniati, R., & Zain, N. (2024). Using Biophilic Design to Enhance Resilience of Urban Parks in Semarang City, Indonesia. Journal of Environmental Design and Planning, 23(1), 1-21
https://doi.org/10.54028/NJ202423402

S

Schaefer, C. (2014). Bishan-Ang Mo Kio park from concrete canal to natural wonderworld. Ecological Urbanism, 1-13

See, V. (2021). Adapting to a Disrupted World. Urban solutions.
https://www.clc.gov.sg/docs/default-source/urban-solutions/urban-solutions-18-adapting-to-a-disrupted-world.pdf

Sen, A. (1999). Development as freedom. The New York Times.

Suksawang, W. (2020) Public response to the appearance of ecological landscape design : A case study of Chulalongkorn University Centenary Park. [PhD thesis, Chulalongkorn University]. CUIR.
https://cuir.car.chula.ac.th/handle/123456789/83524

T

Terrapin. (2016). Biophilic Design Case Studies. https://www.terrapinbrightgreen.com/wp-content/uploads/2015/11/Greenacre-Park-Fall16.pdf

W

Wijesooriya, N., Brambilla, A., & Markauskaite, L. (2023). Biophilic design frameworks: A review of structure, development techniques and their compatibility with LEED sustainable design criteria. Cleaner Production Letters, 4.
https://doi.org/10.1016/j.clpl.2023.100033.

Wijesooriya, N., Brambilla, A., & Markauskaite, L. (2021). Biophilic Water Criteria: Exploring a Technique to Develop an Environmentally Sustainable Biophilic Design Framework. Springer, Cham.
https://doi.org/10.1007/978-3-030-65181-7_35

Wilson, O. E., (1984). Biophilia. Harvard University Press.

X

Xue, F., Lau, S. S., Gou, Z., Song, Y., & Jiang, B. (2019). Incorporating biophilia into green building rating tools for promoting health and wellbeing. Environmental Impact Assessment Review, 76, 98-112,
https://doi.org/10.1016/j.eiar.2019.02.004.

Z

Zare, G., Baharvand, M., Faizi, M., & Masnavi, M. R. (2022). A Review of Biophilic Design Conception Implementation in Architecture. Journal of Design and Built Environment 21(3), 16-36 https://doi.org/10.22452/jdbe.vol21no3.2

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. Frontiers of Architectural Research, 11(1), 114-141. https://doi.org/10.1016/j.foar.2021.07.006

IMAGE SOURCES

A

Arielly, M., & Frankel, F. (n.d.). Greenacre Park [Photograph]. Sasaki. https://www.sasaki.com/projects/greenacre-park/

H

Han, L. S. (2016). A biophilic design [Photograph]. Asla. https://www.asla.org/2016awards/169669.html

Han, L. S. (2016). A community centric park [Photograph]. Asla. https://www.asla.org/2016awards/169669.html

Holmes, D. (2019). Chulalongkorn University Centenary Park [Photograph]. Worl Landscape Architect. https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Holmes, D. (2019). Green Corridors [Photograph]. Worl Landscape Architect. https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Holmes, D. (2019). Masterplan [Floorplan]. Worl Landscape Architect. https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Holmes, D. (2019). Section [Section]. Worl Landscape Architect. https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

Holmes, D. (2019). Stationary water bikes [Photograph]. Worl Landscape Architect. https://worldlandscapearchitect.com/chulalongkorn-centenary-park-green-infrastructure-for-the-city-of-bangkok/?v=5dae429688af

R

Ramboll Studio Dreiseitl. (2016). Illustartive site plan [Masterplan]. Asla. https://www.asla.org/2016awards/169669.html

S

Sasaki (1971). Greenacre Park Floorplan [Floorplan]. Sasaki. https://www.sasaki.com/projects/greenacre-park/

Sasaki (1971). Greenacre Park Section [Section]. Sasaki. https://www.sasaki.com/projects/greenacre-park/

