Tidal Gardening: An Architectural Response to Flood Mitigation on the Salmon River

by

Yao Chen

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Dalhousie University is located in Mi’kmaq’i,
the ancestral and unceded territory of the Mi’kmaq.
We are all Treaty people.

Contents

Abstract

As climate change intensifies and sea-levels rise, flooding is once again a problematic event that is predicted to occur more and more frequently worldwide. The destructive power of the flood is a real threat to our habitat, public health, livelihoods, and agriculture. Coastal and riverine environments naturally deal with floodwater dispersion through saltwater marshes and floodplains. Wetlands are the typical environment for natural filtration processes. Can an architecture that integrates flood control infrastructure with natural means of floodwater management, dispersion, and filtering provide opportunities for inhabitation and research? This thesis investigates the potential uses of a floodplain environment, combined with an integrated ecological water treatment process as a ground for architecture. The site is a university campus in Truro, Nova Scotia, adjacent to the Bay of Fundy. The architectural response centres on spaces that invite people to observe, learn and celebrate hydrology phenomena and processes.

Acknowledgements

My deepest thanks to my supervisor Brian Lilley. His great passion, broad insights, and intelligence in architecture constantly drove this thesis to a new level. His candidness and humor made the process a delightful journey. Thank you to my advisor Talbot Sweetapple for the insightful advice from an experienced architect’s perspective.

My thanks to my parents. It is their dedication and effort that created the condition for me to pursue my own life. Thanks for their unreserved support, encouragement, company, and love.

Chapter 1: Introduction

The relationship between man and his environment is an eternal topic in architecture. Architecture is not a shelter separating man from the sun, earth, atmosphere, oceans, rivers, streams, and plants. Instead, good architecture leads people to read, understand, appreciate and live with nature. Nature is not to be opposed and conquered; instead, it should be treated as an ally and friend. The power and potential of nature are treasures to be explored and utilized.

Water is one of the most valuable and powerful resources on the earth. Human history is twinned with utilizing water and harnessing water. Since the beginning of civilization, the flood has been a significant issue people face (Patton 2005, 1) because it could cause severe damage to agriculture and human dwelling. As human activities aggregate, the number and frequency of floods increase worldwide (Nur 2020, 112). How to handle floods has become a practical question for both architects and engineers. Based on local environmental research, this thesis aims to find a way to transform a floodplain in Truro, Nova Scotia, into a tidal water garden and, at the same time, revive the natural water purification process for the community.

Truro is located in the central part of Nova Scotia, close to the Salmon River's outlet to the Cobequid Bay, the east end of the Bay of Fundy. The town and its vicinity are influenced by two water bodies, the Bay of Fundy and the Salmon River. By the end of this century, the average temperature in Nova Scotia will increase 4.5 degrees Celsius, and the average winter temperature will go up from minus 3.7 degrees to 1.3 degrees. Climate warming will directly lead to total precipitation increase and more intense rainfalls. The relevant sea level rise is expected to be 1 meter (Ramen and Webster 2022). These two reasons increase the flooding problems in the Truro area. Thus, Truro becomes a good location for exploring inhabited landscapes in a complex environment. Ideally, there would be no inhabitation of a delicate ecosystem such as a saltwater marsh or tidal floodplain. However, given the predicted environmental challenge, a balanced development that both protects and enhances local inhabitation is worth exploring.

The thesis starts with studies of the local hydrology system, exploring the resources and challenges to the town and how people treated and harvested them over time. Then, it will examine local ecology systems, especially vegetation. The distribution of local plants, their features, and how they can be applied to the project will be considered.

This project intends to transform the floodplain into a public amenity and research facility. The park will draw people's attention to current natural phenomena; offer people a place for recreation; provide a chance to learn more about nature. The floodplain to the south of Dalhousie University is chosen to take advantage of local facilities, where existing gardens are valuable educational sources to the public. The water garden will be the continuation of the current university gardens and contribute to them, by extension.

The next chapter focuses on the project's fundamental techniques and design inspirations. Dyke-built techniques and solar aquatic systems will be introduced as the critical methods in floodwater control and water treatment. Architectural case studies in similar conditions that inspire this project will also be studied.

Since the project is not only a group of buildings but also a public common, the site strategy is a vital part. The relationship between the new garden and existing gardens, the views and water features in the new garden, water flow control, water treatment, and circulation on site will all be discussed in Chapter 4.

Three main buildings are designed to achieve the project's recreation and education function: the restaurant, the learning centre, and the reception building. These three buildings integrate with the dyke systems and the solar aquatic systems. Water features play a dominant role in and outside of the buildings, creating different experiences for people. Moreover, being ecological-friendly is an essential aspect concerned when designing these buildings.

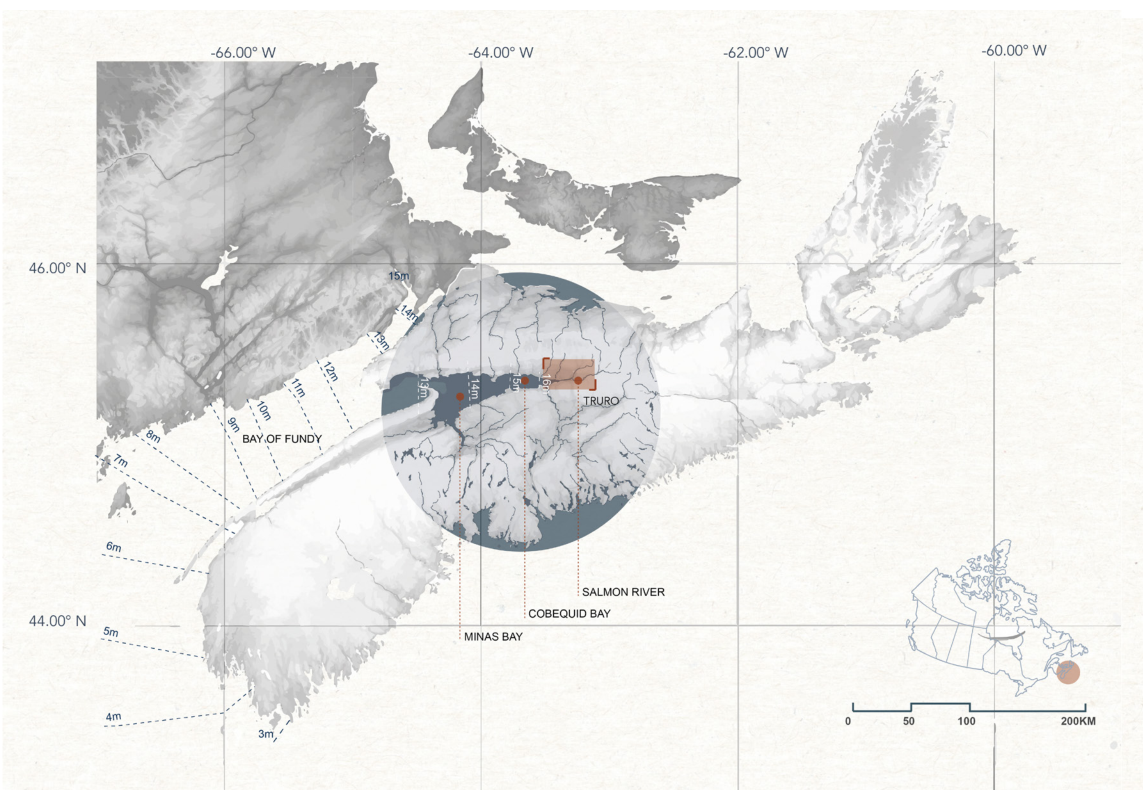
This thesis adopts traditional and modern water management methods into an architectural project, and proposes to transform a floodplain into a place for public engagement. It suggests a new concept for flood prevention. This landscape-architectural form could potentially be applied to similar conditions in other regions worldwide. Combining architecture with infrastructural projects opens up many possibilities for inhabitation and engagement with natural phenomena.

Chapter 2: Site

Truro is the shire town of Colchester County, which is in the central area of Nova Scotia. It is a one-hour drive away from Halifax. The study area covers the town of Truro and its vicinity area, including the village of Bible Hill and Salmon River within Colchester County. The site lies in the lowlands at the head of Cobequid bay (Hennigar 1968, 3), the east end of the Bay of Fundy. The Salmon River, the primary watercourse in Colchester County, runs through the Truro area and discharges into the Cobequid bay.

The Bay of Fundy and the Highest Tide in the World

The magnitude of tides in the Bay of Fundy is the highest globally (CNSFDRP 1988, 7-1). The tidal height was

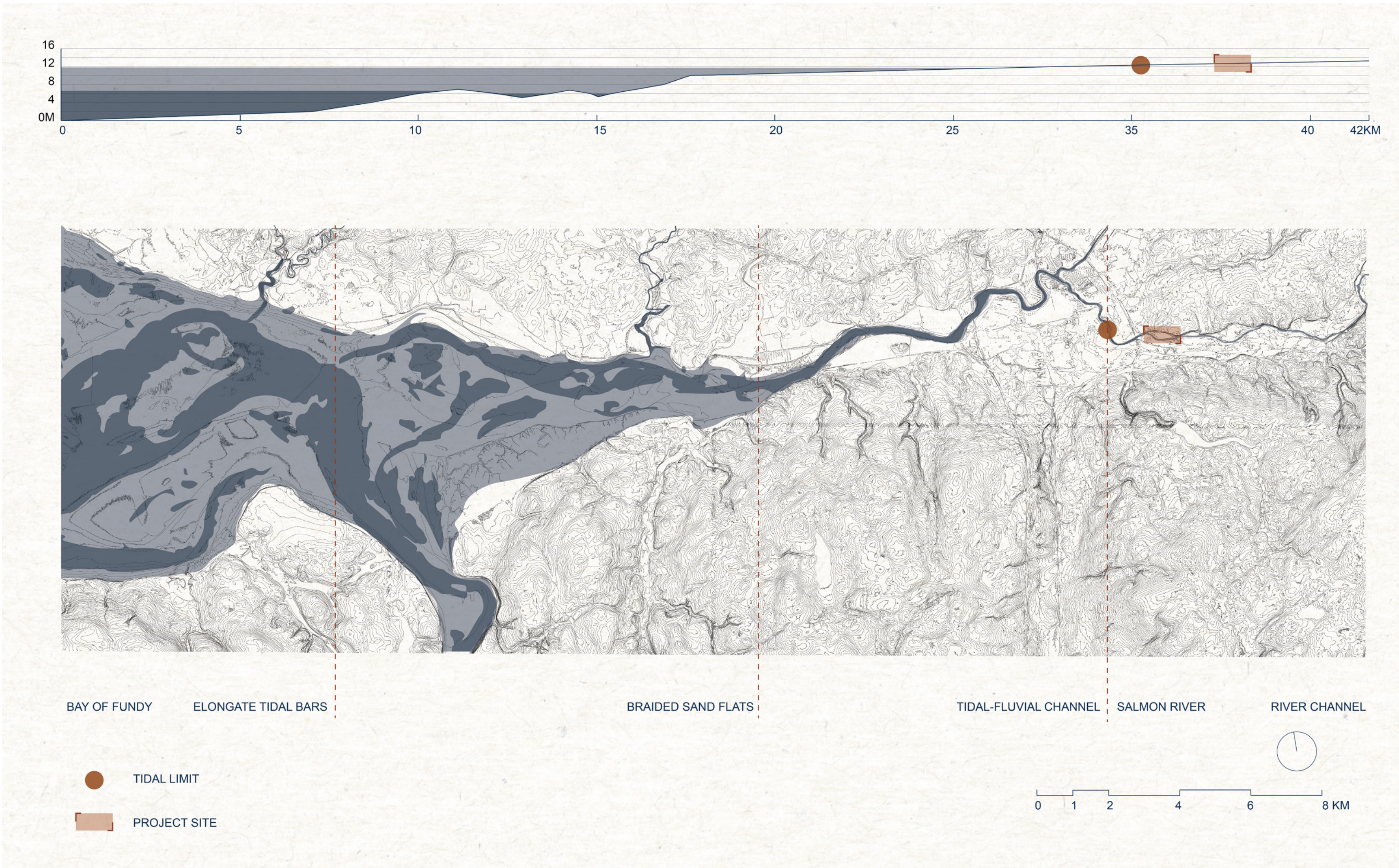


Map of Nova Scotia with the location of the Truro area (data from Nova Scotia. 2012 and Vivid maps n.d.)

recorded at 16.1m in 1969 (ATPEMC 1969, 5). The high tide brings fertile soils to the coastline. On the other hand, it increases the risk of flooding in the Truro area.

The tide rushes up the bay every 12 hours and 25 minutes, stronger in January and weaker in July (CNSFDRP 1988, 7-5). The dramatic tidal change shapes the Bay of Fundy - Salmon River estuarine complex. Elongate tidal bars are the outermost area of the estuarine (Dalrymple and Piret 2021, 2197). Braided sand flats and the tidal-fluvial channel are the inner part of the estuarine (Dalrymple et al. 2011, 81). At high tide, the water occupies the whole width of the sand flat. At low tide, the shallow channels appear and cross into a network (Dalrymple and Piret 2021, 2197). Known by its name, the tidal-fluvial channel is where the main river channel gets invaded by the tide. The tide can travel 15 kilometres on the river channel before reaching the tidal limit. The tidal limit is around 2 kilometres from the project's site (see Bay of Fundy - Salmon River estuarine complex map on page 7). By the end of this century, the relevant sea level will rise 1 metre (Ramen and Webster 2022), which will push the tidal limit further. According to Canada-Nova Scotia Flood Damage Reduction Program, an increase of 1.60 metres in the tide peak could cause an increase in water level of 0.34 metre at the Park Street Bridge, which connects the main roads across the town of Truro and Bible Hill (CNSFDRP 1988, 8-35). In the past 100 years, high tides have contributed to more than ten floods among the forty flood events. These floods were concentrated in January, February, April, and October. As a result of sea-level rise, the tide will affect the flood events more significantly.

