



Blue Carbon Learning Center Design Along the Chao Phraya River: A Case Study of Wetland Zones in Nonthaburi Province

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ARTICLE INFO	ABSTRACT
Published Online: 11 August 2025	This research presents a design framework for a Blue Carbon Learning Center situated in the peri-urban context of Nonthaburi Province, Thailand. The area, located along the Chao Phraya River, holds strong potential for the development of ecological learning hubs within riparian wetlands (Smithsonian Institution, 2025; UNEP, 2010). The project aims to foster the conservation of natural resources through participatory, community-based environmental education (Kolb, 1984; Orr, 2004). The design concept is grounded in the Blue Carbon paradigm, emphasizing the restoration of aquatic ecosystems such as riparian forests, natural wetlands, and tributary canals. These ecosystems play a vital role in carbon sequestration, urban environmental balance, and the natural filtration of air pollutants (McDonough & Braungart, 2002; Ekvitayavetchanukul, 2024). In particular, the integration of native aquatic vegetation and green infrastructure contributes to reducing airborne particulate matter (PM2.5), thus enhancing local air quality and public health resilience. The spatial layout of the learning center is strategically tailored to the region's lowland floodplain geography and integrates community-driven activities such as native aquatic planting, eco-cultural knowledge platforms, sustainable water management, and the application of clean technologies in educational architecture (Cheonggyecheon Project, 2021; Siriporn, 2021). Universal Design principles are embedded throughout to ensure accessibility and inclusivity for all users. The proposed Blue Carbon Learning Center is envisioned as a model for green urban development in expanding metropolitan zones, promoting environmental literacy while supporting the local circular economy and improving urban air quality (UNEP, 2010).
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INTRODUCTION

In the present era, rapid urban expansion has led to a significant decline in green spaces and natural ecosystems, particularly in peri-urban areas. This urban encroachment has not only contributed to biodiversity loss and disrupted carbon sequestration processes but also exacerbated air quality issues, notably the rise of fine particulate matter (PM2.5) in densely populated regions (Ekvitayavetchanukul, 2024). One of the key strategies to address both the climate crisis and urban pollution is the promotion of Blue Carbon management referring to the carbon storage capacity of aquatic ecosystems

such as mangroves, wetlands, and riparian vegetation along rivers and coastlines (UNEP, 2010; Smithsonian Institution, 2025).

Nonthaburi Province, located on the outskirts of Bangkok, lies along the Chao Phraya River and features a lowland terrain enriched with traditional canals and freshwater wetlands. This geographic and ecological context presents an opportunity for restoring urban green infrastructure, rehabilitating aquatic ecosystems, and developing Blue Carbon models for conservation, education, and air quality mitigation. Notably, native hydrophytic plants in wetland

systems also play a role in capturing airborne pollutants thus contributing to improved respiratory health and microclimatic regulation in urban settings (Patnada Wellness & Ekvitayavetchanukul, 2024).

These wetland areas have the potential to serve as community-based learning platforms and prototypes of sustainable urban development that integrate environmental preservation with circular economy models and improved quality of life. The concept of establishing a Blue Carbon Learning Center in Nonthaburi's wetlands emerges as a vital initiative to empower local communities and academic institutions in co-managing natural resources. The center is envisioned as a public space that supports participatory learning and serves as a hub for knowledge on freshwater ecosystems, climate action, air quality resilience, and sustainable design principles (Kolb, 1984; Orr, 2004; McDonough & Braungart, 2002).

This research aims to propose a site-sensitive design framework for the Blue Carbon Learning Center that aligns with the physical geography, community dynamics, and climate vulnerabilities of Nonthaburi. The study focuses on spatial planning, zoning of educational and ecological functions, the application of clean technologies, use of environmentally friendly materials, and the assessment of environmental and health impacts, particularly the reduction of PM2.5 exposure through green design. The proposed center serves as a replicable model for other urban and national contexts seeking to enhance sustainability, public health, and climate resilience.