APPENDIX A - BD FRAMEWORK MATRICES

TABLE A1

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Water	» Build Waterscapes such as Fountains, constructed wetlands, ponds, water walls, rainwater spouts, aquaria, etc. » Access To Natural Water Features such as waterfalls, rivers, streams, oceans,etc.	» Create Multiple sensory experience of water, and diverse water configuration and appearance » Expand The Water Area » Prioritise Fluctuating water Over stagnant water	» High-volume and large-turbulence water that affect acoustic quality and humidity » Negative (biophobic) emotional responses (e.g. fear deepwater) » Artificial water features may increase energy consumption
Air	» Increase natural ventilation using operable windows, vents, narrower structures, etc. » Simulate natural air and ventilation through operable windows, vents, airshafts, porches, clerestories, HVAC systems, etc.	» Enrich sensory variability and reduce boredom and negativity by imitating the subtle changes of natural air and ventilation » Broaden the acceptable range of thermal comfort to decrease energy demand	» Natural ventilation may increase the circulation of pollutants (e.g. PM2.5) » Ventilation when outdoor humidity is high will bring excess moisture that increases the risk of mould contamination
Daylight	» Bring in natural light via glass walls, clerestories, skylights, atria, reflective colours/materials, etc. » Mimic the spectral and ambient qualities of natural light, such as by arranging multiple low-glare electric light sources, ambient diffused lighting on walls/ceiling, and daylight preserving window treatments	» Dynamic lights and shadows form transitions between indoor and outdoor spaces, which are fascinating. » High-contrast lights bring attention and evoke a sense of sacredness. » Support productivity and boost retail sales	» Glares and spilling light interfere with visual performance, and intense dynamics might be distracting. » Could lead to overheating and decreased building performance
Plants	» Bring vegetation indoors by potting plants and indoor green walls. » Incorporate plants into buildings by using green roofs, green walls and facades, large atria with park-like settings, green pockets, etc.	» Increase green space coverage, native plants ratio, and biodiversity. » Improve shading/sheltering ability and reduce building energy consumption. » Edible plants promote food production for urban farming. » Provide accessible green spaces and support physical exercise. » Provide visual connections with green spaces for restoration, stress reduction, productivity, and positive mood. » Reduce air pollution and optimise air quality	» Could cause structural problems, excessive humidity, insect trouble, odour issues, etc. » Single plants and isolated gardens have limited impacts. » Highly artificial designs require intensive energy and maintenance.

Table A1, Optimized BD Framework by Zhong et al. (2022)

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Animals	» Create spaces to accommodate animals, such as ponds, aquariums, etc. » Build animal-friendly living areas to attract animals like nest boxes, gardens, green roofs/walls, etc.	» Increase biodiversity and enrich local species. » Form an ecosystem with interconnected plants, soil, water, and geological features	» Contact with some specific animals (e.g. snakes and spiders) or the sight of dead animals may cause negative (biophobic) emotions
Landscape	» Build landscapes in the sites such as constructed wetlands, grasslands, prairies, forests, and other habitats. » Create interior landscapes in atria, courtyards, entry areas, hallways, etc. » Provide window views of natural landscapes like forests, seascapes and water motifs	» Enhance coherent and ecologically connected landscapes. » Optimise the natural landscape, and minimise management requirements	» Contrived superficial decorations, isolated, exotic plant configurations. » Lack of participation and immersion. » Lack of shelter and inappropriate distance and height to view the landscape
Weather	» Enhance exposure to weather through operable windows, porches, balconies, terraces, courtyards, etc. » Enhance awareness of meteorological conditions by using transparent roofs, rainwater collectors and spouts, etc. » Simulate the experience of weather, like sunlight, airflow, humidity, temperature, and barometric pressure	» Allow visual access to weather (more cost-effective) and physical experiences to perceive weather. » Optimise window views. » Adopt permeable surfaces for stormwater management. » Integrate rainwater treatment systems into landscape design	» Extreme weather conditions and climate change are not beneficial to human health and comfort
Time & Seasonal Change	» Present the views of the building facade and appearance that change after long-term exposure to nature. » Provide views of seasonal changes in plants.	» Create a sense of maturity (e.g. materials weathered over time) to resist the inauthentic and unreliable feeling of the artificial environment. » Provide various sensory experiences	» Building envelopes may be damaged or become dilapidated over time. » Perception of seasonal changes depends on individual preferences. » Differences in the visual effects of plants in different seasons cause instability
Form & Shape	» Imitate the contours and motifs of organisms (biomorphic design) in building forms, structural systems, components, and interior spaces. » Biomorphic elements could be botanical/animal	» Create the cultural and ecological connections with surrounding environments in the expression of form and aesthetics » Enrich architects' creativity	» Overuse and repetition of forms and shapes can cause visual boredom

Table A1, Optimized BD Framework by Zhong et al. (2022)