Due to the tide, the most fertile soil in Truro is along the coastline. The high-energy waves carry a large number of particles. When they reach their highest elevation, their velocity decreases, and their capability to move sediments reduces (Nova Scotia. DAM 1987, 7). Clay, sand, and silt deposit over the area that the tide has just covered. After bleaching out the seawater, this soil is fertile for the growth of hay and pasture, the main animal feed in the agricultural industry. Compared to the upland, where fertile soils are only at the top 15 to 30 centimetres, rich soils at the coast are accumulated to the top 75 centimetres (Nova Scotia. DAM 1987, 9). The European settlers discovered the value of the soil and transformed the coasts into dykelands. The dykelands has produced grass crops for two hundred years without additional fertilizer. The technique of dyke construction will be discussed in Chapter 3.

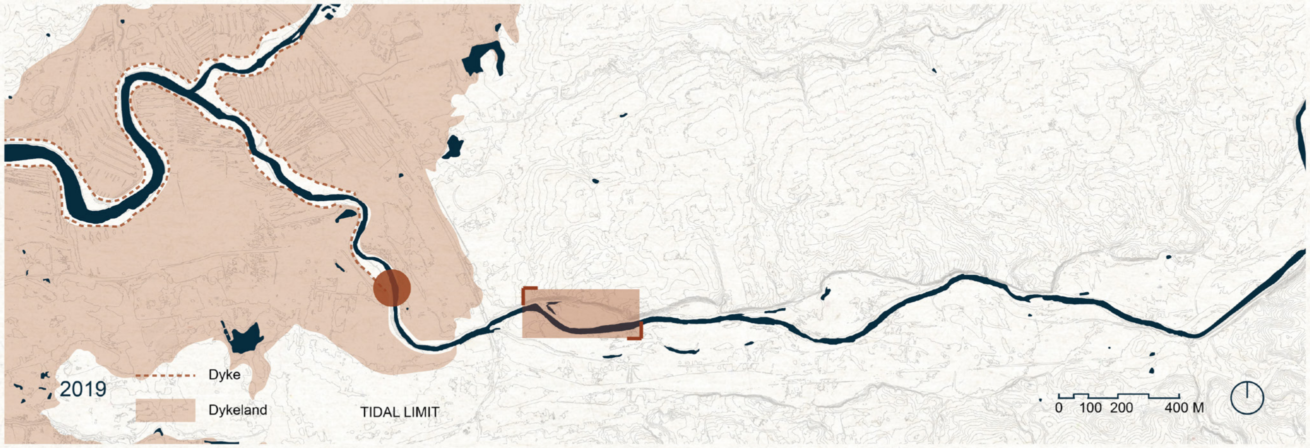


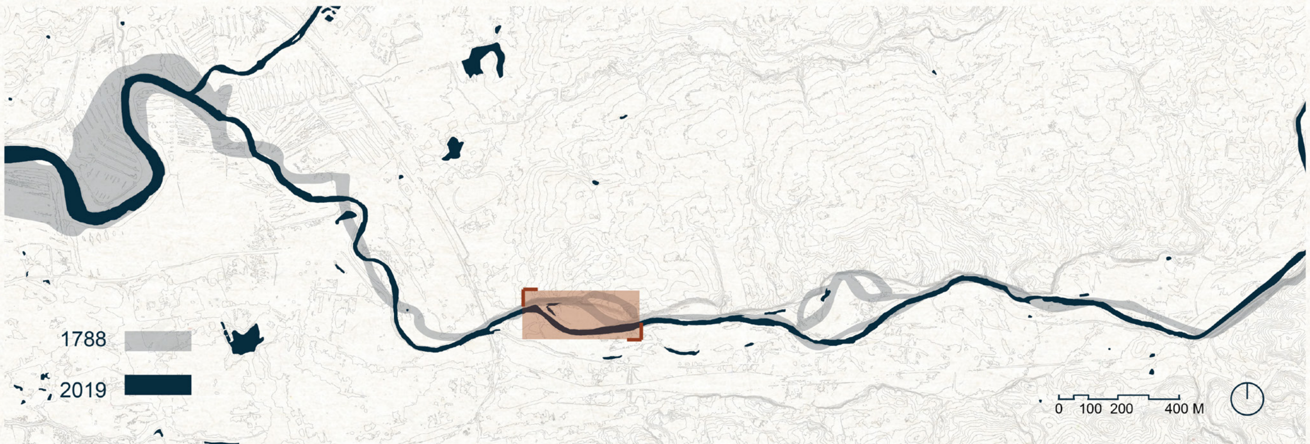
The Bay of Fundy - Salmon River estuarine complex map (base map from Dalrymple et al. 2011)

Dyke, Dykeland and the Salmon River

Salmon River, the main river draining the Truro area, flows toward the west to the Bay of Fundy. The marshland at the head of the Bay of Fundy and along the Salmon River was the last significant area the Acadians settled (Percy 1996, 2). The agricultural potential of the salt marsh was apparent to the French colonists. The dyke-built technique they used to reclaim marshland in Europe was soon applied at the Bay of Fundy. In the late 18 century, they constructed the dyke system along the Salmon River to create the dykeland (see map of dyke and dykeland along the Salmon River on page 9). The shape of the Salmon River channel was formed by the dyke in the 18th century. Since then, it did not change significantly until now (see map of Salmon River river channel change on page 9).

The Acadians faced two main challenges in constructing dykeland in the Truro area: building tall and strong dyke to keep the tide out and discharging the freshwater accumulated from the upper lands (Nova Scotia. DAM 1987, 31). To solve the first problem, they built a high dyke that can reach two metres tall with a base of five metres. These dykes were anchored by a narrow trench, called a “key,” down the centre of the dyke (Nova Scotia. DAM 1987, 33). The second issue was solved with an invention called aboiteau. It was a wood tunnel with a small sluice gate inside. When the tide is low, the freshwater can flow through the tunnel, while when the tide is high, the force of the seawater will push the hinged door, so the saltwater can not rush in. Hay was the main crop Acadians planted to feed the animals on the dykeland. Other grain and vegetables were also produced. The cordgrass (Sporobolus alterniflorus) on the dykewall was





Dyke and dykeland along the Salmon River map (top) (base map from Nova Scotia. Department of Mines 1972)
Salmon River river channel changes from 1788 to 2019 (bottom) (base map from MemoryNS n.d.)

harvested in the late fall to be used as winter fodder (Nova Scotia. DAM 1987, 21).

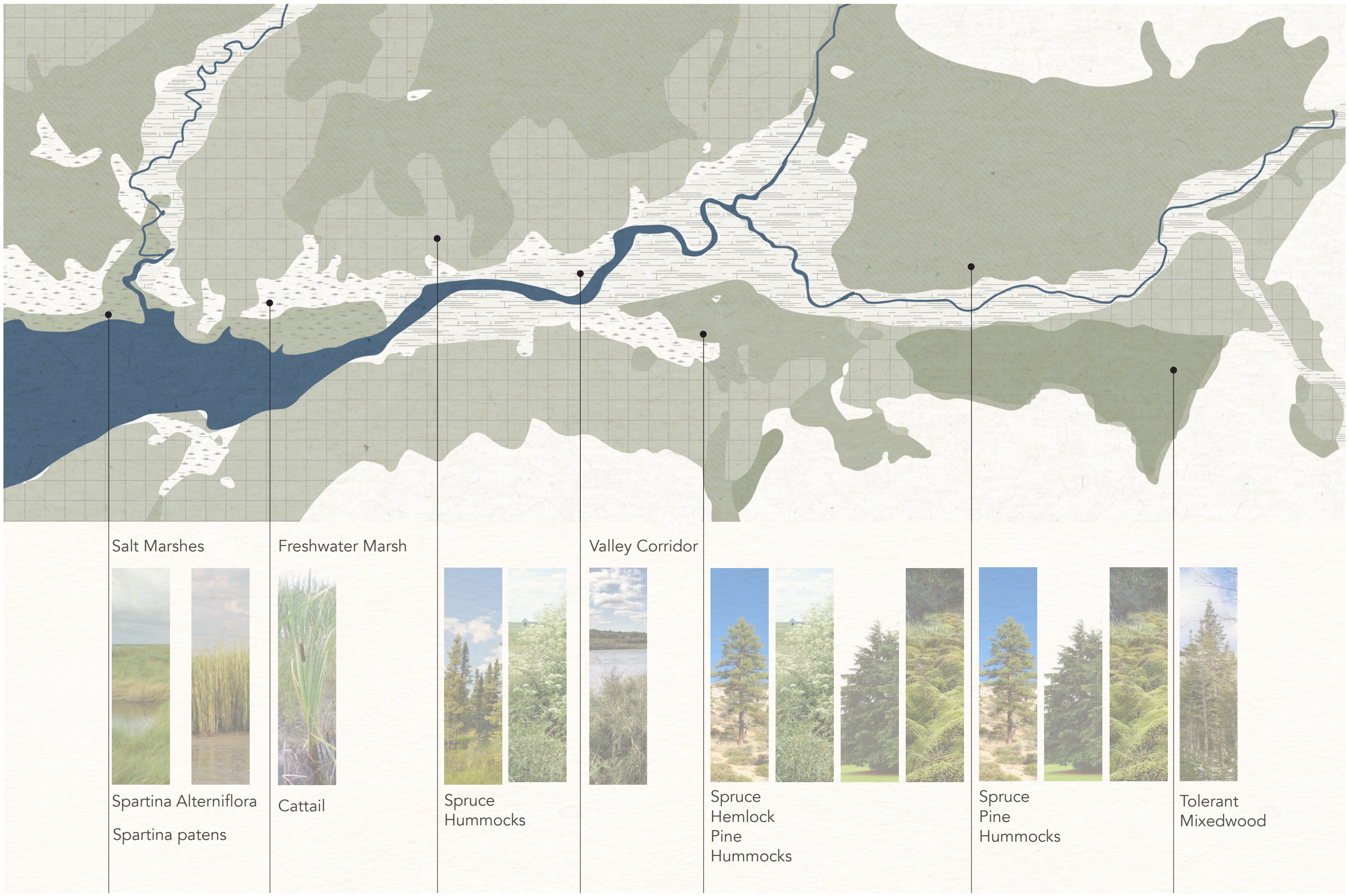
Ecosystems and Vegetation Distribution

There are three ecosystems at the head of the Bay of Fundy and the bank of the Salmon River: the salt marsh, the freshwater marsh, and the valley corridor. Salt marshes mainly cover the area along the coasts, whereas freshwater marsh is located at the upper land of the salt marsh. Vally corridor, also known as the riparian network, contains the river channel.

The salt marsh is the most terrestrial extreme among all the coastal environments (NWWG 1988, 265). Species that grow there can survive in saltwater (Phleger 1971, 908). Spartina alterniflora and Spartina patens dominate the lower parts of the salt marsh. These are the sods Acadians planted on the dyke as well. In the higher regions, the species are much more abundant (NWWG 1988, 265). Many of them are maritime families, which bloom in the spring, and some are decorative, such as Hordeum jubatum.

Cattails and bulrushes dominate freshwater marshes. These are the species most frequently used in constructed wetlands as well. In shallow water ponds and open water, many local aquatic plants can be found in different layers of the watercourse. Yellow (Nuphar variegata) and white water lily (Nymphaea odorata) are very commonly used in landscape pools. Wild calla (Calla palustris) also has ornamental value when it blooms.

The valley corridor refers to the belt that follows the network created by the river system (Marsh 2005, 386). The floodplain is the flat low ground adjacent to the river. Some trees tolerant of flooding flows can survive on the floodplain. But in Nova Scotia, Myrica gale, Carex rostrata, and Carex lasiocarpa are more common in the moisture region of the floodplains (NWWG 1988, 287) (see vegetation distribution map on page 12).



Distribution of different ecosystems and vegetations at the head of the Bay of Fundy (base map from Nova Scotia. Department of Mines 1972)

Flood in the Truro Area

Fletcher's Restaurant in floodwater, 2012 (Scott 2012)

The Truro area is primarily influenced by its location and geological context. Located on the bank of the Salmon River and close to the mouth of the Bay of Fundy, flood is one of the prominent natural threats faced by Truro. Since 1920, in the past 100 years, the Truro area has been flooded over 40 times. Floods occurred more frequently in the late winter and the early spring resulting from rainstorms, snowmelt, and ice jams. During the late summer and early fall, heavy rains are the main reason that causes floods. High tides also lead to some flood events. Overall, rainfalls are the primary factor contributing to the flood in these areas (see flood frequency and reason diagram on page 14).

Flood causes many safety, traffic, and economic problems. Places in Truro are affected or damaged by floods to different degrees. Park Street Bridge is closed the most frequently, while the structures of Robie Street have been damaged many times (CNSFDRP 1998, 1-13). Residential and commercial damages occurred on the low-lying land adjacent to the Salmon River. 0.9 metre is the highest floodwater level recorded.

