

Adaptive Deltaic Resilience

An Architectural Framework for Disaster Resilience in the Deltaic Landscape of the Sundarbans

Synopsis Across coastal Bangladesh, dedicated cyclone shelters stand idle for most of the year, institutionally isolated, disconnected from community life, and ecologically blind to the landscape they are meant to protect. At the same time, schools, community halls, and public buildings are repeatedly overwhelmed during disasters, pressed into emergency use without ever being designed for it. This mismatch between everyday infrastructure and disaster infrastructure is not an engineering failure. It is the foundational failure of climate-responsive architecture in Bangladesh's coastal delta.

This project proposes a framework for transformable deltaic infrastructure, architecture that dissolves the separation between everyday and emergency function. Rather than prescribing a singular solution, the framework synthesizes the adaptive intelligence of the Sundarbans, vernacular building traditions, climate-responsive spatial principles, low-carbon material strategies, and community resilience planning into a transferable approach for future interventions.

The framework treats the delta not as a site, but as a source of architectural knowledge. Mangrove ecologies, settlement patterns, vernacular construction, and community adaptation have evolved through centuries of negotiation with water, storms, and salinity. By interpreting these relationships through design, the framework translates ecological and cultural intelligence into spatial systems capable of responding to contemporary climate challenges.

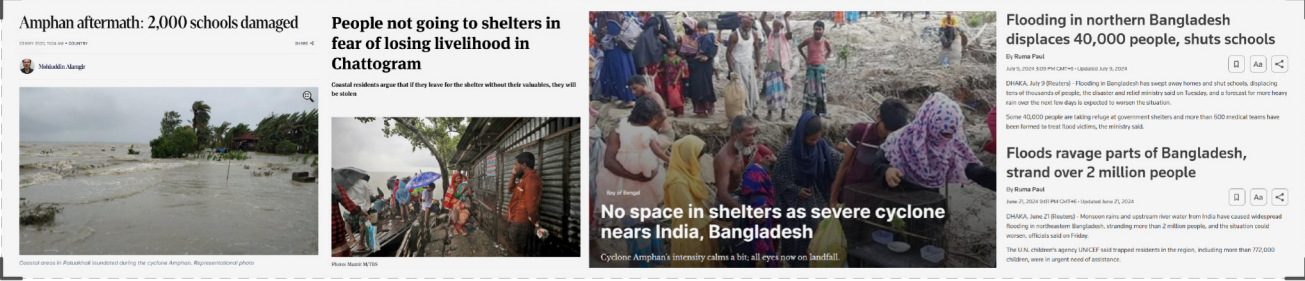
The framework is tested through a prototype, the Mangrove Adaptation and Learning Center at Koyra, Khulna. Functioning as a research, training, and community resilience hub during normal conditions, it transforms into a disaster shelter and emergency coordination centre during cyclones. The prototype demonstrates how the framework generates context-responsive solutions adaptable to comparable deltaic settlements across the region.

By grounding architectural intelligence in the living knowledge of the Sundarbans, the framework contributes toward a scalable model for transformable infrastructure, serving both the everyday needs of vulnerable communities and the emergency demands of a landscape under permanent climate threat.

Site Koyra, Khulna, Bangladesh.
8.2 acre / 33,446 sq m (Approx.)
Prototype Mangrove Adaptation and Learning Center, A Research Facility

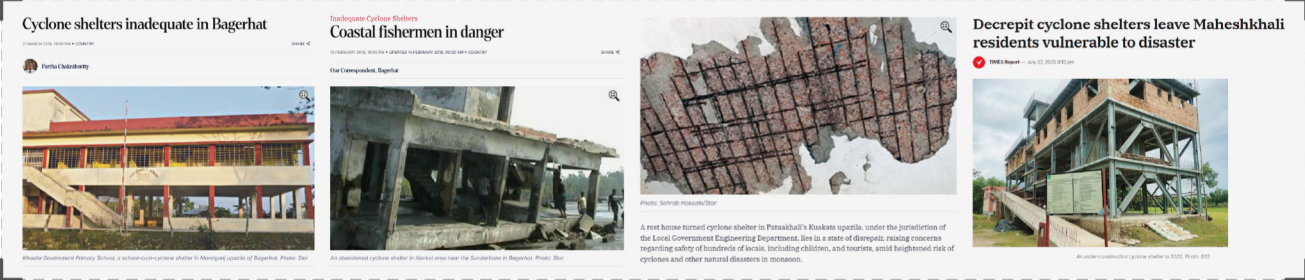
Disaster Vulnerability in Coastal Bangladesh

Recurring cyclones, storm surges, and flooding expose millions across the delta



Inadequate Shelter Infrastructure

Cyclone shelters across the coastal belt remain structurally deficient and chronically underutilised



Everyday Buildings, Emergency Shelters

During disasters, schools and community facilities are forced into emergency use, without ever being designed for it



THE PROBLEM

Separation of
Everyday and
Disaster
Infrastructure

THE RESPONSE

Transformable
Dual-Use
Infrastructure

THE SOURCE

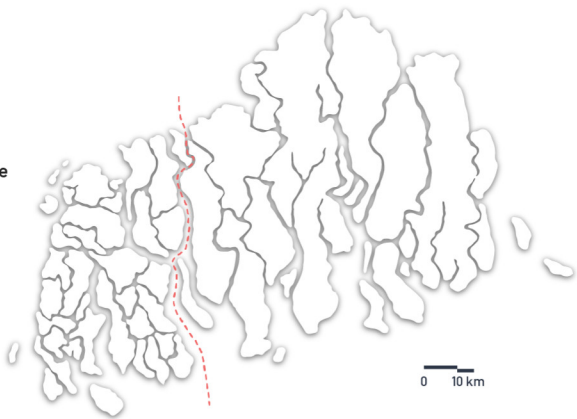
Adaptive
Intelligence
of the Sundarbans
Region

The persistent separation of everyday infrastructure from disaster infrastructure is the foundational failure of climate-responsive architecture in Bangladesh's coastal delta. This project proposes a framework for transformable infrastructure that dissolves that separation, translating the adaptive intelligence embedded within the Sundarbans landscape into spatial systems capable of serving both everyday life and climatic emergencies.

The Sundarbans

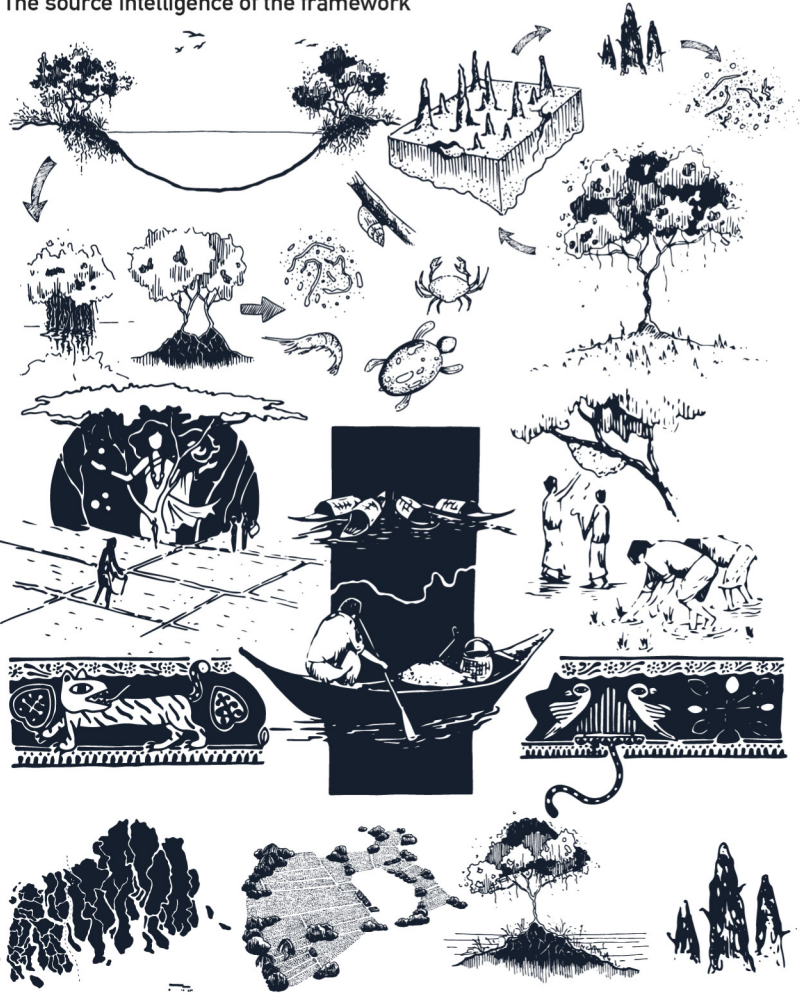
Total Area: 10,277 sq km
Bangladesh: 6,017 sq km
India: 4,260 sq km