1.1 Background and Significance of the Problem

Urban expansion in the Bangkok Metropolitan Region, particularly in Nonthaburi Province, has increasingly encroached upon natural areas, especially riparian wetlands, canal systems, and green spaces. This encroachment is driven by infrastructure development, housing expansion, and urban economic activities, which have significantly degraded aquatic ecosystems. As a result, the ability of these ecosystems to sequester carbon and maintain local environmental balance has been compromised.

The concept of Blue Carbon has garnered growing attention as a key mechanism in climate change mitigation. It emphasizes the restoration and conservation of aquatic ecosystems, such as wetlands, riparian forests, and native hydrophytic vegetation, that can serve as long-term carbon sinks. According to the Smithsonian Institution (2025), wetland ecosystems are capable of storing up to four times more carbon than terrestrial forests. Moreover, they offer additional ecosystem services including flood mitigation, water purification, and biodiversity support, which are particularly relevant in Nonthaburi, a region frequently exposed to seasonal flooding and water management challenges.

At the same time, Nonthaburi possesses high potential to be developed as a hub for environmental learning and

sustainable urban development. The province's geography, rich in natural waterways, located adjacent to the Chao Phraya River, and supported by communities that still rely on local water resources, makes it an ideal candidate for ecological restoration projects. Establishing a Blue Carbon Learning Center in these wetland areas would not only rehabilitate degraded ecosystems but also serve as a catalyst for environmental education, ecotourism, and community-based green economic development.

Therefore, this research plays a critical role in proposing the design of a Blue Carbon Learning Center that aligns with the socio-ecological context of Nonthaburi's floodplain and riverine landscapes. The aim is to create a multifunctional public space that cultivates environmental awareness, supports community stewardship, and promotes urban sustainability in the face of ongoing metropolitan growth.

1.2 Research Objectives

This research aims to:

1. Study and analyze the wetland context along the Chao Phraya River in Nonthaburi Province to identify suitable sites for the development of a Blue Carbon Learning Center.
2. Design an architectural and site planning concept for the Blue Carbon Learning Center that aligns with the local topography, community lifestyle, and surrounding ecological systems.
3. Promote sustainable urban development by establishing the learning center as a prototype for integrating environmental knowledge with public and youth education.
4. Develop a master plan that supports conservation-based activities, experiential learning, ecotourism, and the growth of community-centered green economies.
5. Propose environmentally responsible design strategies through the selection of sustainable materials, green technologies, and adherence to Universal Design principles, along with guidelines for preliminary environmental impact assessment (EIA/EHIA).

1.3 Scope of the Study

This study defines its scope in the following dimensions:

1) Geographical Scope

The research focuses on wetland areas and riverbanks along the Chao Phraya River in Nonthaburi Province, particularly in locations that still exhibit ecological potential and accessibility for community-based development. Targeted areas include:

- Riverfront zones in Bang Kruai District
- Khlong Bang Bua Thong and Khlong Om (natural canal systems)
- Tha Nam Non area and adjacent public parks near aquatic environments

2) Content Scope

The content of this study encompasses the exploration and design of a Blue Carbon Learning Center, with a focus on the following key aspects:

- Analysis of local topography, aquatic ecosystems, and existing land use patterns
- Master plan development for ecological education, ecosystem restoration, and community engagement
- Selection of sustainable materials, clean technologies, and incorporation of Universal Design principles for accessible learning environments
- Preliminary guidelines for environmental and health impact assessments (EIA/EHIA)

3) Timeframe

The research was conducted over a period of four months, from January to April 2025, and was divided into three main phases:

- Phase 1: Site context analysis and community needs assessment
- Phase 2: Conceptual design and spatial planning
- Phase 3: Prototype development, master plan finalization, and policy-oriented recommendations

1.4 Limitations of the Study

This research recognizes several limitations that should be taken into consideration:

1) Limitations in Topographic and Ecological Data

Some data related to wetland ecosystems, native aquatic plant species, and physical site characteristics in Nonthaburi Province may be outdated or incomplete. This necessitated supplementary field surveys in conjunction with secondary data from government and local agencies.

2) Limitations in Community Participation

Designing a learning space that aligns with community needs requires collaboration from local leaders, government stakeholders, and residents. However, limitations in time availability, public perception, and community understanding of the “Blue Carbon” concept, which remains relatively new, may have affected the depth of engagement.