Based on the frequency of floodwater flow, floodplains are categorized as 1:20 year floodplains (floodway) and 1:100 year floodplains (floodway fringe). Water flows deep and fast on floodways while it flows shallower and slower on floodway fringe. The floodway and floodway fringe are expected to flood completely every 20 and 100 years. That is, 5% and 1% chance to flood in any given year (CNSFDRP 1986). In Truro, areas around the river confluence and the salmon river's valley are the high-risk flood zone. The project site is on a Salmon River floodplain (see flood risk map on page 16).

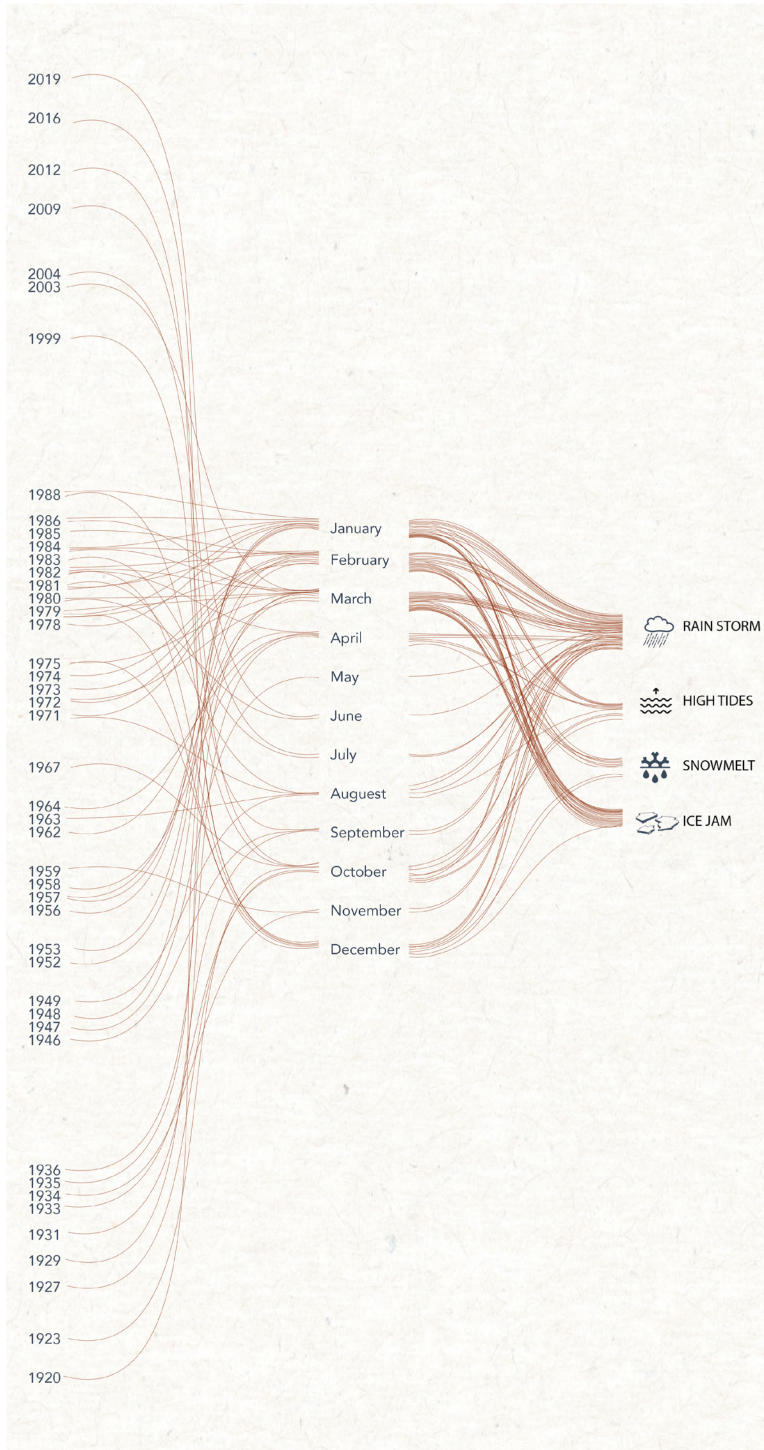
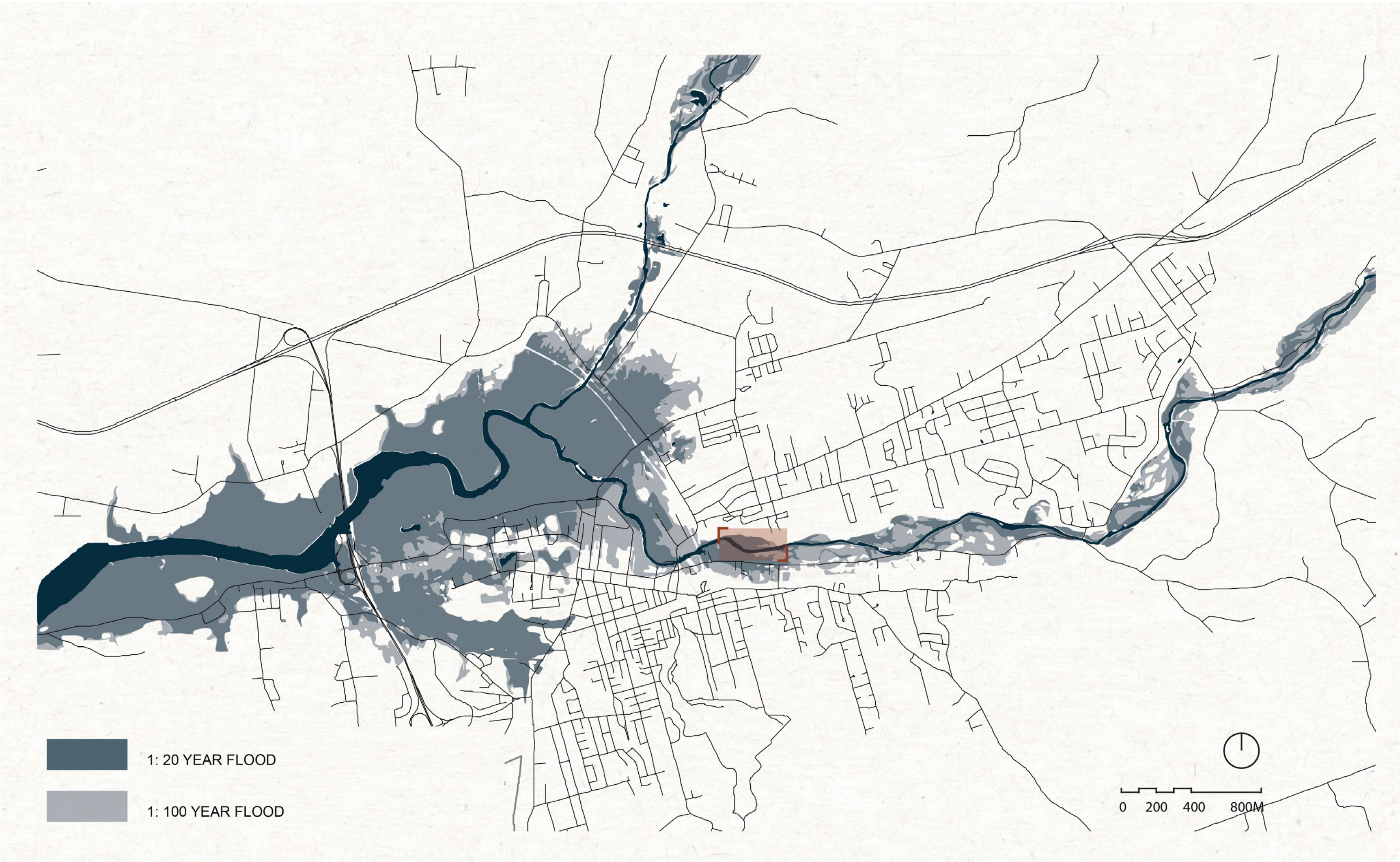


Diagram showing years, months, and the reasons for historical flood events (data from CNSFDRP 1998)



Truro area flood risk map (base map from CNSDRP 1986)

Dalhousie Agricultural Campus

The floodplain chosen for this programme is on the south side of the Dalhousie Agricultural Campus. The campus is located on the north side of the Salmon River, north of the town of Truro (see map on page 20). The main subjects in this school include animal since, aquaculture, plant, food, environmental sciences, engineering, and social sciences. There are many gardens and greenhouses on the campus to meet teaching and study requirements. These gardens function as living classrooms for students, testing fields for new ornamental pieces, and habitats for many local plants, which cover over 11 hectares area. All of the outdoor gardens are open to the public and are good learning and recreational resources for the local community.

Existing Gardens

Because of its dynamic gardens, the campus is picturesque for its residents and neighbours to live, work, learn, enjoy, and relax. Gardens on the campus bedded various plants and showcase the functions and values of this vegetation. From north to south, there is the Chef's Garden, the Alumni Garden, the Herb Garden, the Rock Garden, and the Pollinator Garden. These gardens provide valuable teaching tools in class and create idyllic places in daily life.

Initiated by students, the Chef's Garden is a market garden that provides educational resources and food to the students. It is a collection of diverse crops. Since 2011, more than 20 types and 3,000 pounds of food have been produced yearly in the garden (Dalhousie University n.d.c). Around two-thirds of the produce is served in the school cafeteria, while the left is donated to the local food bank. On-campus food supply is also an excellent example of local-grown food, which is much more eco-friendly than food transported over a long distance.

The Alumni Garden was originally a research nursery established to test the winter hardiness of exotic species (Dalhousie University n.d.a). The garden then managed to emphasize its teaching aspect. In the meantime, it provides space for the students' class projects: the gazebo, pavement circle, and perennial garden are still the garden's features. This garden also offers opportunities for the community to learn about specialist plants. Once a week, members of the Friends of the Garden programme meet and help implement changes to the garden (Dalhousie University n.d.d). Containing roses and other perennials, this garden has become the most popular place for a walk, weddings, and graduation.

Like the Chef's Garden, faculty members and students originally designed the Herb Garden. It bedded not only herbs but also medical, culinary, and dyeing plants. The garden follows a traditional "four-quarter" layout, which can date back to medieval times (Dalhousie University n.d.e). The sundial at the centre of the garden tells the secret between the sun and plants. The wattle gate built of local alder branches and the wooden benches are also a students' projects. The garden's fences are piled from granite which seems to indicate its unique connection to the Rock Garden across the campus.

The Rock Garden is designed on a south-facing slope. The cliff surface mimics weathered cliff faces (Dalhousie University n.d.f). The gravel scree bed provides habitat to alpine and saxatile plants. Dry streams transport rainwater to the damp area, which bedded the plants like moist soil.

All the rocks used in the garden are local Colchester County red granite. Two cedar bridges, not surprisingly, are works of students. The Rock Garden is a remarkable piece of landscape work. It is an excellent example of botanical study and rock garden construction. Due to its aesthetic value, it also is a tourist attraction for visitors.

Local shrubs and flowers are taken care of in the Pollinator Garden. Also known as the Butterfly Garden, this garden demonstrates the possibility of the urban fringe garden in an urban area for wildlife (Dalhousie University n.d.b). A small front yard garden could be home to numerous little insects. A mown path connects the ends of the garden. Perennial flowers planted along the path attract bees and butterflies to nectar and foliage. This garden provides a perfect observation opportunity for insect lovers and students. It is a living classroom to learn about pollinators.

These gardens created many different microenvironments and are vivid classrooms for the students. They demonstrate a variety of outstanding contributions vegetation made to the earth and human. The use of local materials is a characteristic of these gardens, which advocate the topic of sustainability and enhance the connection between these gardens to their location. Moreover, these gardens are the platform for students to create built, highlighting the school's hands-on learning spirit. Their breathtaking sceneries are a gift for the locals as well.

Water as a critical element is not significant in all these gardens. Thus, a garden based on a hydrology system has the potential to complement existing gardens. Adjacent to the Salmon River, the floodplain becomes a good location for developing an aquatic plant garden, which will open a new research and learning phase for the students and become an attraction to the community.

Local Attractions

Besides the gardens, the landscape architecture work on the campus tells Mi’kmaq’s story and their wisdom in time and plants. The Mi’kmaq organized their life and agricultural activities based on the sun and moon cycle. Twelve wooden sticks and boards marked the name of twelve months in Mi’kmaq’s language. The elm tree in the middle function as a sundial, pointing to the time of the day. Small plants around it were used for medicinal purposes by the Mi’kmaq. This piece of work links the campus to the history of the land. It also shows that in the past, how tightly humans life had been connected to nature.

Berlin Wall relic sections are situated at the south of the campus. They display another history in front of their visitors, telling the story about the Cold War era. They are another attractor to the visitors.