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Form & Shape	motifs, shells, spirals, egg, oval, tubular forms, arches, vaults, domes, etc.		
Patterns & Geometries	» Adopt fractals, hierarchically organised ratios, and scales in designs. » Use the Fibonacci series (0, 1, 1, 2, 3, 5, 8, 13, 21, 34 .) or Golden Ratio (1:1.618). » Choose the intermediate ratio (1:1.3e1.75)	» Construct in two/three dimensions (such as floors, walls, furniture, windows and arches) to increase the variety. » Use computers to generate complex shapes and structures and allow the use of novel materials. » Simultaneously increase structural efficiency and aesthetic appeal. » Generate visual complexity	» Complex architectural shapes often require higher budgets. » May cause chaos and disorder in the building, and make residents feel uncomfortable and unpleasant
Mechanism	» Learn from other species to meet the functional needs (Biomimetic or Biomimicry), such as termites and spiders inspired the efficiency of climatic controls and the structural strength of building materials.	» Enhance building performance in terms of indoor comfort and energy consumption. » Improve the efficiency of building resources and the ability to self-compensate and regulate. » Innovate building shape and structural design » Improve the durability of the building	» Inevitable human error in mimicking nature may cause an unbalanced system and further endanger the whole larger ecosystem. » Focus on imitation of external form and silhouette, but neglect economy and feasibility in structure and construction
Images	» Present natural scenes, plants, animals, water, landscapes, or geological features in paintings, photographs, videos, and fabrics. » Natural images should include a rich variety of species, landscapes, or human survival experiences in nature.	» Provide opportunities to connect with nature in special enclosed environments (e.g. radiation rooms in hospitals). » Generate positive distractions to release anxiety, fear, and stress. » Evoke a sense of natureconnected	» May be less effective than viewing real natural scenes. » Some images produce undesirable effects (e.g., barren/ degraded nature or themeless, isolated, random elements). » Influenced by personal preference for natural image types
Material, Texture & colour	» Adopt natural materials like wood, bamboo, rock, stone, clay, etc. » Consider textures beyond materials, such as light, colour, and sound. » Use natural colours such as blue, green, and other earth colours	» Arouse the impression of natural variability by using different materials and colours. » Allow rough and unfinished textured surfaces. » Replace steel, concrete, etc. as building materials in reducing carbon footprint and promoting sustainability. » Bend/curve natural materials to create organic shaped buildings	» The effectiveness of the colour (green) design in real environments is uncertain. » Excessively bright or high-contrast colours produce pressure effects, and some colours (e.g., rotting brown) generate negative associations. » Disputes exist between unprocessed, crafted, and synthetic natural materials

Table A1, Optimized BD Framework by Zhong et al. (2022)

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Prospect & Refuge	» Conceive spaces with two complementary characteristics: open views/vistas (prospect), and under shelters/ safe environments (refuge). » Achieved inside and outside experiences through window views, and balconies, courtyards, colonnades, etc. » Use controllable lighting to design spaces with refuge effects	» Provide open views and a sense of closure for simultaneous pleasure and safety. » Consider multi-functional prospect-refuge spaces to meet the needs of different activities. » Build attractive scenes by providing prospects. » Help recover from stress and mental fatigue. » Effects can be enhanced by additional complexity and mystery	» Prospect requires focal lengths 6 m, preferably 30 m, and partition heights 107 cm. » The balance between prospect and refuge is difficult to define. » View qualities depend highly on the surrounding environments (e.g., the view of a lake is considered much more comfortable than that of a glacier).
Complexy & order	» Arrange rich details and diversity in an orderly manner. » Consider natural forms, patterns, and geometries, especially in exposed building structures, facades, and details. » Choose materials with specific textures and colours or carefully arrange the variety and placement of plants.	» Enhance information richness in masterplans, landscapes, building forms/structures, and materials. » Arouse visual interest and preference. » Use computer algorithms to perform mathematical and geometric operations. » Strengthen the aesthetics of building facades	» Boredom may be caused by repeated fractal geometry. » Lack of consensus on the quality of visual and experiential richness and complexity. » Distinct fractal dimensions lead to differences in effects (most consider 1.3e1.5 is comfortable, and 1.5e1.7 is more interesting)
Enticement	» Generate 'peril' using cantilevers, infinity edges, transparent facades, pathways under/over water, scenes defying gravity, etc. » Create 'mystery' through winding paths, translucent materials, imperceptible sound sources, obscuring/ curving the edges, etc.	» Produce aesthetic attraction. » Enhance mystery by slowly revealing spaces or create dramatic shadows. » Opportunities to enrich landscapes and plants	» Creating experiences of peril carries risks of physical injury. » Sense of insecurity can lead to psychological discomfort. » Not applicable to all users and locations. » Increases maintenance costs in landscaped gardens
Connection to Place	» Provide views of prominent landmarks, landscapes, waterscapes, geological forms, etc. » Use indigenous materials and native plant varieties. » Apply landscape features to define building forms or dedicated landscape design such as Savanna-like environments	» Establish connections through various dimensions (e.g., culture, history, geography, and ecology). » Generate a "sense of place" and satisfy preferences for familiar places (place attachment). » Evoke a sense of belonging and support self-identity by integrating parts into the whole (nature bonding). » Support relaxation and psychological comfort and security	» Misunderstanding of culture and context can lead to inappropriate information or abuse. » A sense of loss may be evoked when the designs change negatively or are demolished