UNESCO World Heritage Site
Ramsar Wetland Site



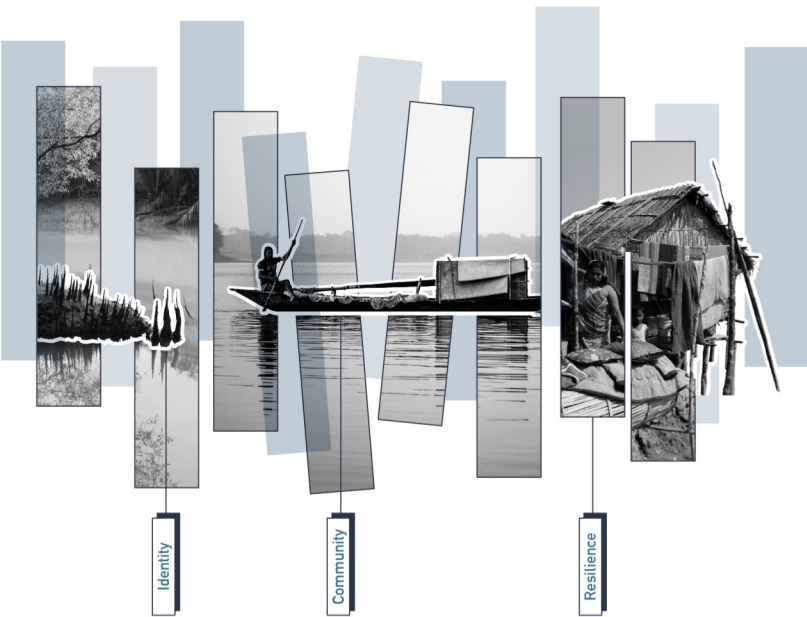
The Living Delta: Ecological Intelligence of the Sundarbans

Vernacular and ecological knowledge embedded in the Sundarbans landscape.
The source intelligence of the framework



Dimensions of Deltaic Intelligence

Ecological, social, and cultural systems that inform resilience across the deltaic Sundarbans landscape.



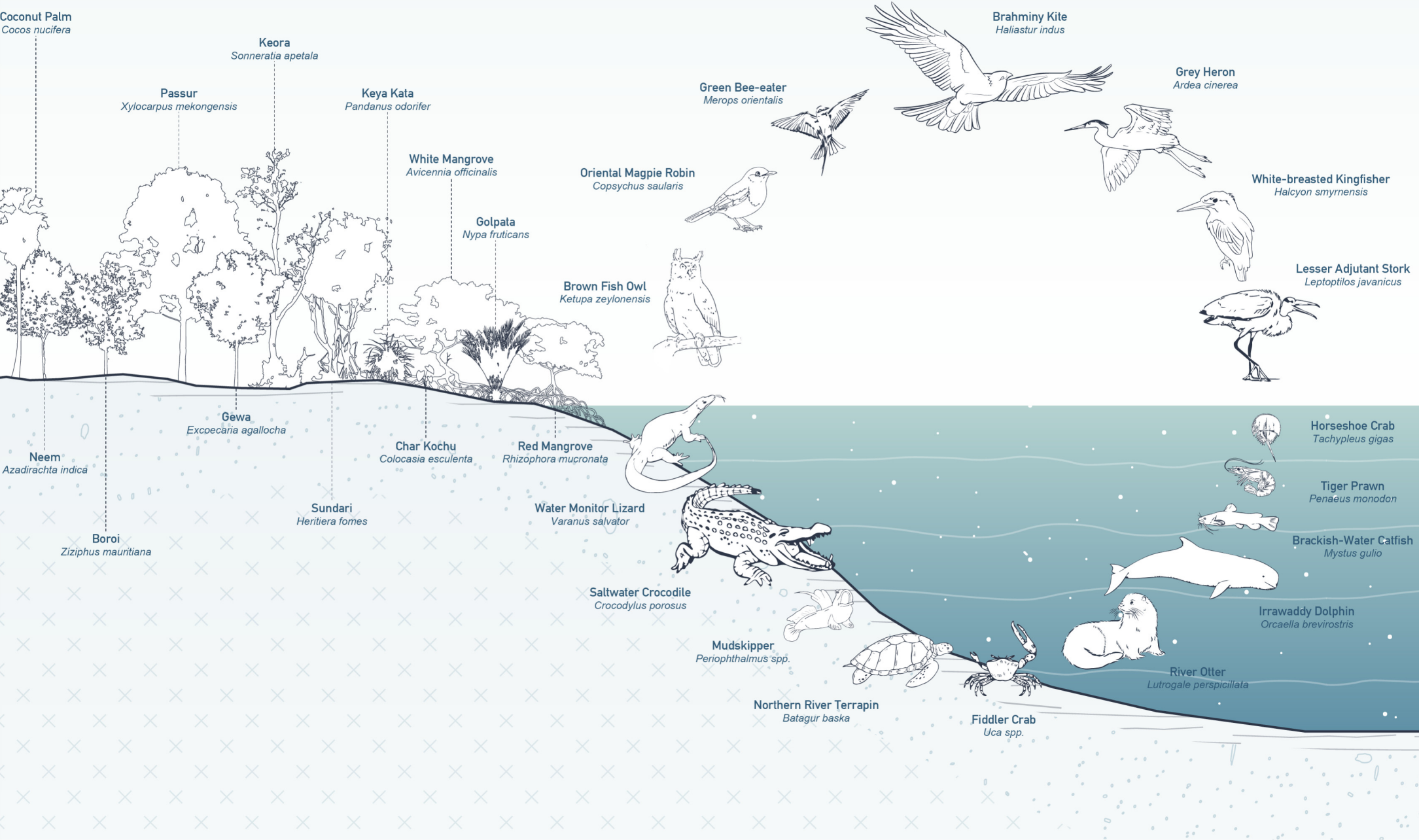
The Sundarbans was understood not merely as the site of intervention, but as a living system of adaptation. For centuries, its ecology, communities, and settlement practices have evolved in response to flooding, cyclones, salinity, and environmental uncertainty.

Rather than imposing an external solution, the study examined how resilience is already embedded within the delta. Layered ecological defenses, regenerative growth patterns, elevated settlements, vernacular construction techniques, and resource-conscious material practices reveal adaptive strategies developed through continuous negotiation with climatic change.

These observations were distilled into three interconnected dimensions of deltaic intelligence, Identity, Community, and Resilience, which collectively informed the architectural framework. The resulting approach translates knowledge embedded within the landscape into transferable principles for transformable, adaptive and climate-responsive infrastructure.



Site Specific Flora and Fauna





The death toll of animals from the flooding in the Sundarbans has climbed to 100 after Cyclone Remal hit the world's largest mangrove forest on Sunday.