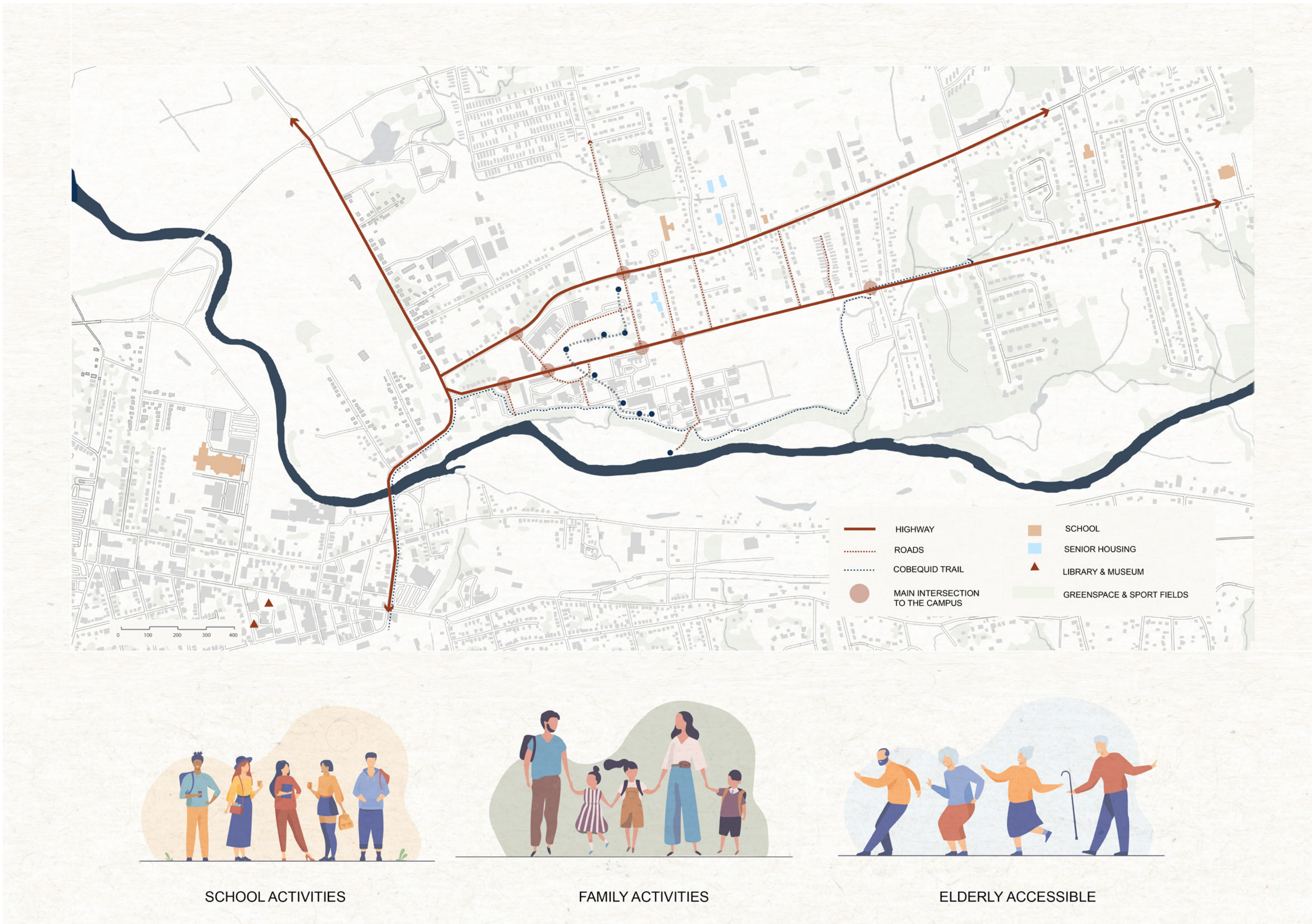
Starting at the Bible Hill Recreation Park, the 18-kilometer Cobequid Trail at the south of the campus extends to the outlet of the Salmon River (Municipality of Colchester n.d.). The trail is covered with crushed gravel. The view of the Salmon River, Acadian dykelands, and twice-a-day tide bore are the main attractions of the trail. The trail’s smooth surface and stunning scenery make it a perfect walking and cycling route. The main circulation entrances to the water garden are connected to the trail. Together with the gardens, all the attractions make Dalhousie Agricultural Campus a worth-visiting place for the public (see the map of the Dalhousie Agricultural Campus on page 20).

Map of the Dalhousie Agricultural Campus and location of existing gardens (base map from Google Maps n.d.).

Local Context

The circulation route around the campus shows a pattern as main roads spread in an east-west direction and bound the east side of the campus, while short community streets connect the main roads in a north-south direction. The Cobequid Trail that defines the south edge of the campus is only accessible to pedestrians and cyclists. The gardens and attritions discussed in the former sections are distributed in a north-south direction. The new water garden on the floodplain would extend this visiting route and emphasize the connection of the campus in this direction.

The university is located in a residential community, where most buildings are single-family houses. The community includes schools and some senior housing. Therefore, except for being used as a teaching and study area for the university, the new water garden project would be a place for school and family activities. And it needs to be elderly-friendly (see context map on page 22).



Context map of Dalhousie Agricultural Campus (data from Google Maps n.d.)

Chapter 3: Methods, Theory and Case Studies

Dyke-Built Technology

To build a dyke, the first step is to dig the “key”, a narrow trench in the middle of the dyke path. The key locks the dyke into the ground and prevents it from sliding (Nova Scotia. DAM 1987, 33). The key also stops the saltwater from infiltrating and eroding the new mud of the dyke. Sod bricks are arranged at each side of the dyke to protect the dyke from erosion. After the first layer of sods is in place, the key would be filled with fresh marsh mud and compacted by foot. Then, people place a new layer of sod on top of the first layer and repeat the process until the top of the dyke.

Other than sod, Acadians also use planks to strengthen the dykewall. The plank-facing would be buried in a trench along the dyke and tied inside the dyke fill. The plank-wall dyke creates a more smooth and even surface and provides the potential for building public facilities. A similar pattern is adopted in the dyke system in the water garden (see dyke diagrams on page 24).

Solar Aquatic Systems

Designed by John Todd, solar aquatic systems were created to treat wastewater by replicating the process of wetland purifying water in nature (ECO-TEK n.d.a). A solar aquatic system encompasses underground tanks, climate-controlled greenhouse, and outdoor constructed wetlands. Water flows between tanks and gets treated by aquatic systems. The process includes sedimentation, filtration, clarification, adsorption, nitrification and denitrification, volatilization, and anaerobic and aerobic decomposition (University of Idaho n.d.).

The first step happens in an anaerobic (without oxygen) bioreactors chamber sceptic tank, where solid is separated from liquids. The sludge will be pumped out regularly through pipes on the bottom of the sceptic tank and treated in an outdoor reed bed. Water is then sent to the anoxic chamber, where nitrates are converted to nitrogen gas. Moving out of the tank, the water flows through the root of wetland plants, and the solids get suspended furthermore. The open aerobic

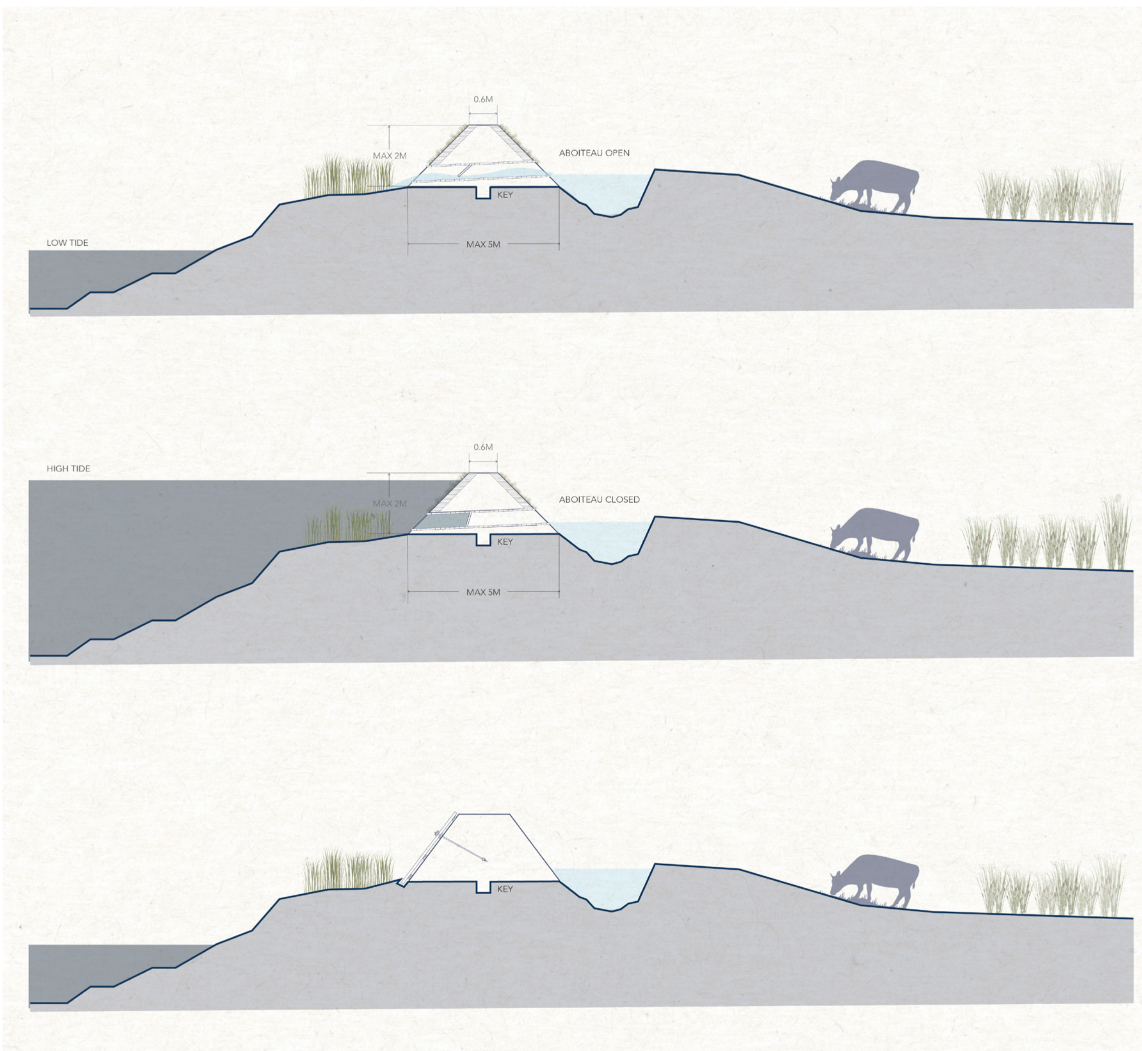
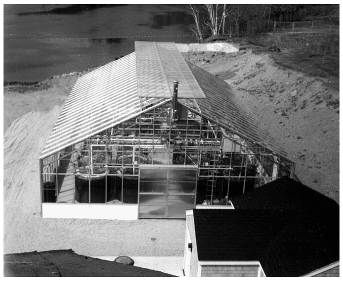


Diagram showing how aboiteau works. The position of aboiteau changes with the direction of the water flow (top two). Plank-faced dykwall (bottom) (data from Nova Scotia. DAM 1987) reactor and clarifiers (together as aerated lagoons) are the most aesthetic-pleasing part of the system, where various plants are involved. Each tank forms an ecosystem with vegetation covering the surface supported by racks. In the open aerobic reactor, the suspended roots provide habitats for the bacterias, and microorganisms, which break down the wastes (Building Green. n.d), while the plants absorb nitrate. The water is then transported into the sand filter, the last stop of water clarification. There is no soil in these pools. Any remaining organic compounds are digested by microorganisms living between the sand grains. Toxins are absorbed by the macrophyte species growing from the sand. In the final step, the clear water will be sterilized in an indoor UV light room (see diagram on page 27).

Constructed wetlands can function in different climates. In a cold climate, when the wastewater temperature is about 5 degrees celsius, the performance of the wetland changes little (Mander and Jenssen 2003,16). The vegetation litter and snow are good materials that prevent the earth's heat from escaping to the air. Plants can also be installed deeper to increase the depth of the insulation layer.