Table A1, Optimized BD Framework by Zhong et al. (2022)

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Connection of Spaces	» Conceive interior-exterior connections in transitional spaces, such as porches, patios, balconies, courtyards, pavilions, gardens, entry areas, foyers, atria, etc. » Consider mobility in spaces like entrances, exits, corridors, stairs, high glass elevators, etc	» Enhance spatial order and create sequential connections of spaces with clear boundaries, ideal patterns of movement, and the overall identity. » Encourage mobility (promenading) to avoid sedentary situations. » Enable interaction within the building by reaching differently designed natural scenes via paths or ramps	» Transitional spaces are complex and involve multiple challenges for design, construction, and maintenance. » Single-function paths can create monotony and boredom

Table A1, Optimized BD Framework by Zhong et al. (2022)

TABLE A2

THE 17 SDG	CHALLENGES	BENEFITS OF BD	RELEVANT BB ELEMENTS
3. Good Health & Well-Being	» Healthy And Comfortable Indoor Environment » Non-toxic substances environment » Obstruct disease transmission and bacterial contact » Physical Exercise Spaces	» Reduce air pollution and optimise air quality » Optimise thermal comfort » Provide psychological restoration » Reduce stress » Increase healing rates » Enhance Positive Emotions » Encourage Physical activity	» Plants » Air » Daylight » Plants » Landscape » Images » Materials, texture, and colour » Prospect and refuge » Entcitement
11. Sustainable Citiesand Communities	» Safety, inclusiveness, robustness, and settlements » Affordability, accessibility, mobility, and health of houses and infrastructure	» Increase liveability and enable higher density » Decrease violence and crime	» Water » Air » Daylight » Plants » Landscape » Weather » Connection To Place
13. Climate Action	» Climatic comfort with minimum energy consumption » Resilient to changing conditions (e.g. extreme-rain fall, floods, hurricanes, drought, and heat waves) » Sensitivity To Local Culture, topographic, and climatic conditions » Climate Adaptation Solutions With Co-benefits	» Reduce energy consumption through vegetative climaticeffects » Reduce the urban heat island effect » Enhance Wind Protection » Sensitive To Local topography and climate	» Water » Air » Daylight » Plants » Landscape » Weather » Connection To Place
15. Life on Land	» Protection, restoration, and support of ecosystems and biodiversity	» Improve biodiversity (species diversity preservation and regeneration » Provide habitats for animals in urban areas	» Plants » Animals » Connection To Place

Table A2, 4 0ut of the 17 SDGs, describing the connection between BD and the SDGs.

TABLE A3

ORGANIC OR NATURALISTIC				PLACE OR VERNACULAR	
ENVIONMENTAL FEATURES	NATURAL ELEMENTS	NATURAL PATTERNS & PROCESSES	LIGHT & SPACE	PLACE-BASED RELATIONSHIPS	EVOLVED HUMAN-NATURE RELATIONSHIP
» Color » Water » Air » Sunlight » Plants » Animals » Natural materials » Views and vistas » Facade greening » Geology and landscape » Habitat and ecosystems » Fire	» Botanical Motifs » Tree and columnar supports » Animal motifs » Shells and spiral » Egg, oval, and tubular forms » Arches, vaults, domes » Shapes resisting straingt lines and right angles » Simulation of natural features » Biomorphy » Geomorphology » Biomimicry	» Sensory variability » Information richness » Age, change, and the patina of time » Growth and efflorescence » Central focal point » Patterned wholes » Bounded spaces » Transitional spaces » Linked series and chains » Integration of parts to wholes » Complementary contrasts » Dynamic balance and tension » Fractals » Hierarchically organized ratios and scales	» Natural light » Filtered and diffused light » light and shadow » Reflected light » light pools » Warm light » Light as shape and form » Spaciousness » Spatial variabillity » Space as a shape and form » Spatial harmony » Inside outisde spaces	» Geographic connection to place » Historic connection to place » Ecological connection to place » Cultural connection to place » Indegious materials » Landscape orientation » Landscape features that define building form » Landscape ecology » Integration of ecology and culture » Spirit of place » Avoiding placelessness	» Prospect and refuge » Order and complexity » Curiosity and enticement » Cange and metamorphosis » Security and protection » Mastery and control » Affection and attachment » Atraction and beauty » Exploration and discovery » Information and cognition » Fear and awe » Reverence and spirituality