3) Limitations in Budget and Resources for Prototyping

The creation of the site master plan and design prototype was conceptual in nature and not implemented in physical form. As such, the outcomes of this study remain at the level of theoretical or conceptual design rather than actual construction-ready plans.

4) Limitations in Research Duration

Given the constrained research timeframe of four months, long-term monitoring and evaluation of the project’s impact were not feasible. Further phases involving pilot testing, iterative design adjustments, and stakeholder re-engagement would be necessary for full implementation.

5) Limitations in Blue Carbon Model Coverage

This study focuses primarily on freshwater wetlands and riparian ecosystems. It does not encompass the broader spectrum of Blue Carbon systems found in brackish or saline

environments, such as mangroves or estuarine zones, which are typically present in coastal provinces.

LITERATURE REVIEW AND RELATED STUDIES

The design and development of a Blue Carbon Learning Center in Nonthaburi Province requires an interdisciplinary review of theories, concepts, and case studies. These inform a site-specific and context-sensitive approach that integrates environmental sustainability, learning theory, and urban ecological planning. The literature reviewed in this study is categorized into five key thematic areas:

2.1 Concept of Blue Carbon

“Blue Carbon” refers to the carbon captured and stored by aquatic ecosystems such as mangroves, wetlands, and seagrass meadows. According to UNESCO and UNEP (2010), these ecosystems can sequester greenhouse gases at rates significantly higher than terrestrial forests, while also providing critical services such as shoreline protection and water quality regulation. The Smithsonian Institution (2025) further emphasizes the role of urban wetlands in moderating local climate, reducing flood risks, and enhancing urban biodiversity.

2.2 Environmental Learning Center Design

Designing an environmental learning center involves promoting experiential learning, where users engage directly with ecological systems. As proposed by Kolb (1984) and David Orr (2004), effective environmental education must arise from real-world experiences contextualized within the learner’s local environment. This may include interactive exhibits, native planting zones, small-scale ecological experiments, and the use of digital media to support blended learning.

2.3 Sustainable Design Principles

Sustainable Design refers to planning and development that considers environmental, economic, and social dimensions. Emphasis is placed on using renewable materials, energy-efficient systems, and community-relevant infrastructure. McDonough and Braungart (2002) introduced the “Cradle to Cradle” design framework, advocating for waste-free circular systems where all materials and processes are regenerative and reusable.

2.4 Urban Wetland Development Case Studies

Several international and regional case studies demonstrate successful models of urban wetland revitalization:

- Cheonggyecheon Stream, Seoul, South Korea – Transformed a degraded inner-city canal into a thriving green corridor and learning environment.
- Khlong Ong Ang, Bangkok, Thailand – A formerly polluted drainage canal rehabilitated into a cultural, recreational, and educational hub.
- Urban Wetland Park, Guangzhou, China – A multifunctional park integrating ecological

restoration with environmental education and leisure spaces.

These cases underscore the feasibility and multifunctional potential of wetland-based learning centers within urban contexts.

2.5 Relevant Research in Thailand

- Chaiyasuwan, S. (2021) studied ecological restoration strategies along the Chao Phraya River for urban resilience in Bangkok’s periphery.
- Kanjanawat, P. (2020) proposed design models for carbon-sequestering urban wetlands in metropolitan fringe areas.
- Bamrungwong, T. (2022) explored community-driven ecological learning center models in suburban schools, emphasizing participatory design processes.

RESEARCH METHODOLOGY

3.1 Research Design

This study employed a qualitative research methodology integrated with design research. The process involved site-specific investigation, contextual analysis, and master plan development for a Blue Carbon Learning Center in Nonthaburi Province. The methodology emphasized participatory design, engaging stakeholders to ensure the proposal aligned with both ecological systems and community needs. The research outcomes were translated into a conceptual prototype design, aiming to reflect the potential integration of Blue Carbon education with sustainable spatial planning.