Selected aquatic plants can be planted in the open aerobic tanks, and most of them have an ornamental value. Cyperus alternifolius and Alocasia odora are featured for their beautiful leaves. Canna generalis, Iris pseudacorus, and Zantedeschia aethiopica bloom in different colours and shapes. A well-designed solar aquatic greenhouse could be as pretty and vivid as a typical botanical garden. The prolific, finely divided roots are essential for bacterias and microorganisms. Large wood plants or invasive are not helpful in these open aerobic tanks (University of Idaho n.d.). Smaller water plants such as Lemnoideae (duckweed)

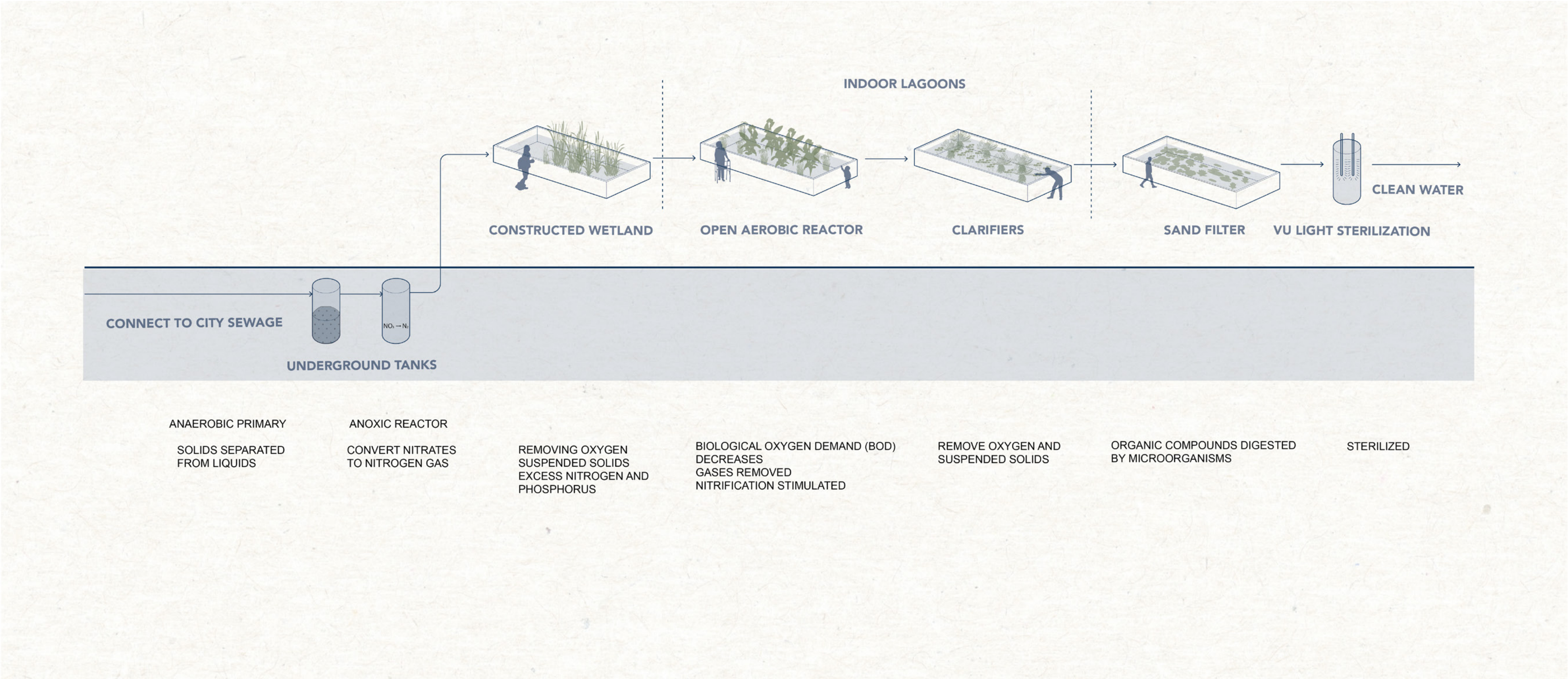


The greenhouse containing the Bear River solar aquatics facility (EEAI 1995)

Bear River solar aquatics facility (ECO-TEK n.d.b)

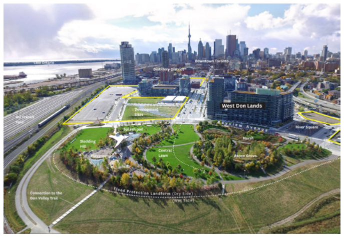
and Pistia (water lettuce) are commonly seen in the clarifiers. Local freshwater species such as cattails (Typha spp) and bulrushes (Scirpus spp) are the best choices to plant in the outdoor wetland.

The first solar aquatic water treatment plant in North America was established in Bear River, Nova Scotia, in 1995. The solar aquatic system will be used to purify the wastewater from the campus. It usually takes four days to purify the water. The treated water will be applied to agricultural fields and a natural swimming pool, which will be discussed in the water treatment process in Chapter 4.



Process of solar aquatic water treatment (data from University of Idaho n.d.)

Case Studies



Aerial photo of Corktown Common (Blanthorn n.d.)

Inspiring precedents are examined in this part. Water plays a vital role in these projects. They provide modern sights on how water can be integrated with architecture. Water sometimes is a challenge, but it is also a unique opportunity for a site. The architects do not see water as an enemy. Instead, water is treated as a valuable resource to be studied, admired, and protected. The idea of floodwater protection, wetland conservation, botanic treated water harvest, and water scenery creation in these examples are developed into primary principles of the water garden proposal. Combining education, entertainment, and research functions is the core of programme design.

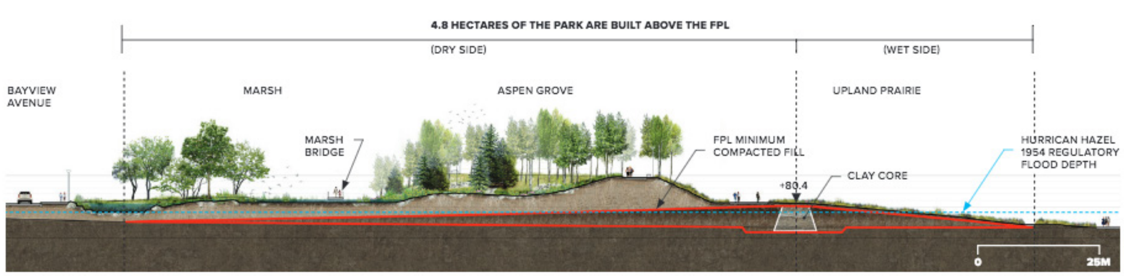
Site plan of Corktown Common (Blanthorn n.d.)

Corktown Common: Transforming a Floodplain into a Public Amenity

Toronto, Ontario, Canada

Lead Design Team: Michael Van Valkenburgh Associates

Positioned on a massive flood protection landform (FPL), Corktown common successfully transformed a floodplain into a public park. The park protects 209 hectares of the city from flooding. In the meantime, it provides magnificent public amenities for the community (Waterfront Toronto n.d.). The goals were achieved by constructing a 4-metre



Section of Corktown Common through wet and park sides (Blanthorn n.d.)

high clay substructure along the edge of the site. The clay core not only reshaped the river's floodplain but also formed the park's basis (Blanthorn n.d.). It divides the area into two halves. The prairie slope helps prevent floodwater on the wet side. The dry side with a gentle slope is the recreational park, where there is an urban marsh, a central meadow, a splash pond, a sledding hill, and a playground.

Moreover, the common also meets the goal of water conservation. Water supply from the city is used in the splash pond and then gets sterilized and purified in the constructed marshland to be used for on-site irrigation. Runoff and surplus water are also sent to the marsh for recycling.

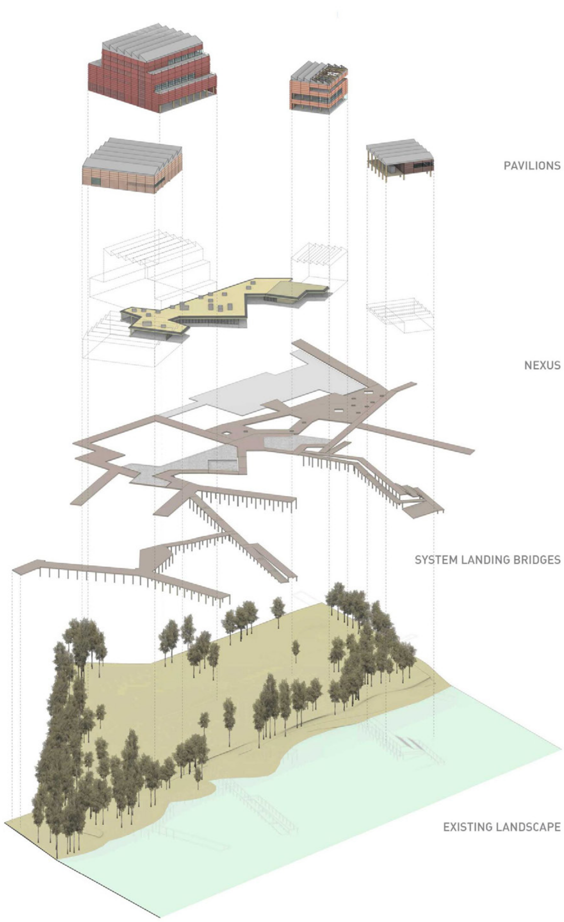
This project is inspiring in terms of how to achieve multiple goals through reforming a flood-risk zone. The flood-proofing structure can be well combined with local topography and provide space for amenity facilities and natural water treatment. Protection is not the only mission of a flood-proofing project. It can also contribute to the local community and the environment.

Wetland Museum: Layered Construction and Multi-Functional Program

Fetsund, Norway (concept project)

Design team: Estudio Herreros

Seated on the bank of the Glomma River, the Wetland Museum connects the history, the wetland, and the human, raising the awareness of the value of this fragile ecosystem (Estudio Herreros n.d.). This museum shows a solution to building construction on a wetland. To protect the wetland and, in the meantime, bring people close to the landscape, the architects accomplished the project by creating different layers on the site (see axonometric diagram below). The landing decks are constructed above the wetland as the first layer to protect the wetland from being directly stepped on. The deck branches onto the water, providing a landing bridge for people to paddle boats. Prominent buildings are set on the inland ground, connected through the low building on the deck. In this way, the project is built sustainably, as the environment is experienced but not disturbed. The best way to encourage people to learn about an ecosystem is to allow people to get close to it and do different activities around



Axonometric diagram showing different architectural layers of the Wetland Museum (Estudio Herreros n.d.)

it. By staying around the ecosystem, people observe, get curious about it, and are willing to know more about it. This building has a cafe, a shop, an auditorium, classrooms, workshops, and an exhibition hall, which provide spaces for various events (see building plan below). The education mission of the museum is well integrated with relaxation and entertainment.

Borden Park Natural Swimming Pool: A Chemical-Free Public Pool

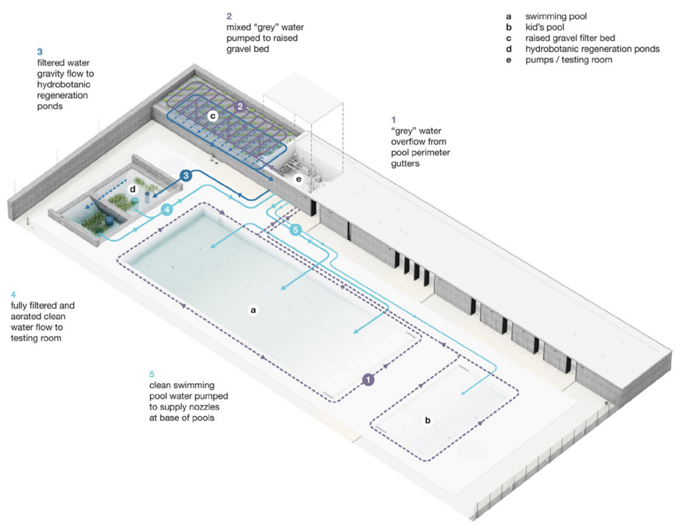
Edmonton, Alberta, Canada

Design team: gh3*

The Borden Park Natural Swimming Pool is a pioneer in the natural swimming pool in Canada. Different from the traditional water treatment process, a natural swimming

Building plan of the Wetland Museum (Estudio Herreros n.d.)

pool relies on natural materials and vegetation to clean the water. The “living water” passes through the hydro botanic regeneration pond that contains plants, microorganisms, nutrients, gravel, and sand at the north end of the pool (González n.d.). The clean water is then pumped and tested before sending to the swimming pool. The swimming pool can accommodate precinct 400 swimmers in total. A natural pool creates a win-win situation for both the swimmers and nature. On the one hand, the botanical treatment is visually pleasing to the users. It allows those who are sensitive to chemicals to enjoy playing in the water. On the other hand, pollution caused by chlorinated water can be erased, especially in an outdoor environment. A natural



Programme and water circulation axonometric diagram of the natural pool (gh3* n.d.)

Photo of the sand filters and the swimming pool (gh3* n.d.)

pool is almost the best way to show people the excellent performance of botanic water treatment. The Borden Park project proved that a public natural swimming pool is feasible under Canada's strict public pool guidelines.

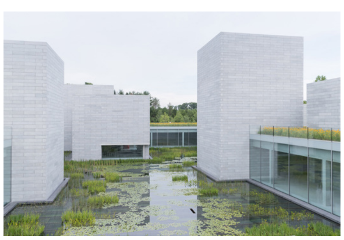
Glenstone Museum: An Enclosed Water Court

Potomac, Maryland, United States

Architect: Thomas Phifer

Semi-bedded into the landscape, the museum comprises a series of enormous concrete blocks, which form a connected circular route for the visitors. These cubed volumes enclose a water court. Concrete pavilions are illuminated by tall glass panels that extend to the green roof. These opening moments lead visitors to admire the peacefulness of the water. Guests can wander on the platform on the water to sit and relax. The drainage is designed in the gap along the edge of the water court, which makes the building looks like growing up from the water. The water court has an ornamental function and purifies the water harvested from the roof. Water in the court is filtered through the planted gravel beds, followed by a conventional purification process to keep it clean (Biohabitats n.d.). This project is a good combination of landscape, water features, and architecture. The enclosed shape of the building emphasizes the water court in the centre. The glazing window minimizes the boundary between the pond and the indoor spaces. It creates a special atmosphere where people are both indoors and by the waterside. The wooden deck is an extension of the indoor spaces on the water. It makes visitors feel like they are floating on the water and create a chance that allows people to get closer to the water to admire it.

Museum submerged in the landscape (TPP n.d.)



Water court of the museum (TPP n.d.)

Deck platform on the water court (TPP n.d.)

Chapter 4: Site Strategy and Programme

The best way to encourage people to learn about an ecosystem is to put people into that environment. To raise people's awareness about climate change and the local flood issue, the project is chosen to be at the floodplain along the Salmon River. The water garden functions as an on-site academic lab, a public-education classroom, and, more importantly, a recreational amenity for the community. On regular days, It would be the most exciting field trip choice for young kids; it would be a park where people would have a walk after supper, and it would be a destination to spend a whole summer day with the family. When a flood happens, the water garden becomes an observation station and protects the site from surges. The key to the design is how the project integrates with its context and interacts with the water components.