Cyclone Amphan makes landfall across Sundarbans World Heritage properties

- Sidh-2007
- Aila-2009
- Fani-2019
- Bulbul-2019
- Amphan-2020
- Remal-2024
- Next?

Cyclone Remal: Vast swathes of Sundarbans under water due to tidal surge

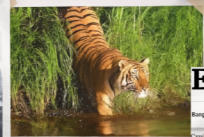


Sundarbans: no time to heal between cyclones



In 2007, Cyclone Sidh ripped through the Sundarbans, the world's largest mangrove forest. The forest took the brunt of the storm, saving human lives by slowing down its destructive force.

Infrastructure Failure



Climate Vulnerability

Irrawaddy dolphin also at risk like the Gangetic dolphin



Sundarbans Census: Dolphins declining



Ecological Loss

Endangered masked finfoot of the Sundarbans



Resilience



Govt to ban new industries within 10km of Sundarbans



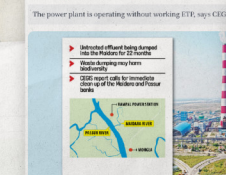
What if disaster infrastructure and everyday infrastructure were the same thing?

Policy Gaps and Failures

Cyclone shelters inadequate in Bagerhat



Rampal fouling 2 Sundarbans rivers



Cyclone Mocha: 13,000 houses damaged in Cox's Bazar



I kept finding the same contradiction, shelters built but abandoned, everyday buildings collapsing when storms hit. The evidence pointed to one failure: infrastructure that serves only one condition of existence. The Sundarbans already knew the answer. This framework is its translation.

Dolphin number rising in Sundarbans sanctuaries



Tiger population rising in Sundarbans



Five new fish species found in Sundarbans



Five new species of fish have been found in the Sundarbans of Bangladesh. Among them, one was discovered for the first time in the world. This discovery has brought the number of fish species in the largest mangrove forest up to 323.

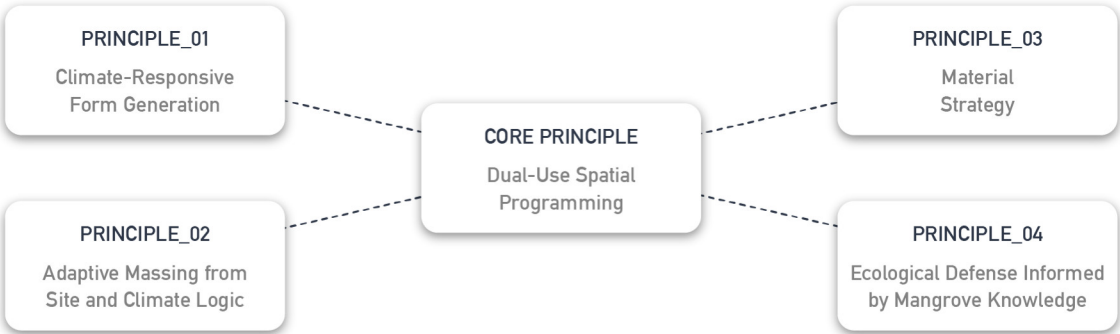
145 bird species spotted during the first bird festival in Sundarbans



RESPONSE?

The Framework

Five principles derived from the adaptive intelligence of the Sundarbans delta. Dual-use spatial programming is the core, the remaining four exist to make it structurally, materially, and ecologically possible.



From Ecological Intelligence to Resilience



Framework Logic & Objectives

The framework translates the adaptive intelligence of the Sundarbans delta into a replicable system for transformable, disaster-resilient infrastructure.

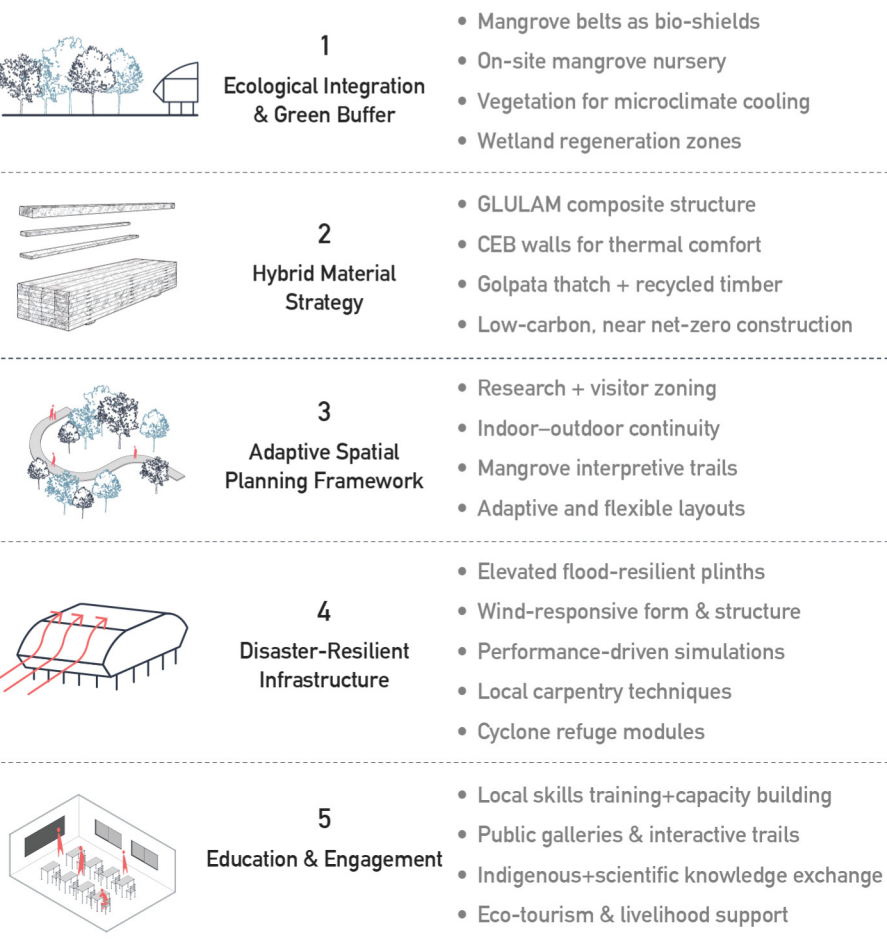


Alignment with SDGs

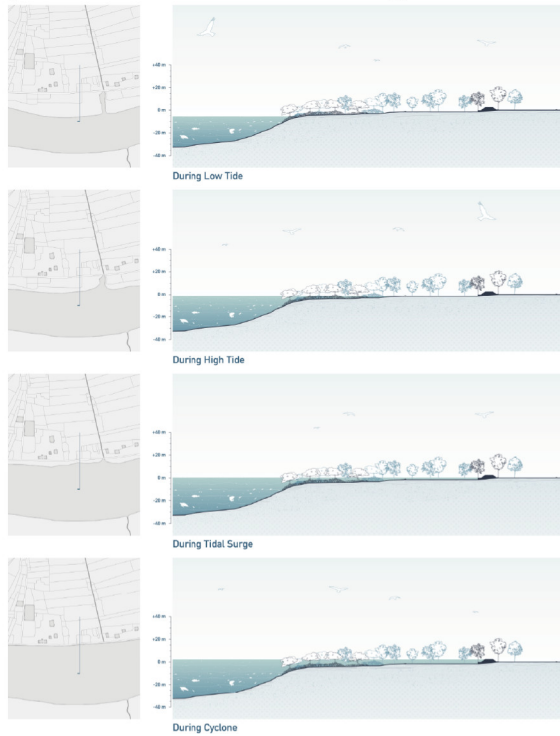
Five SDGs addressed through context-responsive design strategies