3.4 Data Collection Procedures

Table1: Data Collection

Step	Activity	Description
1	Secondary Data Review	Collected foundational data on Nonthaburi’s geography, zoning, environmental conditions, and land-use policy from academic sources and government databases
2	Site Observation	Conducted field visits to riverside areas (e.g., Chao Phraya River, Khlong Bang Kruai) to assess ecological characteristics and land utilization
3	Key Informant Interviews	Conducted semi-structured interviews with local leaders, educators, youth groups, and planners to identify site needs, community expectations, and limitations
4	Community Workshops / Focus Groups	Organized stakeholder engagement activities to exchange ideas and ensure participatory input into the spatial and functional design
5	Conceptual Development	Design Synthesized all findings to produce a site-specific master plan and conceptual design prototype tailored to ecological, social, and urban contexts

3.5 Data Analysis

The data collected from this study were analyzed through both qualitative and spatial lenses to inform a site-specific and context-responsive design of the Blue Carbon Learning Center in Nonthaburi. The analysis process was structured into three main components:

3.2 Population and Sampling

- Population:
Residents living along the Chao Phraya River in Nonthaburi Province,including communities in Bang Kruai, Mueang Nonthaburi, and Bang Bua Thong,as well as local teachers, students, urban designers, and municipal officers involved in environmental and land-use planning.
- Sample Group:
A total of 15 key informants were selected through purposive sampling, consisting of:
 - 5 community leaders
 - 3 local educators or school representatives
 - 3 urban designers or environmental planning experts
 - 4 youth representatives or conservation group members

3.3 Research Instruments

The research utilized the following tools:

- Semi-structured interview form; to guide in-depth qualitative interviews
- Observation checklist; to document spatial use and user behavior on-site
- GIS and base maps; to support spatial analysis and site suitability assessment
- Design software; including *SketchUp*, *AutoCAD*, and *Lumion*, used to develop the conceptual architectural design and visualizations

1) Qualitative Content Analysis

Data obtained from key informant interviews and community focus groups were analyzed using content analysis techniques. The process involved:

- Transcribing interviews and workshop discussions

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- Categorizing information into thematic groups, such as community needs, spatial constraints, and expectations for educational activities
- Synthesizing key insights to define functional requirements and inform spatial zoning for the site master plan

2) Spatial Analysis

Data gathered from field observations, aerial imagery, and urban planning maps were used to assess the suitability of the site through spatial analysis, based on criteria such as:

- Proximity to natural water bodies, including the Chao Phraya River and Khlong Bang Kruai
- Flood resilience and elevation safety of the site
- Accessibility for public and community engagement
- Connectivity to existing public infrastructure and alignment with broader urban development plans

3) Design Synthesis

Findings from both qualitative and spatial analyses were integrated into the final design synthesis phase to produce:

- A central design concept rooted in ecological and community values
- A comprehensive site master plan outlining functional zones
- Conceptual perspective renderings to visualize proposed spatial experiences
- Guidelines for material selection, emphasizing environmentally friendly and locally sourced materials
- An initial framework for environmental and health impact assessment (EIA/EHIA), supporting sustainability and community well-being

RESEARCH RESULTS

This research focused on designing a Blue Carbon Learning Center within the ecological and community context of Nonthaburi Province. Emphasis was placed on riparian wetlands and riverside environments along the Chao Phraya River, which present significant opportunities for ecological restoration and environmental education. The research findings are presented in three major sections:

4.1 Site and Context Analysis

Field surveys and secondary data collection revealed that riverside areas in Bang Kruai and Tha Nam Non possess distinctive ecological features:

- Low-lying floodplain areas rich in native wetland vegetation capable of carbon sequestration
- Local communities that still rely on aquatic ecosystems for livelihoods, including canal-side gardening and water usage from the river
- Public green spaces and underutilized vacant land that could be transformed into active environmental learning zones

4.2 Community Needs Assessment

Through semi-structured interviews and participatory focus groups, the following needs and expectations were identified from local residents:

- A learning space for both youth and the general public to engage with environmental knowledge
- A recreational area that supports family-oriented activities and nature appreciation
- Opportunities for eco-tourism and green job creation that benefit the local economy
- Public infrastructure such as walkways, open-air pavilions, outdoor classrooms, and demonstration areas supporting both education and practical sustainability practices