The Water Garden: Extension of the Existing Gardens

The water garden extends the existing gardens in terms of location, application of the curved geometry pattern, programme choices, and material selection.

To allow people to get closer to the Salmon River and the floodplain, the site is situated on the south side of the campus on the riparian by the river. From the campus to the river bank, the elevation drops around 18 metres. Native trees and grass cover the south-facing slope and the floodplain. Existing gardens spread in a north-south direction which is bounded by the Cobequid trail. Tied to the trail, the water garden spreads onto the river bank, extending the campus further to the south. East access already exists on-site. The west and middle ones allow people from different directions to access the park easily. The west path connects to the accommodation buildings of the campus. The middle one lies on the most gentle slope of the hill, leading to the gardens on the campus. Either approaching after visiting the campus or strolling from east or west on the trail, people would discover an exciting destination behind the woods. The water garden encourages north-south visiting circulation across the trail.

As mentioned in the last chapter, a circle is a classic shape in traditional landscape design. On the campus, circular patterns (whole or partial) can be found in the Alumni Garden, the Herb garden, the landscape architecture project, and the Centennial Amphitheatre. The curve expresses a soft and organic sense, which angular polygons can not compare. Thus, in the water garden, the circular pattern is adopted to create the wavy shape of the project. The dyke system is the fundamental to this project. The form of the dyke is developed from the segments of the three circles. The fluent curve paths suggest that water flow is the principal theme of the garden. The major constructions of the projects are the three arc-shaped on-ground ponds bounded by the dyke. These ponds become wetlands, filter pools, and swimming pools with flowing water. Buildings are designed along the wetlands and pools (see the diagram of site strategy).

The main programmes of the project, from west to east, consist of a restaurant, a reception building, and a learning centre. The “void spaces” created by the curve are developed into two farm fields and a lake. Between the hill and the restaurant, there is the new chef’s garden, in which vegetables and herbs will be planted and served in the restaurant. The garden also provides students another spot to directly work on crops. The idea of this garden comes from the Chef's Garden on the campus and aims to advocate a local, sustainable food supply concept. The experimental rice field is behind the learning centre, which provides the opportunity to test the performance of rice in the Truro environment. It also creates a site to test the submergence tolerance in rice. In front of the reception building, there is the new wetland. The earth dug from this wetland will be used to construct dyke on site. This wetland would also be an excellent location for Ducks Unlimited's conservation programme, which aims to conserve wetlands and habitats for birds (Ducks Unlimited n.d.). These landscape programmes will enrich the research and teaching

Diagram of site strategy. Black lines indicate dyke walls.

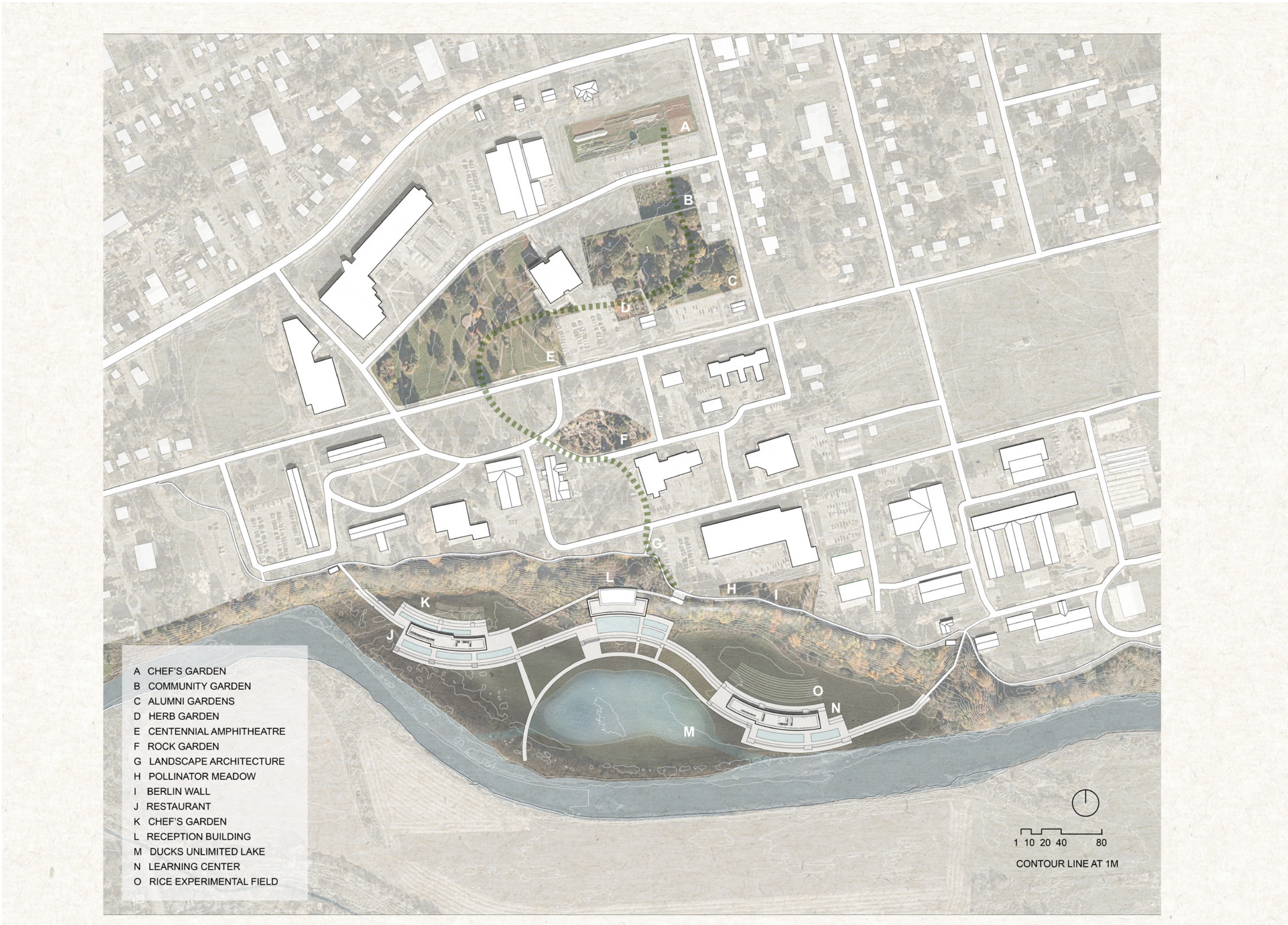
environment of the school and encourage the public to learn more about agriculture and wetland conservation (see site plan on page 38).

The use of local wood and stone materials is one of the features of the school's gardens. The wall siding, the gazebo, the benches, the guard rails made of wood, the alder arch, and local red granite can all be seen on the campus. Compared to materials that need long-distance transportation, these local materials are much more environmental-friendly. Moreover, the carbon dioxide equivalents embodied in timber is much less than that of metal materials at the same strength. All the main structures will be mass-timbers in the water garden. Wood siding and deck board will be cedar woods. To respond to the rock garden, the finish and edge of the swimming pool will be paved with local granite (see site section with garden sketches on page 39).

The water garden enlarges the scale of the campus spatially. At the same time, the design element and materials are consistent with the existing gardens, and they convey the same school spirit.

Views and Water Features

The curve shape of the project guides people's views to a dispersed or concentrated angle, which emphasizes different water features and atmospheres. The constructed wetlands are on both sides of the restaurant. The outside of the arc forms an outward view range, which creates an open view and encourages people to see the wetland close by and the river scenery in the background. On the other side of the building, the view is compressed, which creates a more private and quiet feeling for people. The interior



Site map of the campus and the water garden.

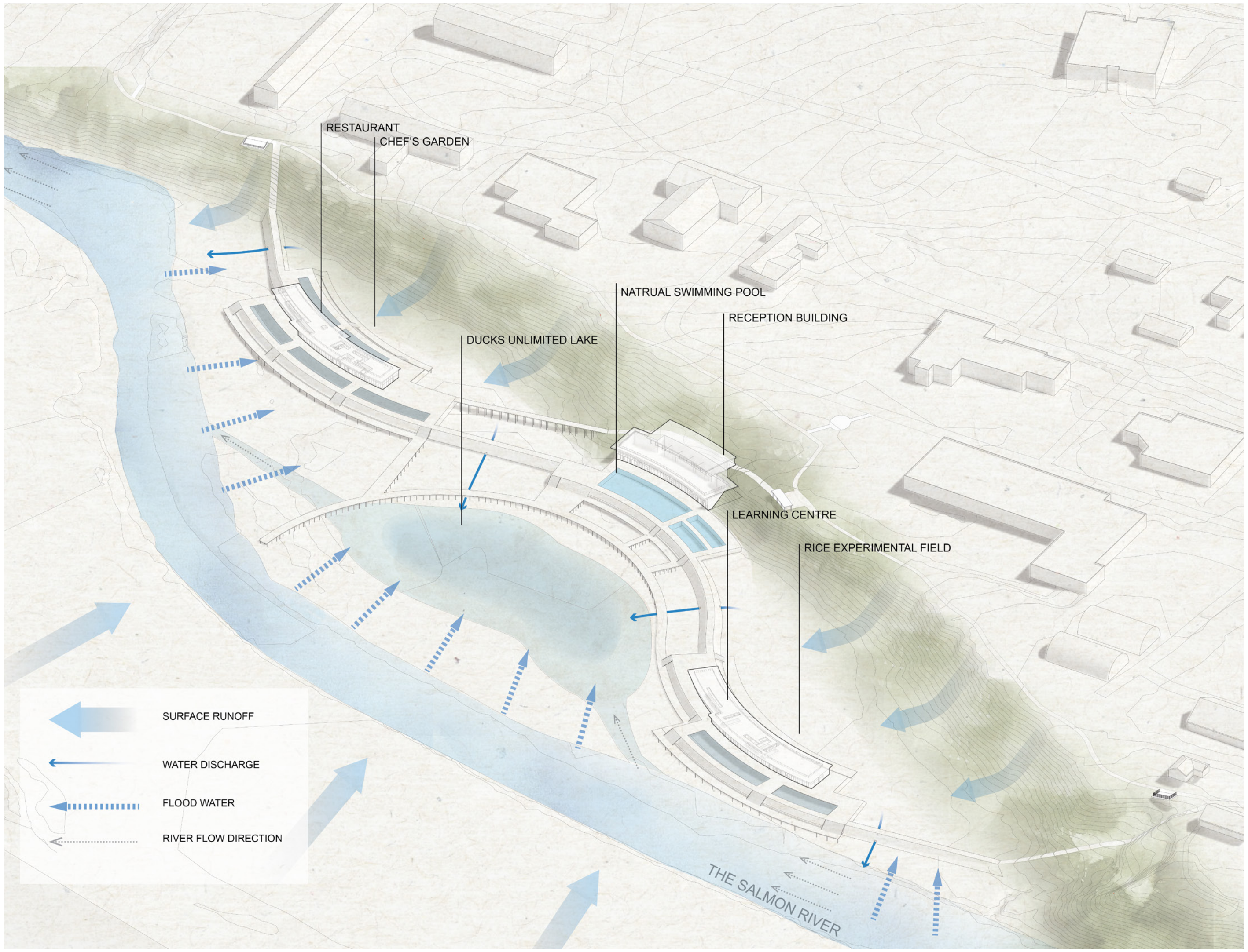
Section of the site and sketches of the existing gardens (from left to right, the Chef's Garden, the Alumni Garden, the Herb Garden, and the Rock Garden).

design of this building follows the same principle and will be discussed in the next chapter. Since bigger groups occupy the main spaces, the learning center has an outward and open view. A broad view encourages creative thinking and promotes children to watch the wetland in front of the classroom. Wetlands beside these two buildings function as water purification facilities. The design intends to let the public notice the excellent performance of the wetlands in the water treatment process. The view of the reception building is centralized in the area in front of it, where the purified water is harvested and used in a natural swimming pool. The shape of the building invites people to admire the clean water and play in it.