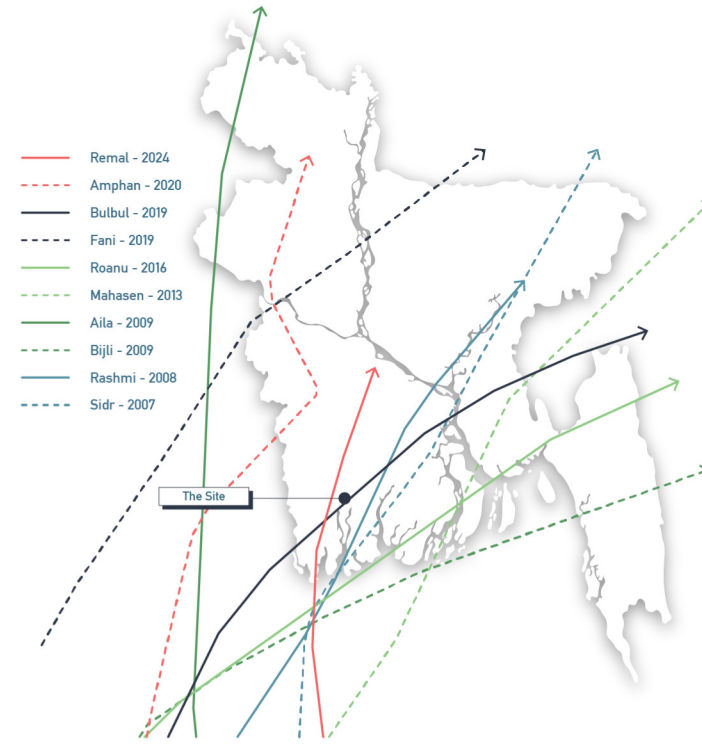
Design Strategy for the Prototype



Section of Site During Different Scenarios (GIS-Informed Flood Modelling)



Paths of Major Cyclones in Recent Years

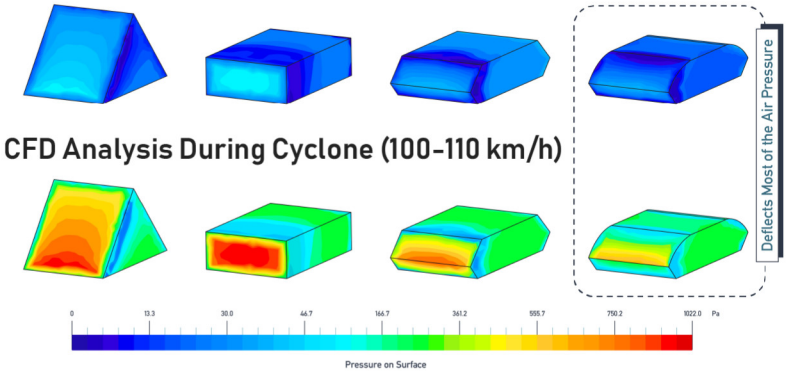


Framework Principle 01_Climate-Responsive Form Generation

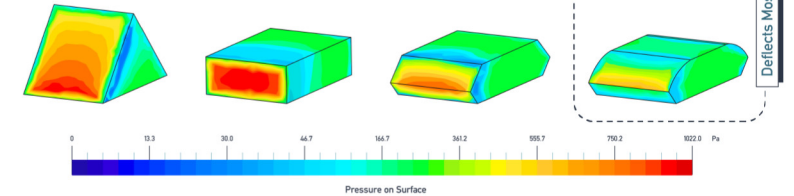
CFD simulations tested alternative roof and massing forms under regular and cyclonic wind conditions. The selected curved profile reduces peak wind pressure by 32–45%, improves airflow, and supports

a lightweight, elevated, disaster-responsive architectural system. Verified against BNBC 2020 serviceability limits, the curved form deflects wind load while drawing from the aerodynamic logic of traditional deltaic roofing.

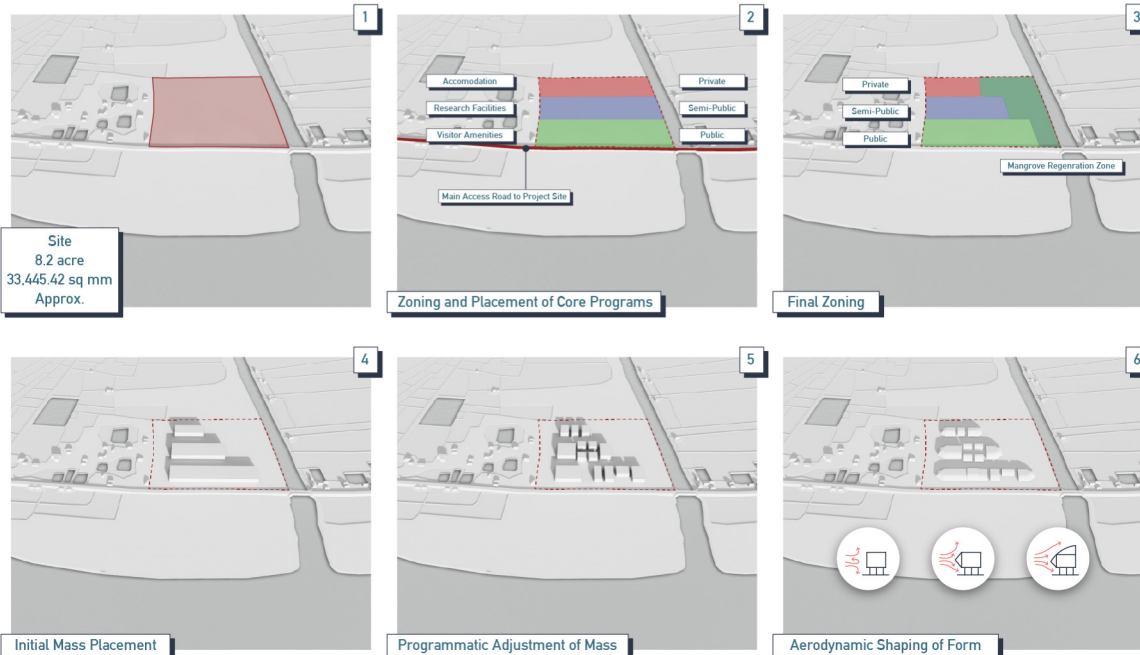
CFD Analysis During Regular Wind Flow (8-15 km/h)



CFD Analysis During Cyclone (100-110 km/h)



Framework Principle 02_Adaptive Massing from Site and Climate Logic



Framework Principle 03_Material Strategy

Vernacular materials and contemporary technology, combined into a near net-zero material strategy.



Framework Principle 02 organises massing from site and climate logic. Building placement emerges from environmental conditions: flood datum sets the elevated plinth level, embankment edge defines the masterplan boundary, and programmatic zoning separates different zones. Aerodynamic shaping follows the principle 01, so the whole composition negotiates wind and water as one system. Framework Principle 03 establishes a hybrid material logic, vernacular materials such as Golpata (Nipa Palm) thatch and local timber joinery are combined with contemporary technologies including Glulam and compressed earth block, forming a near net-zero strategy that reduces embodied carbon and operational emissions without discarding the material intelligence already embedded in the delta.