Table A3, Kellert's (2008) framework which is grounded in biophilia theory and biophilic values derived from evolutionary psychology

TABLE A4

DIRECT EXPERIENCE OF NATURE	INDIRECT EXPERIENCE OF NATURE	EXPERIENCE OF SPACE & PLACE
» Water » Air » Light » Plants » Animals » Views » Landscape » Fire » Weather	» Images » Materials » Texture » Color » Shapes and forms » Information richness » Change, age and the patina of time » Natural geometries » Simulated natural light and air » Biomimicry	» Prospect and refuge » Organized complexity » Mobility » Transisional spaces » Place » Intergarting parts to create wholes

Table A4, BD Experiences and Attributes Framework by Kellert's (2018), which is based on three core experiences and 25 associated attributes.

TABLE A5

NATURE IN SPACE	NATURAL ANALOGUES	NATURE & SPACE
» Visual Connection with nature » Non-visual connection with nature » Non.rhytmic sensory stimuli » Thermal and airflow variability » Presence of water » Dynamic and diffuse light » Connection with natural systems	» Biomorphic Forms and patterns » material connection with nature » Complexity and order	» Prospect » Refuge » Mystery » Risk/Peril » Awe

Table A5, BD Patterns Framework by Browning & Ryan (2020) which focusing on psychological well-being, physiological health,

TABLE A6

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Natural Elements	» Construct waterscapes such as fountains, ponds, constructed wetlands, water walls, rainwater spouts, and aquariums » Provide access to natural water features like waterfalls, rivers, streams, and oceans. » Integrate plants into buildings using green roofs, green walls, facades, large atria with park-like settings, and green pockets. » Create spaces for animals by incorporating ponds, aquariums, and similar habitats. » Design animal-friendly environments with nest boxes, gardens, green roofs, and green walls to attract wildlife.	» Enhance water experiences with diverse configurations and appearances. » Expand water areas and prioritize fluctuating water over stagnant water. » Increase green space, native plant coverage, and biodiversity. » Incorporate edible plants to support urban farming. » Ensure accessible green spaces for physical activity. » Strengthen visual connections to nature for well-being. » Improve air quality and reduce pollution. » Enrich local biodiversity and ecosystem connectivity.	» High-volume, turbulent water may impact acoustic quality and humidity. » Biophobic reactions can arise, such as fear of deep water. » Artificial water features may lead to increased energy consumption. » Potential structural issues include excessive humidity, insect problems, and odors. » Single plants and isolated gardens have limited ecological impact. » Highly artificial designs demand significant energy and maintenance. » Certain animals (e.g., snakes, spiders) or dead animals may trigger negative (biophobic) emotional responses.

Table A6, Biophilic park design Framework, developed to suit the aim and objectives of the research.