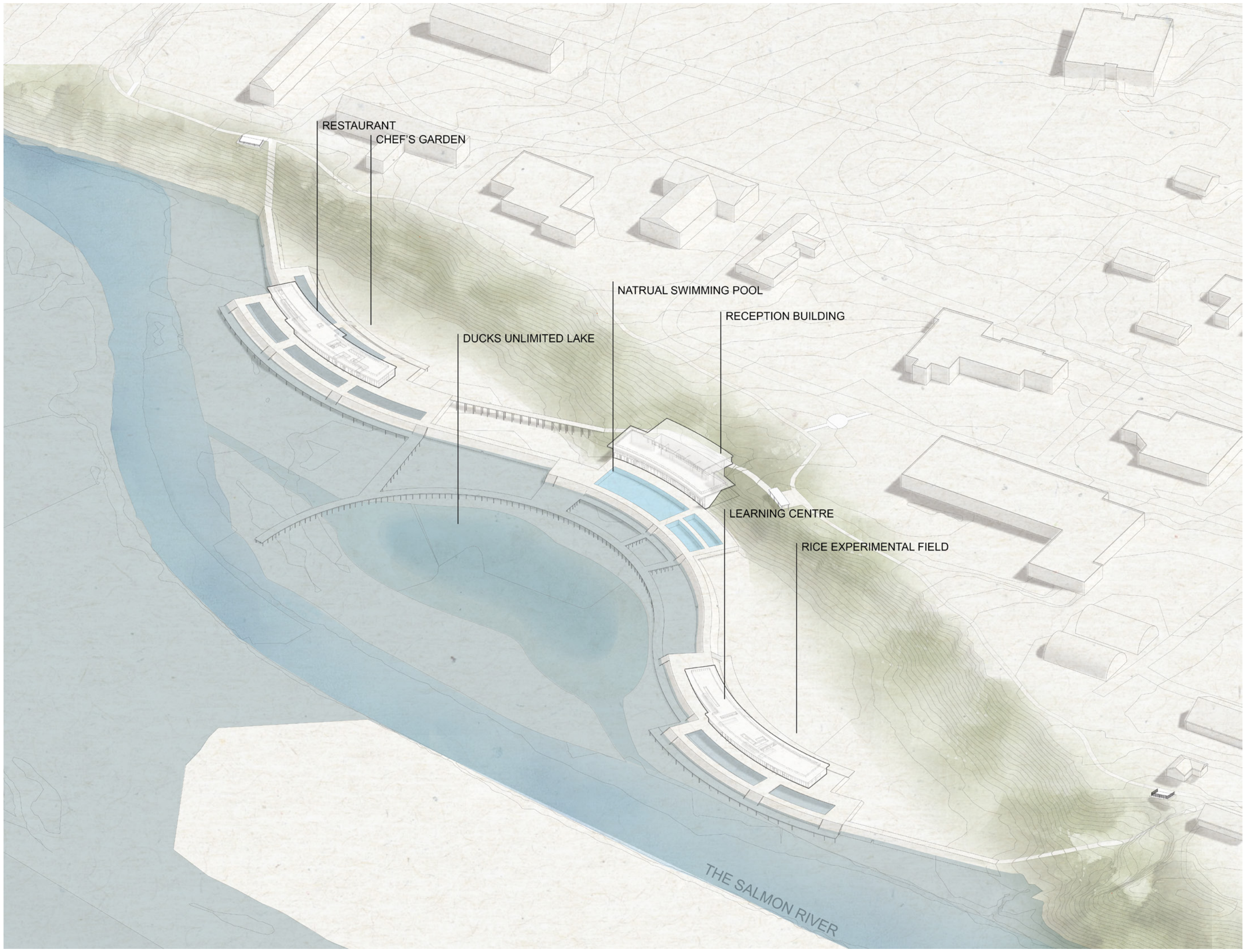
Project concept collage: an abstract hybrid drawing illustrating proposed programmes and user groups.

Surface Water and Floodwater Control

The essential function of the dyke is to control water flow. The fresh surface water runoff from the hill gathers at the new chef's garden and rice field, which can be used for irrigation. The four small watergates can control the flow between the protected area and the river. Once a flood happens in this area, the Ducks Unlimited Lake will behave as the priority buffer to contain the floodwater. The dyke will prevent the floodwater from invading the farm fields (see surface water control and flood control diagram on pages 43 and 44). Since the buildings are all constructed at the level of the dyke top (3 meters above the riverbank level), the structures are totally secured from floods.



Axonometric diagram showing surface water control.

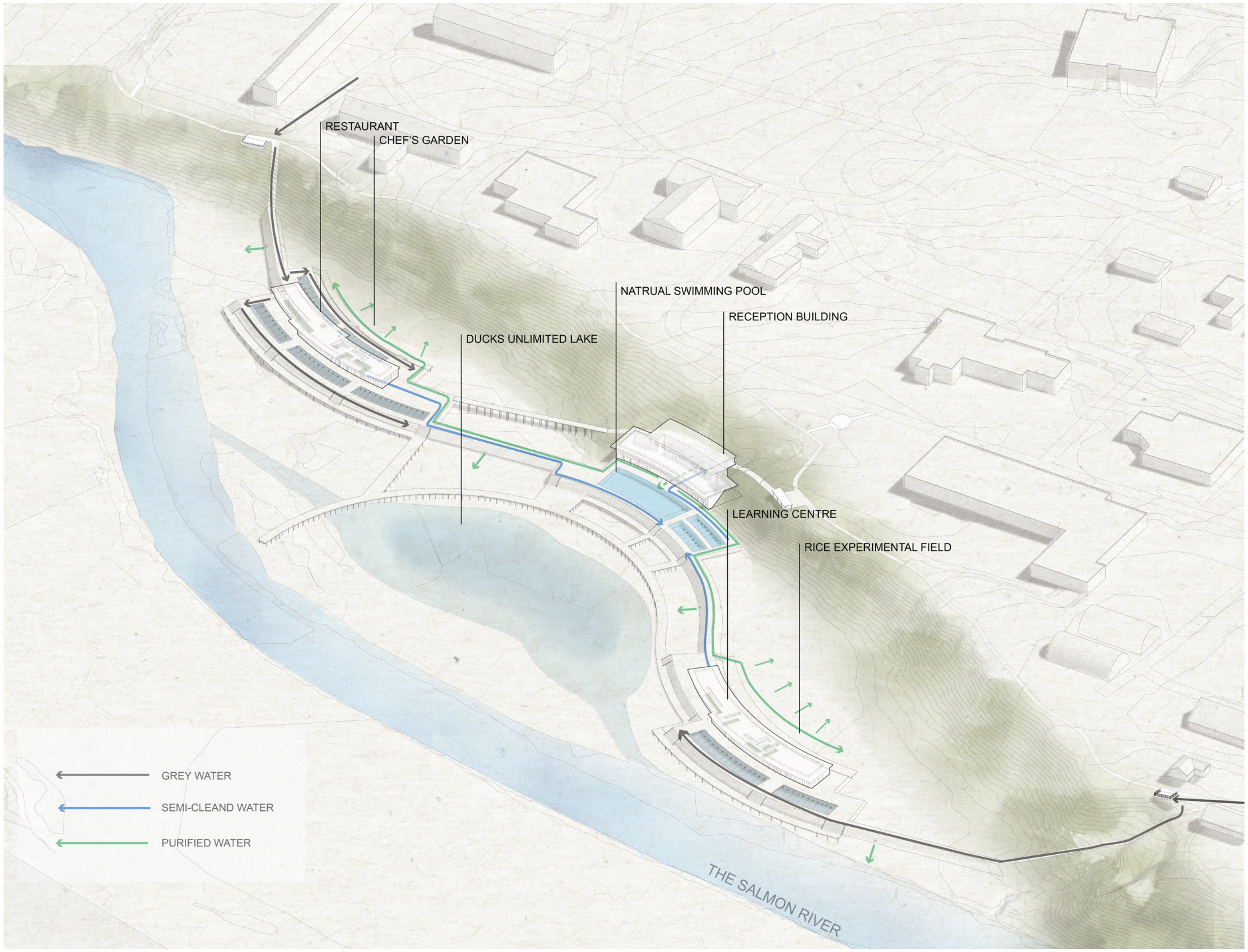


Axonometric diagram showing the dyke system in a flood event.

Water Treatment Process

The whole project works as a water treatment plant. It treats all of the grey water from the campus. Each day the system purifies 60,000 gallons of water. The system includes underground sceptic tanks and anaerobic tanks, constructed wetlands, aerated indoor lagoons, sand filters, and the UV sterilization room. The town's greywater network is connected to the garden's underground tanks at the east and west end. These tanks are designed as viewport platforms, where visitors can see the whole sight of the water garden. The solids are separated from liquids in these tanks. Then the water flows into the outdoor constructed wetlands by the restaurant and the classroom to remove nitrate and reduce the Biological Oxygen Demand (BOD). Afterward, the water is pumped into the indoor lagoons. Microbial live in the roots and scrub the water more deeply.

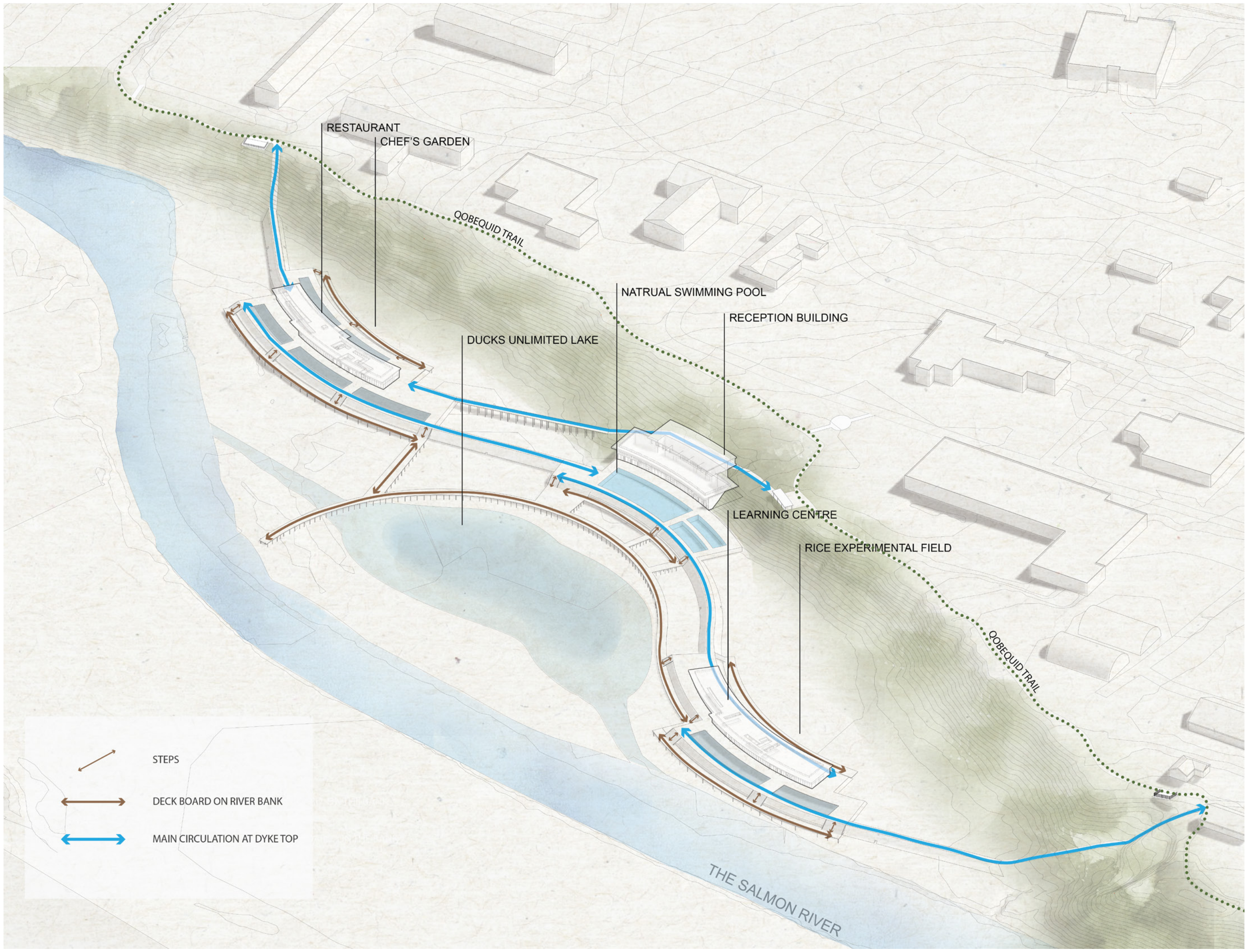
The sand filter pool is located at the east of the reception building, besides the natural swimming pool. The water gets final polished in the sand filter pool before being sent into the UV sterilization room. After that, the clean water is ready to be used in the swimming pool and irrigate the chef's garden and rice field (see the water treatment process diagram on Page 46).



Axonometric diagram showing the water treatment process.

Dyke, Deck and Circulation

The major construction is the three arc-shaped on-ground ponds bounded by the dyke. These ponds become wetlands, filter pools, and swimming pools with flowing water. Buildings are built along the wetlands and pools. The ponds are linked by these three-metre top-wide and three-metre-high dykes. These dykes extend east and west to the Cobequid Trail, guiding people to explore the garden. These dykes evolved from the traditional plank-facing dyke. The top of the dyke is constructed with a deck, providing walking paths for people. Other walkways are constructed along the bottom of the dyke at 60 centimetres above the ground to protect native vegetation. The belt of wooden benches is installed on the lower deck so people can stop and watch the beautiful scenery anytime. The pipes that transport the sewage are buried under the dyke and connected to the existing grey water network (see circulation diagram on page 48).



Axonometric diagram showing the main circulation paths.