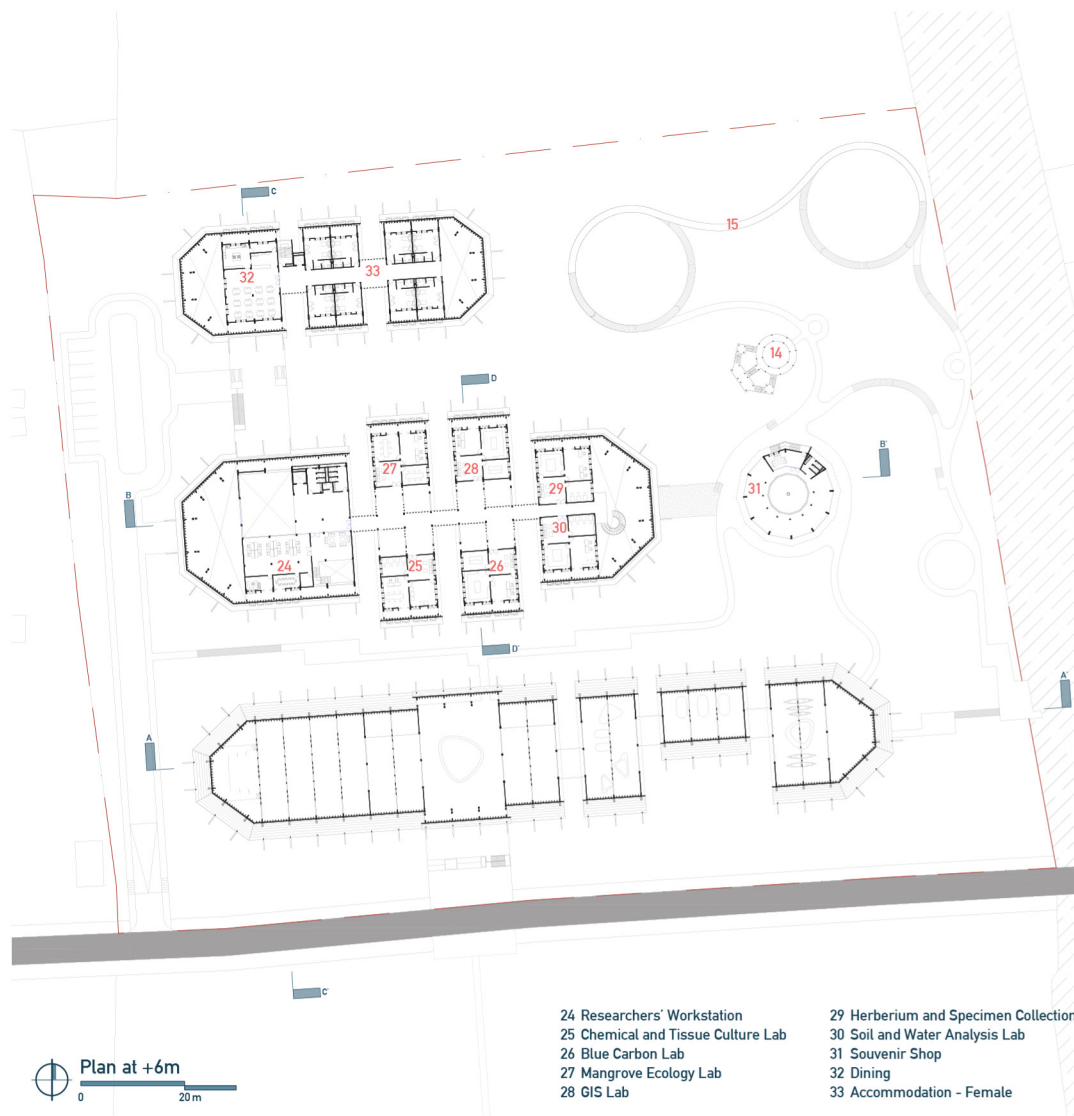
- 1 Embankment Road
- 2 Floodplain
- 3 Visitor Amenities
- 4 Research Facilities
- 5 Accommodation
- 6 Interactive Trail
- 7 Cafeteria and Souvenir Shop
- 8 Boat Dock
- 9 Rai River
- 10 Sundarbans Reserve Forest (Nalian Range)



Plan at +3m

0 20m

- | | | |
|-----------------------------|----------------------------|---------------------------------|
| 1 Embankment Road | 11 Community Gallery | 21 Vehicular Drop-off |
| 2 Floodplain | 12 Waterfront Deck | 22 Lounge and Recreational Area |
| 3 Vehicular Entry | 13 Cafeteria | 23 Accommodation - Male |
| 4 Path to Dock | 14 Observation Deck | |
| 5 Pedestrian Entry | 15 Interactive Trail | |
| 6 Lobby | 16 Administration | |
| 7 Community Hall | 17 Archive and Data Center | |
| 8 Lounge and Ticket Counter | 18 Library | |
| 9 Forest Gallery | 19 Workshop | |
| 10 Biodiversity Gallery | 20 Classroom | |



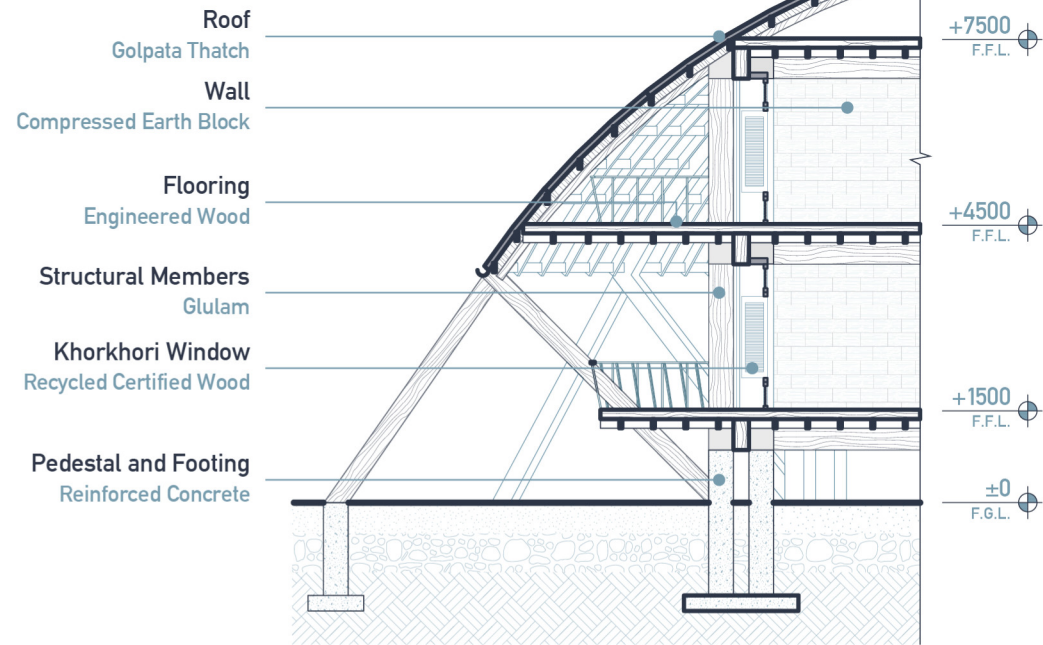
The Prototype_Spatial and Structural Resolution

The prototype is organised across two levels. The ground floor at +3m above flood datum contains all publicly accessible research, community, and visitor programmes. The elevated plinth is not incidental, it is structural to the framework's disaster-response logic.

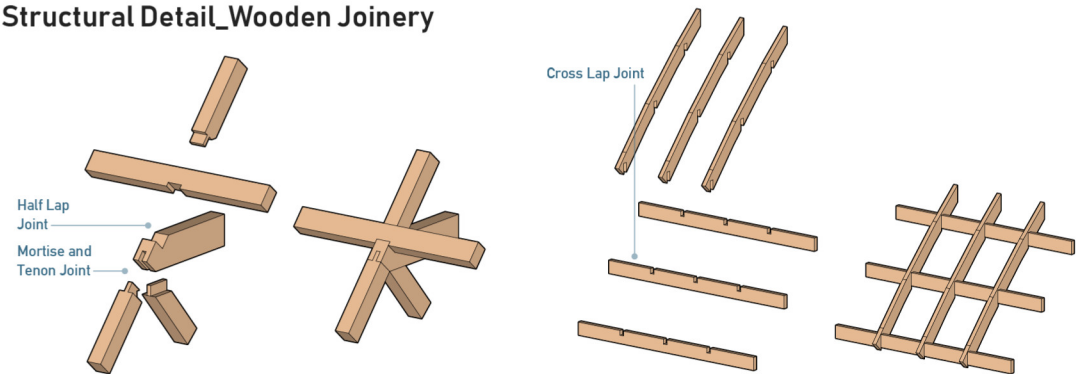
The upper floor at +6m houses research laboratories, workspaces, and accommodation. During cyclone events, upper-floor spaces become priority shelter zones while ground-floor spaces serve as assembly, relief distribution, and coordination.