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Landscape	» Build landscapes in the sites such as constructed wetlands, grasslands, prairies, forests, and other habitats.	» Enhance coherent and ecologically connected landscapes. » Optimise the natural landscape, and minimise management requirements.	» Lack of participation and immersion. » Lack of shelter and inappropriate distance and height to view the landscape
Weather	» Enhance exposure to weather. » Enhance awareness of meteorological conditions by using transparent roofs, rainwater collectors and spouts, etc.	» Allow visual access to weather and physical experiences to perceive weather. » Integrate rainwater treatment systems into landscape design	» Extreme weather conditions and climate change are not beneficial to human health and comfort
Time & Seasonal Change	» Present the views of the material and appearance that change after long-term exposure to nature. » Provide views of seasonal changes in plants	» Create a sense of maturity (e.g. materials weathered over time) to resist the inauthentic and unreliable feeling of the artificial environment. » Provide various sensory experiences	» Building envelopes may be damaged or become dilapidated over time. » Perception of seasonal changes depends on individual preferences. » Differences in the visual effects of plants in different seasons cause instability
Spatial Charatcter	» Mimic natural contours and motifs in architecture. » Use organic shapes: spirals, ovals, arches, domes, and biomorphic elements. » Integrate fractal patterns and hierarchical ratios. » Apply Fibonacci sequence and Golden Ratio. » Prioritize natural materials: wood, bamboo, stone, clay. » Enhance sensory experiences with textures, light, color, and sound. » Use natural colors: blue, green, earth tones. » Arrange rich details in an orderly, harmonious way. » Incorporate natural forms and patterns in structures and facades.	» Connect culture, ecology, and design. » Inspire architectural creativity. » Use computers for complex shapes and materials. » Enhance visual richness and natural variability. » Allow rough textures for authenticity. » Replace high-carbon materials for sustainability. » Integrate information into design elements. » Arouse visual interest. » Apply algorithms for geometric precision. » Strengthen environmental harmony.	» Overuse of forms causes visual boredom. » Complex shapes increase costs. » Uncertainty in green design effectiveness. » Bright or clashing colors create discomfort. » Disputes over natural vs. synthetic materials. » Repeated fractal patterns may be dull. » No consensus on visual richness.
Prospect & Refuge	» Conceive spaces with two complementary characteristics: open views/vistas (prospect), and under shelters/	» Provide open views and a sense of closure for simultaneous pleasure and safety. »	» The balance between prospect and refuge is difficult to define.

Table A6, Biophilic park design Framework, developed to suit the aim and objectives of the research.

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Prospect & Refuge	safe environments (refuge).	» Consider multi-functional prospect-refuge spaces to meet the needs of different activities. » Build attractive scenes by providing prospects. » Help recover from stress and mental fatigue. » Effects can be enhanced by additional complexity and mystery	» View qualities depend highly on the surrounding environments (e.g., the view of a lake is considered much more comfortable than that of a glacier).
Enticement	» Generate 'peril' using cantilevers, infinity edges, transparent facades, pathways under/over water, scenes defying gravity, etc. » Create 'mystery' through winding paths, translucent materials, imperceptible sound sources, obscuring/ curving the edges, etc.	» Produce aesthetic attraction. » Enhance mystery by slowly revealing spaces or create dramatic shadows. » Opportunities to enrich landscapes and plants	» Creating experiences of peril carries risks of physical injury. » Sense of insecurity can lead to psychological discomfort. » Not applicable to all users and locations. » Increases maintenance costs in landscaped gardens
Connection to Place	» Provide views of prominent landmarks, landscapes, waterscapes, geological forms, etc. » Use indigenous materials and native plant varieties.	» Establish connections through various dimensions (e.g., culture, history, geography, and ecology). » Generate a "sense of place" and satisfy preferences for familiar places (place attachment). » Evoke a sense of belonging and support self-identity by integrating parts into the whole (nature bonding). » Support relaxation and psychological comfort and security	» Misunderstanding of culture and context can lead to inappropriate information or abuse.
Connection of Spaces	» Design seamless connections between outdoor spaces like patios, courtyards, pavilions, and gardens. » Ensure smooth transitions between different landscapes, such as wetlands, forests, meadows, and urban green spaces. » Enhance accessibility and flow in pathways, bridges, plazas, trails, and elevated walkways.	» Enhance spatial order and create sequential connections of spaces with clear boundaries, ideal patterns of move ment, and the overall identity. » Encourage mobility (promenading) to avoid sedentary situations. » Enable interaction by reaching differently designed natural scenes via paths or ramps	» Transitional spaces are complex and involve multiple challenges for design, construction, and maintenance. » Single-function paths can create monotony and boredom

Table A6, Biophilic park design Framework, developed to suit the aim and objectives of the research.

BD ELEMENTS	DESIGN STRATEGIES	STRENGTHS & OPPORTUNITIES	WEAKNESSES & THREATS
Mechanism	» Learn from natural systems to improve durability of outdoor infrastructure to withstand extreme weather. » Enhance natural water management and self-regulating landscapes. » Innovate flood-adaptive designs.	» Enhance the efficiency of natural resources and self-regulating systems. » Improve the durability of outdoor infrastructure to withstand climate impacts.	» Inevitable human error in mimicking nature may cause an unbalanced system and further endanger the whole larger ecosystem.

Table A6, Biophilic park design Framework, developed to suit the aim and objectives of the research.