4.3 Blue Carbon Learning Center Design Concept

Table2: The synthesized data informed a master plan design concept composed of five integrated zones

Zone	Zone Name	Description
A	Eco Education Zone	Open-air learning structures focused on Blue Carbon, aquatic plants, and water cycle systems
B	Wetland Restoration Zone	Native wetland planting (e.g., cattails, water hyacinths, aquatic ferns) with an elevated boardwalk for nature interpretation
C	Community Interaction Zone	A multipurpose plaza for exhibitions, public events, and community gatherings
D	Riverfront Recreation Zone	Riverwalk promenade, scenic pavilions, viewing decks, and kayak access points
E	Sustainable Living Zone	Hands-on demonstration plots for urban farming, composting, and aquatic plant product processing workshops

4.4 Conceptual Master Plan

The spatial arrangement of Zones A–E is integrated via a continuous “Green Learning Trail”, which ensures fluid circulation and access across all functional areas. The design adheres to Universal Design principles, providing inclusivity

for users of all ages and abilities. The site planning also incorporates natural water management systems such as constructed wetlands, retention basins, and vegetated swales, which enhance both environmental functionality and immersive learning experiences.



Figure 1: Blue Carbon Center map draft



Figure 2: Elevation layers of the Blue Carbon Center Map



Figure 3: Ecological Learning and Public Learning Center Zone

Table3: Function Table of Each Zone in the Blue Carbon Learning Center

Zone	Zone Name	Primary Function	Activities and Features
A	Ecological Zone	Education	Environmental education and Outdoor learning space, interpretive signage, interactive exhibits about wetlands, carbon cycles, and aquatic ecosystems
B	Natural Restoration Zone	Biodiversity recovery and habitat restoration	Mangrove planting, wetland vegetation, boardwalk trails, observation decks, habitat simulation
C	Community Zone	Interaction	Public engagement and Multipurpose plaza, local market space, exhibition hall for events and sustainability campaigns
D	Riverfront Zone	Recreation	Relaxation and passive Riverside promenade, picnic areas, pavilions, scenic viewpoints, canoe docks
E	Sustainable Demonstration Zone	Living	Green living and vocational Urban farming plots, composting demonstration, green building materials, eco-workshops

DESIGN SUMMARY AND RECOMMENDATIONS

5.1 Summary of Design Outcomes

This research aimed to design a Blue Carbon Learning Center within the contextual landscape of Nonthaburi Province, integrating knowledge from riparian ecosystem management, wetland restoration, and sustainable urban development. The design promotes experiential learning for all ages, while embedding ecological and community-driven principles. The master plan consists of five primary functional zones:

- Zone A: Ecological Education Zone
An interactive learning area featuring exhibitions, outdoor classrooms, and hands-on exploration of Blue Carbon ecosystems.

- Zone B: Natural Restoration Zone
A biodiversity restoration space for native aquatic plants and habitats, with elevated walkways for nature interpretation.
- Zone C: Community Interaction Zone
A social gathering space for exhibitions, workshops, and community-based events.
- Zone D: Riverfront Recreation Zone
A recreational riverside area supporting quality of life through public seating, viewing decks, and low-impact water activities.
- Zone E: Sustainable Living Demonstration Zone
A practical zone showcasing urban agriculture, composting, and value-added processing of local natural materials.

The proposed master plan and conceptual models reflect sensitivity to river-adjacent topography, ecological connectivity, natural water circulation, and inclusive access aligned with Universal Design principles.

5.2 Recommendations

For Real-World Project Implementation

- Government agencies and local organizations should collaborate with communities to implement the center as per the proposed design.
- A comprehensive Environmental Impact Assessment (EIA) should be conducted, alongside structured public engagement throughout all phases.

For Future Design Development

- Incorporate digital learning technologies, such as AR/VR, to enrich the educational experience.
- Implement a Carbon Tracking System to allow real-time awareness and monitoring of carbon reduction impacts, encouraging long-term climate literacy.

For Academic Extension

- This research can serve as a baseline for evaluating socio-economic and ecological impacts of community-based Blue Carbon initiatives.
- The model could be further developed as a replicable framework for other wetland-rich provinces across Thailand with similar ecological potential.

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