The Khorkhori window, recycled certified wood, continues the vernacular material logic at the envelope scale. Together, the joinery system and window detail embed traditional craft knowledge within a performance-driven, cyclone-resistant structural assembly.

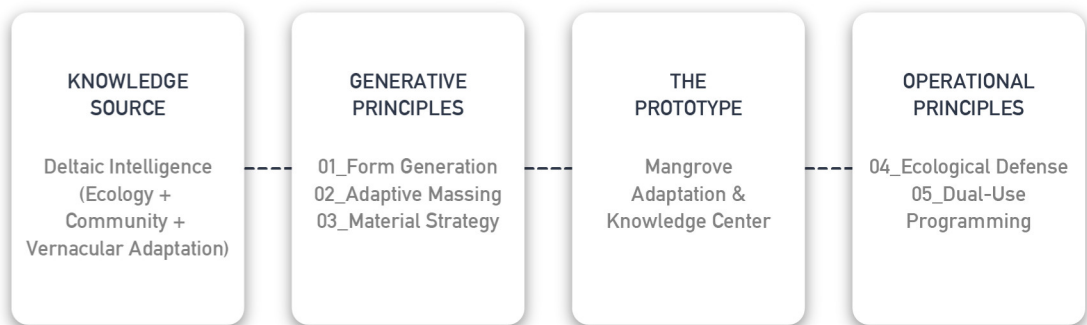
Structural Detail_Section



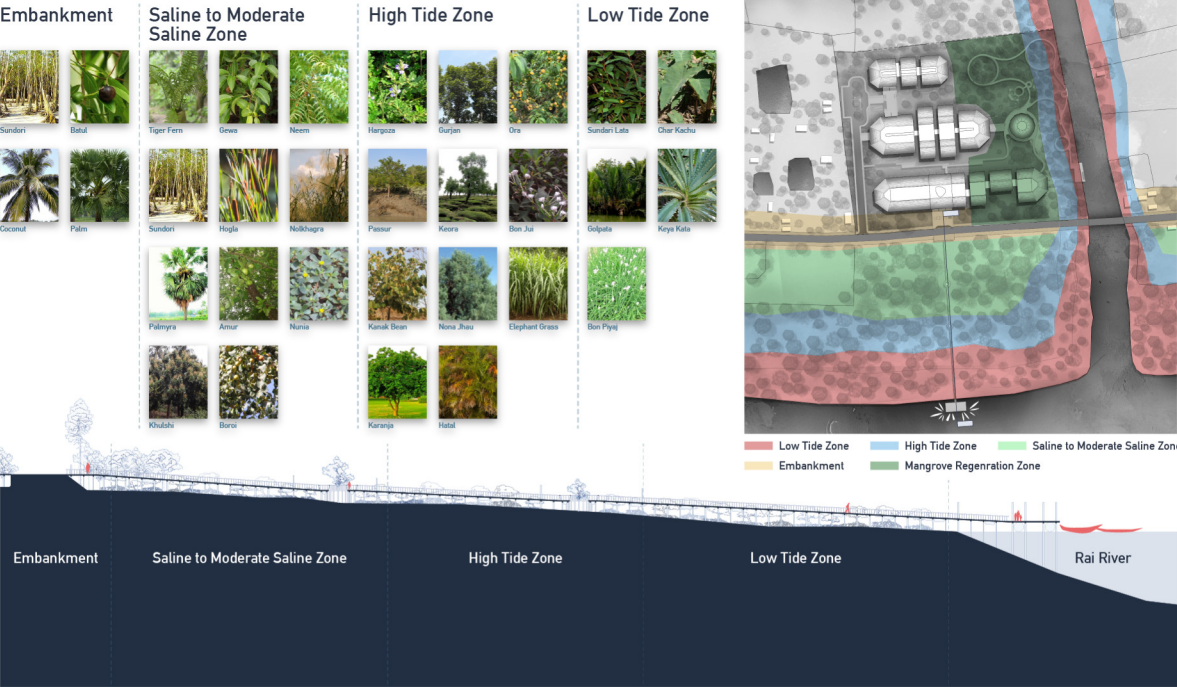
Structural Detail_Wooden Joinery



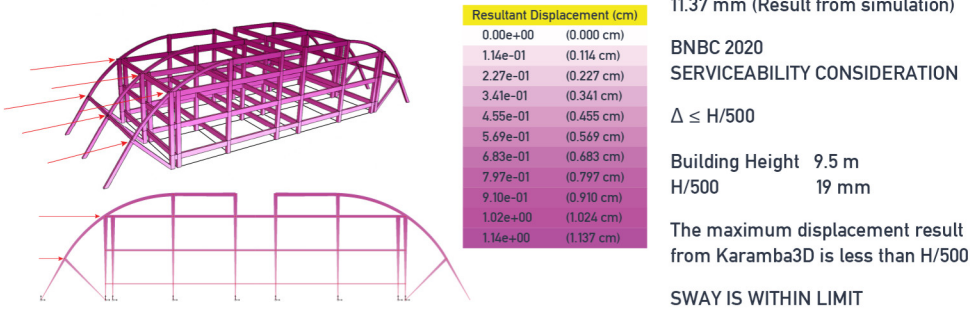
Translating the Framework into Architecture



Framework Principle 04_Ecological Defense Informed by Mangrove Knowledge



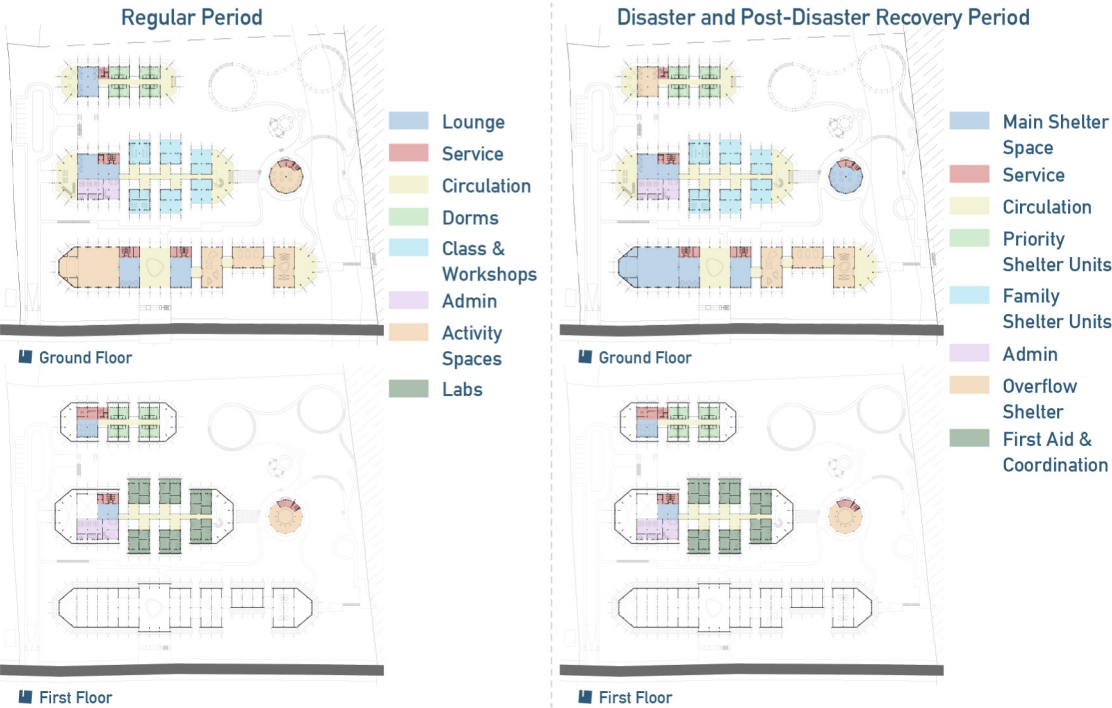
Structural Displacement Analysis



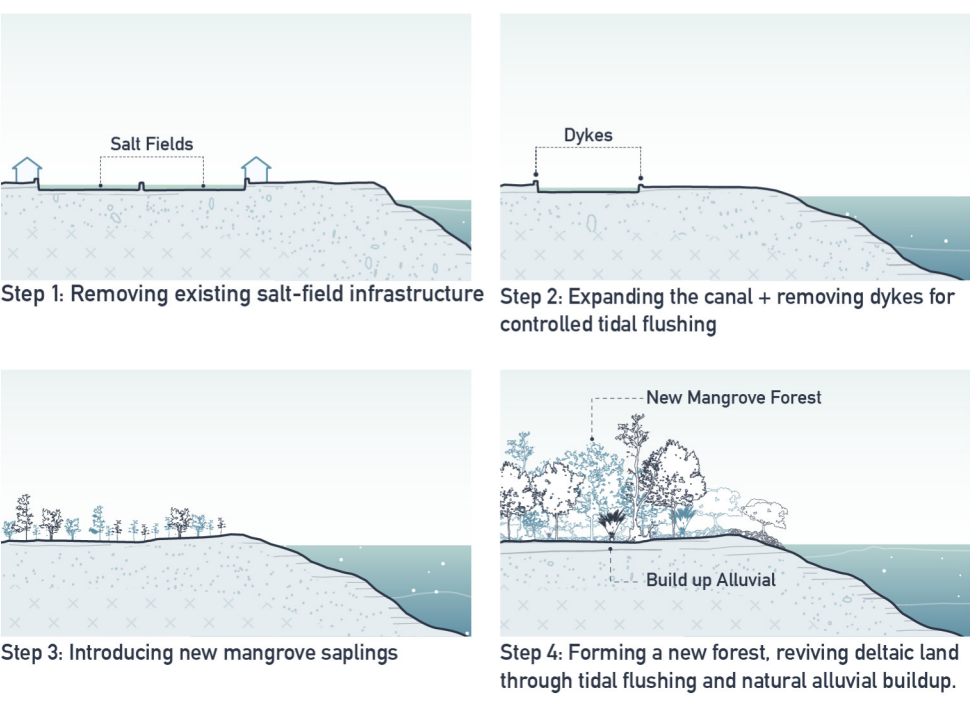
Principle 04 translates mangrove resilience into a four-zone landscape defense, from embankment to river, each zone planted by salinity tolerance to buffer storm energy before it reaches the built structure. Landscape is not decoration; it is the framework's outermost defensive layer. Site remediation extends this: saline fields are recovered through tidal flushing and mangrove planting, reviving deltaic land through natural alluvial buildup.

Every space performs two roles without retrofit. During normal conditions, labs, community halls, and visitor facilities serve daily life. During cyclones, the same spaces transform, halls become shelter, labs become coordination centres. To validate this as evidence-based design, Karamba3D structural analysis confirmed the Glulam frame performs within BNBC 2020 serviceability limits under cyclonic wind loads. The structure proves it holds.

Core Framework Principle_Dual-Use Spatial Programming



Site Remediation_Saline Land Recovery and Mangrove Regeneration



Everyday Use_Community
& Cultural

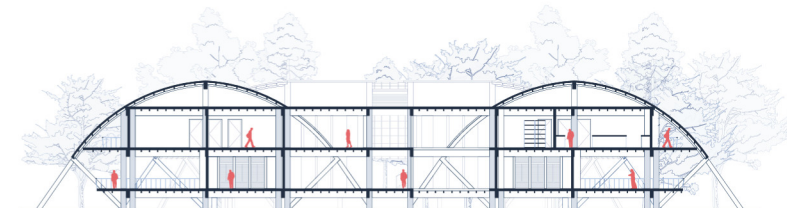
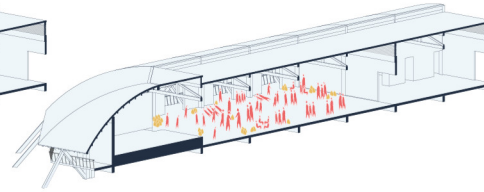
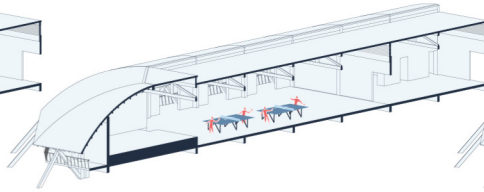
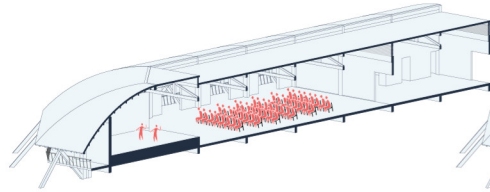
Festivals
Performances
Traditional music/dance
Storytelling
Community meetings

Everyday Use_Recreational
& Social

Movie screenings
Indoor games
Seasonal fairs
Weddings
Communal feasts

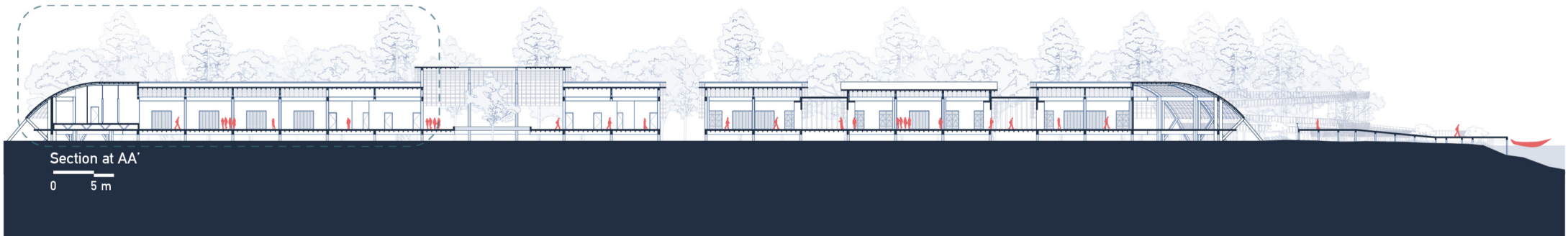
Emergency Use_Cyclones
& Other Disasters

Emergency assembly
Shelter during cyclones
Safe gathering point
Space for relief and aid distribution



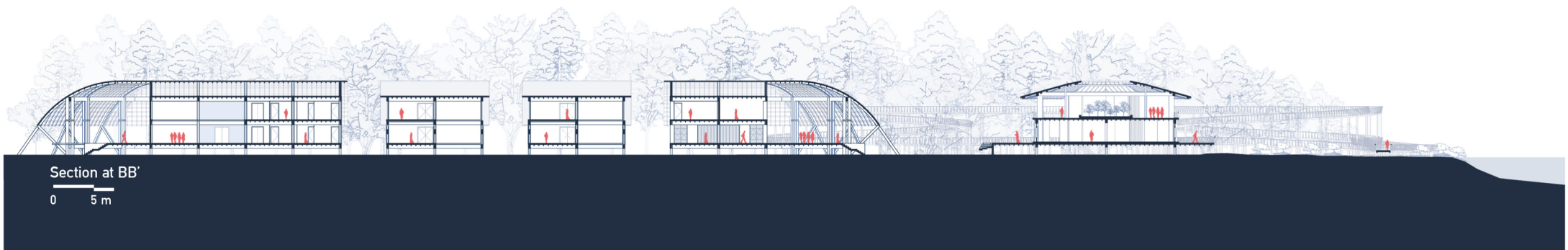
Blowup Section of Research Facility at DD'

0 5 m



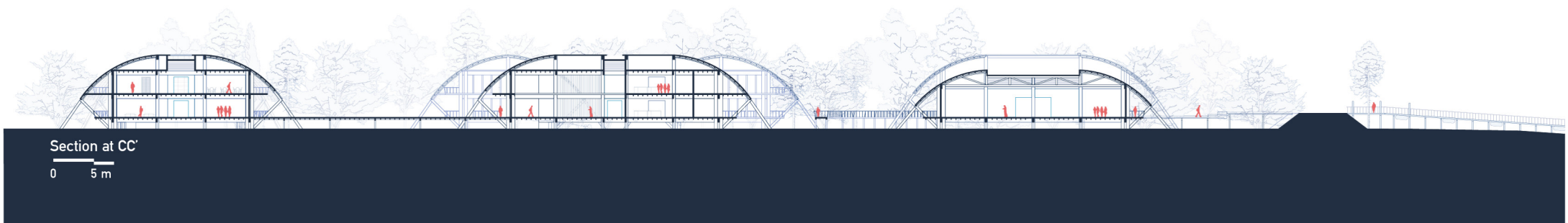
Section at AA'

0 5 m



Section at BB'

0 5 m



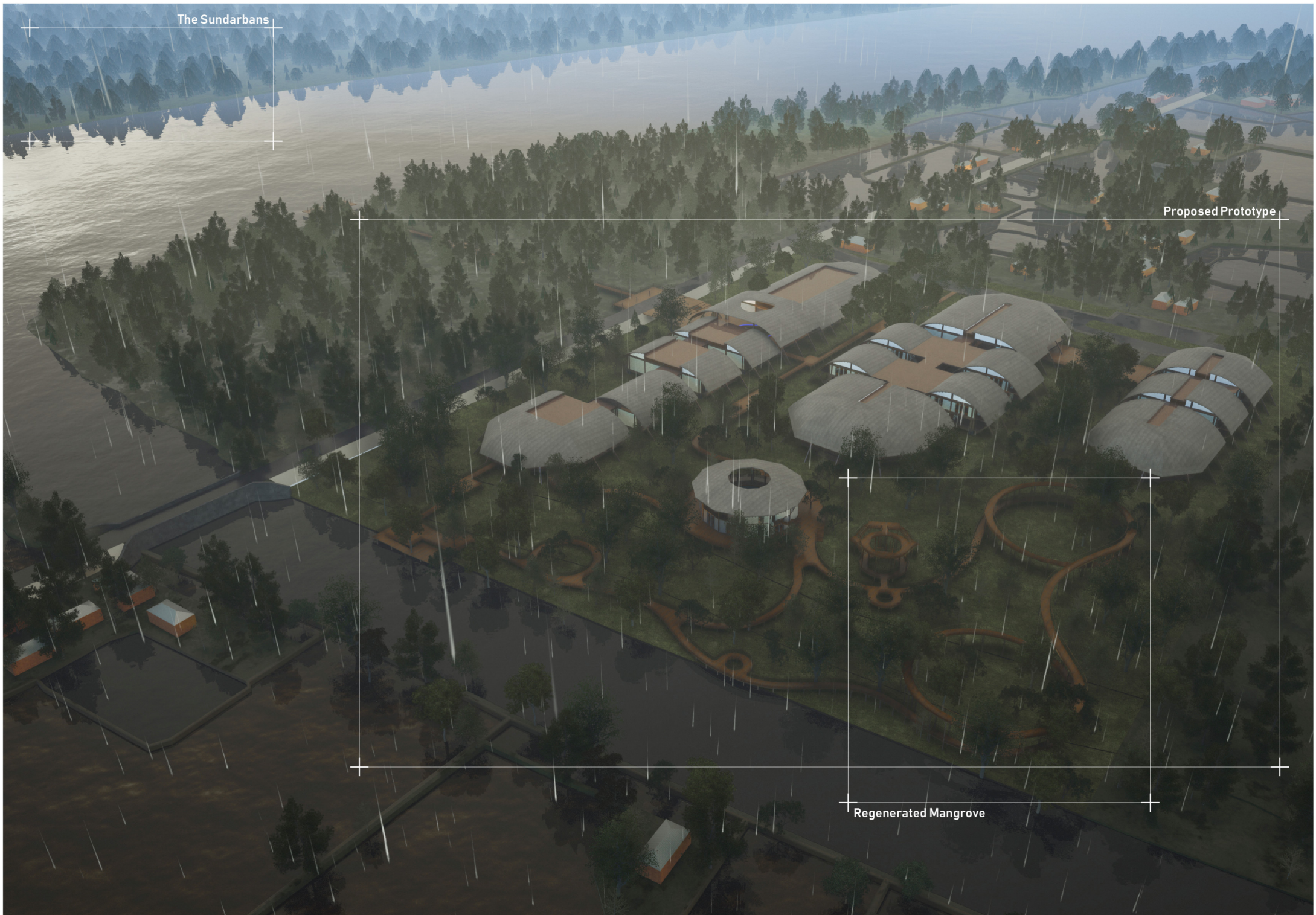
Section at CC'

0 5 m

The Sundarbans

Proposed Prototype

Regenerated Mangrove





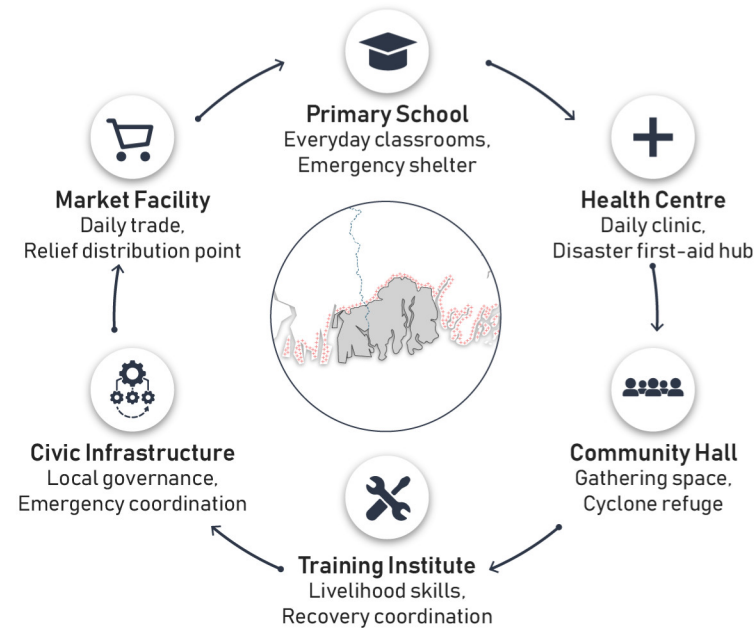
Structure

Community Space



Observation Deck

Interactive Trail



The Framework Beyond the Prototype

The Mangrove Adaptation and Learning Center demonstrates one possible manifestation. The same five principles can generate schools, health centres, training institutes, and civic buildings across comparable deltaic landscapes, wherever communities face permanent climate vulnerability and inadequate infrastructure response. The framework does not prescribe a form. It prescribes a logic – one the delta has always known.