Chapter 5: Project Design

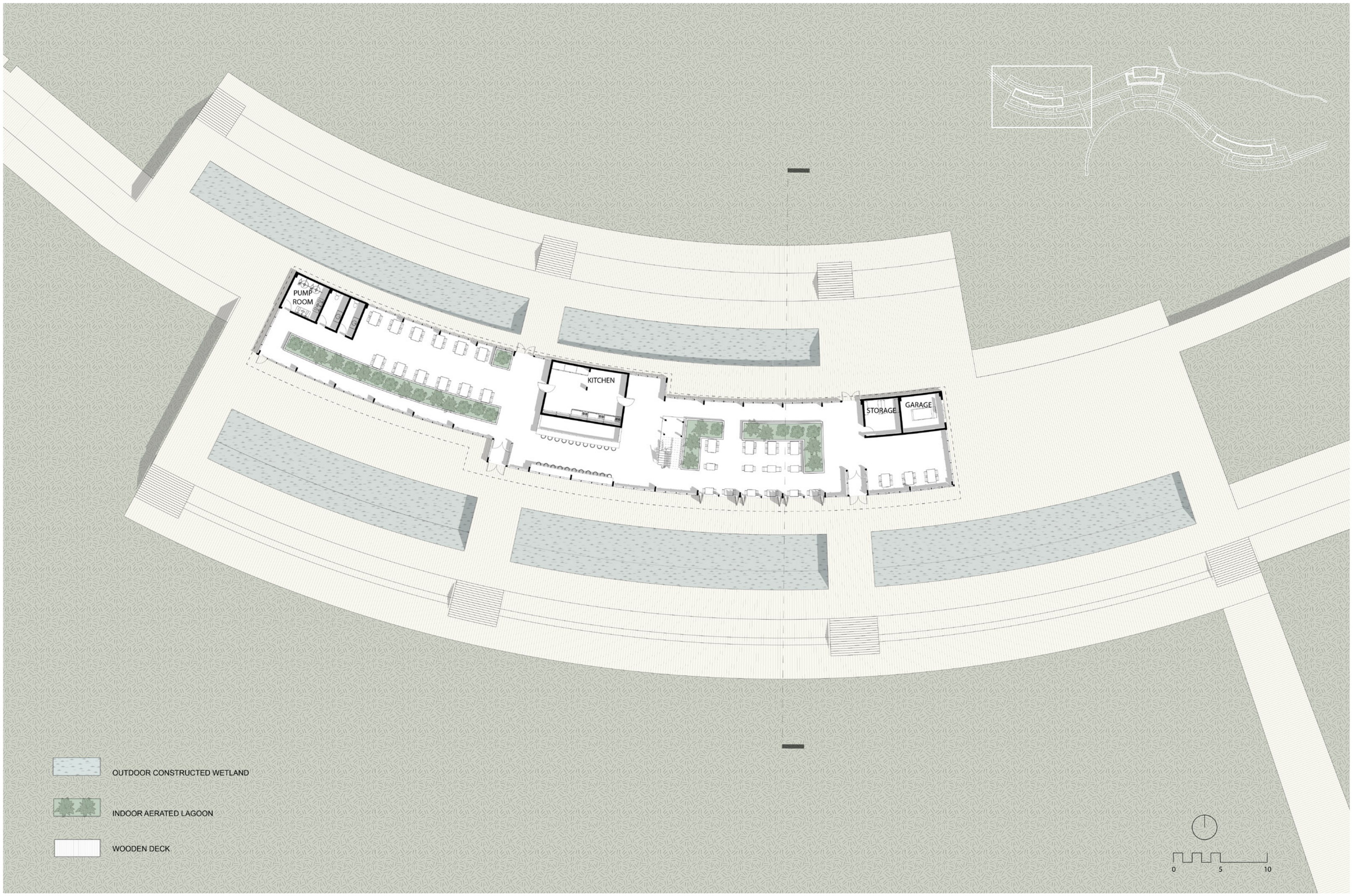
As referred to earlier in the last chapter, the main building of this project includes a restaurant, a reception building, and a learning centre, offering spaces for various activities. People can explore more about natural water filtration processes while playing and relaxing in the garden. Each building is designed to integrate indoor and outdoor water features. This project establishes living classrooms for the university academic team to gain test material directly. It also invents a science centre for school children and the public to learn about a living water treatment process. By inviting people to the site, the project brings the natural water purification process to their sight and proves its efficiency.

The restaurant and the learning centre are designed with similar principles, and their water facilities function at an early stage of water treatment. Thus, these two buildings will be discussed first. The reception building will be introduced later. And at the end of this chapter, how sustainable design is applied to these buildings will be explained by taking the learning centre as an example.

The Restaurant

The restaurant mainly serves the public. Customers enjoy the beautiful scenery of the river, the wetland, and the greenies indoors while enjoying the food on their plates. Water is the secrete that connects all these things. The shape of the building follows the arc shape of the wetland pond. The building consists of a west wing and an east wing with servant spaces located at the ends of each wing. The kitchen, the reception, and the bar are in the centre of this building to ensure the best view for the server to look after the dining space and provide food service. The indoor aerated lagoons become the soft barrier that divides spaces. The lagoons also form a semi-closed space in which the dining area is nested. When sitting there, the visitors would feel secure and intimate with nature. The west and east wing are designed to create different dining environments and experiences. In the west wing, the lagoon is on the south side, which filters the lights and directs the view toward the hill and chef's garden. Dinning space on this side intends to be more private and enclosed. In contrast, dining spaces on the east side are more open and bright, emphasizing the broad view of the Salmon River. The roof is also accessible to people, where customers can enjoy their meals on the patio during the summer days. The roof terrace also allows people to observe the indoor and outdoor vegetarians from a different angle.

Because part of the food served in this restaurant is directly from the chef's garden at the back, visitors might also choose to harvest food by themselves. The garden-to-table pattern also advocates the idea of consuming local food, which leaves a smaller carbon footprint.



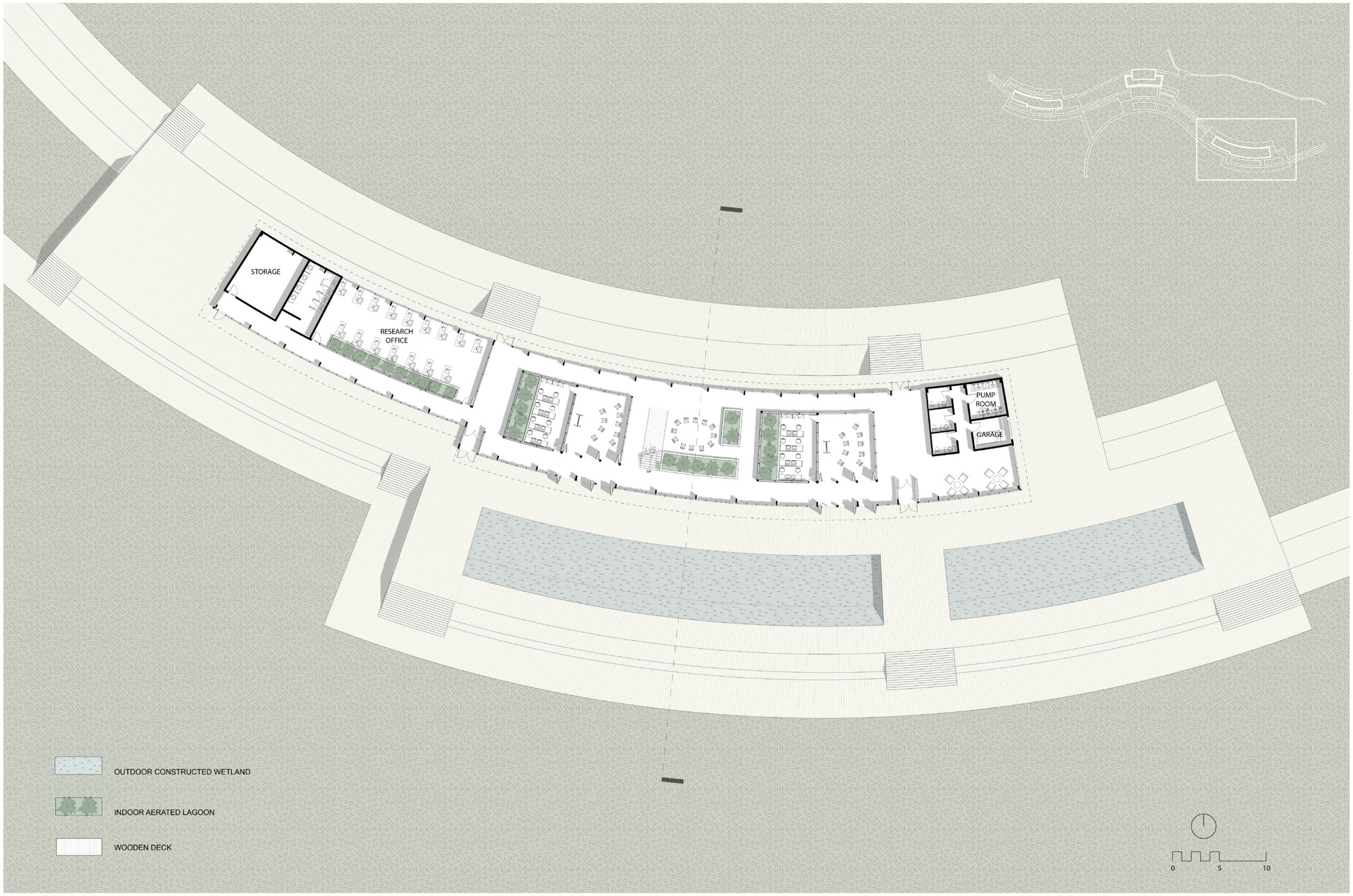
Plan of the restaurant building.

Section of the restaurant building.

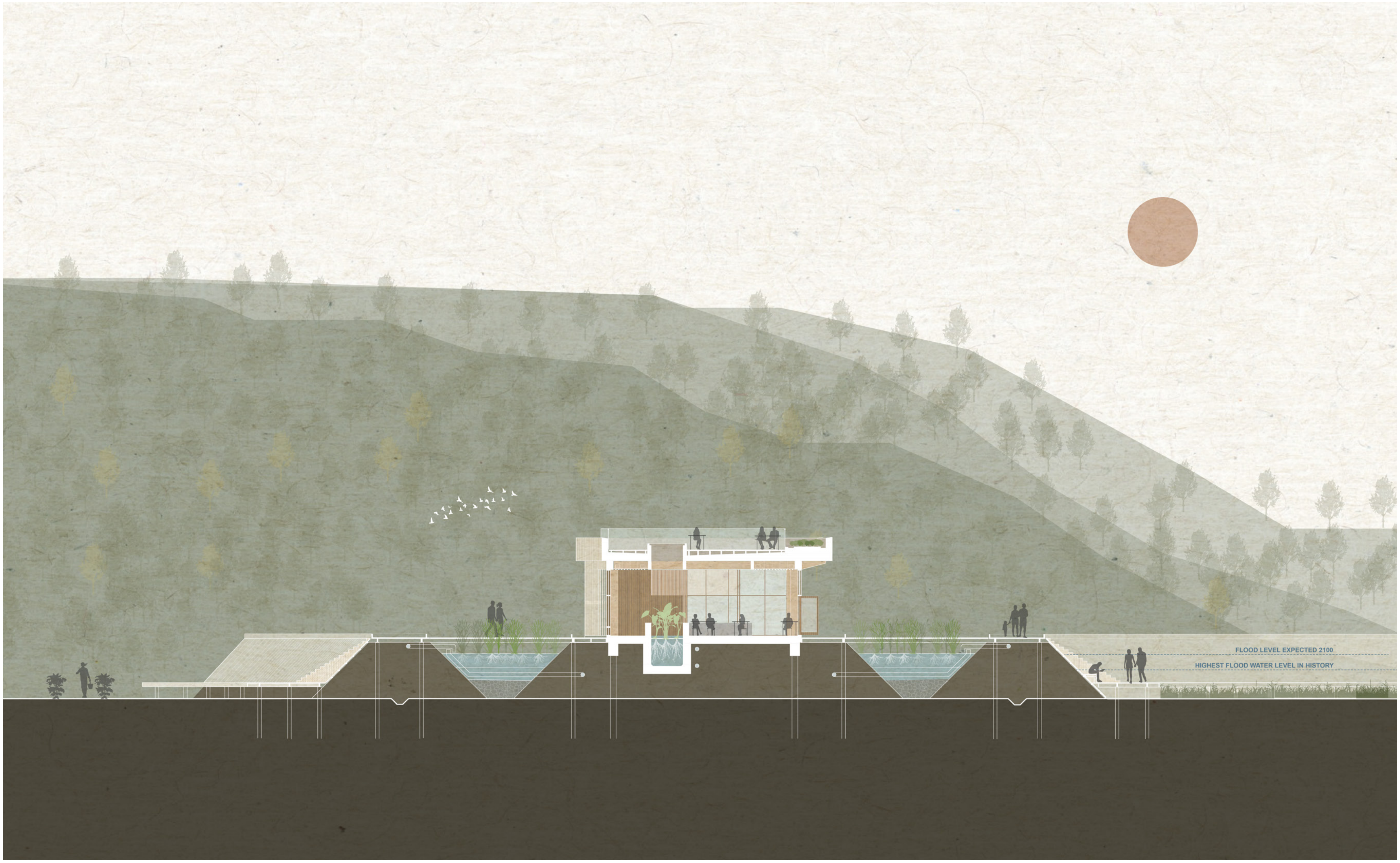
Interior perspective of the restaurant.

The Learning Centre

The learning centre is primarily for research and experiments, both for the academics and the children. Like the restaurant building, servant spaces are at both ends of the learning centre. The west part of the building contains the offices for the researchers, and the east part contains the classrooms and labs. Indoor aerated lagoons in this building are boundaries that define spaces, planters that ornament rooms, and academic sources that provide direct experiment materials for researchers and students. Due to acoustic reasons, there are two enclosed classrooms and one open-to-air seminar space. The enclosed classroom consists of a lagoon, a lab, and a teaching space. It would be very convenient for the school children to learn the fundamental theories and then take samples and witness the test results. The limit between indoor and outdoor spaces is blurred by applying folding doors on the walls. The outdoor deck is wide between the classroom and the wetlands. Children can have outdoor gatherings, observations, and discussions on the board. The roof terrace is also open to the users. On a warm and sunny day, students could sit on the deck or go to the roof to have a special class.



Plan of the learning centre building.

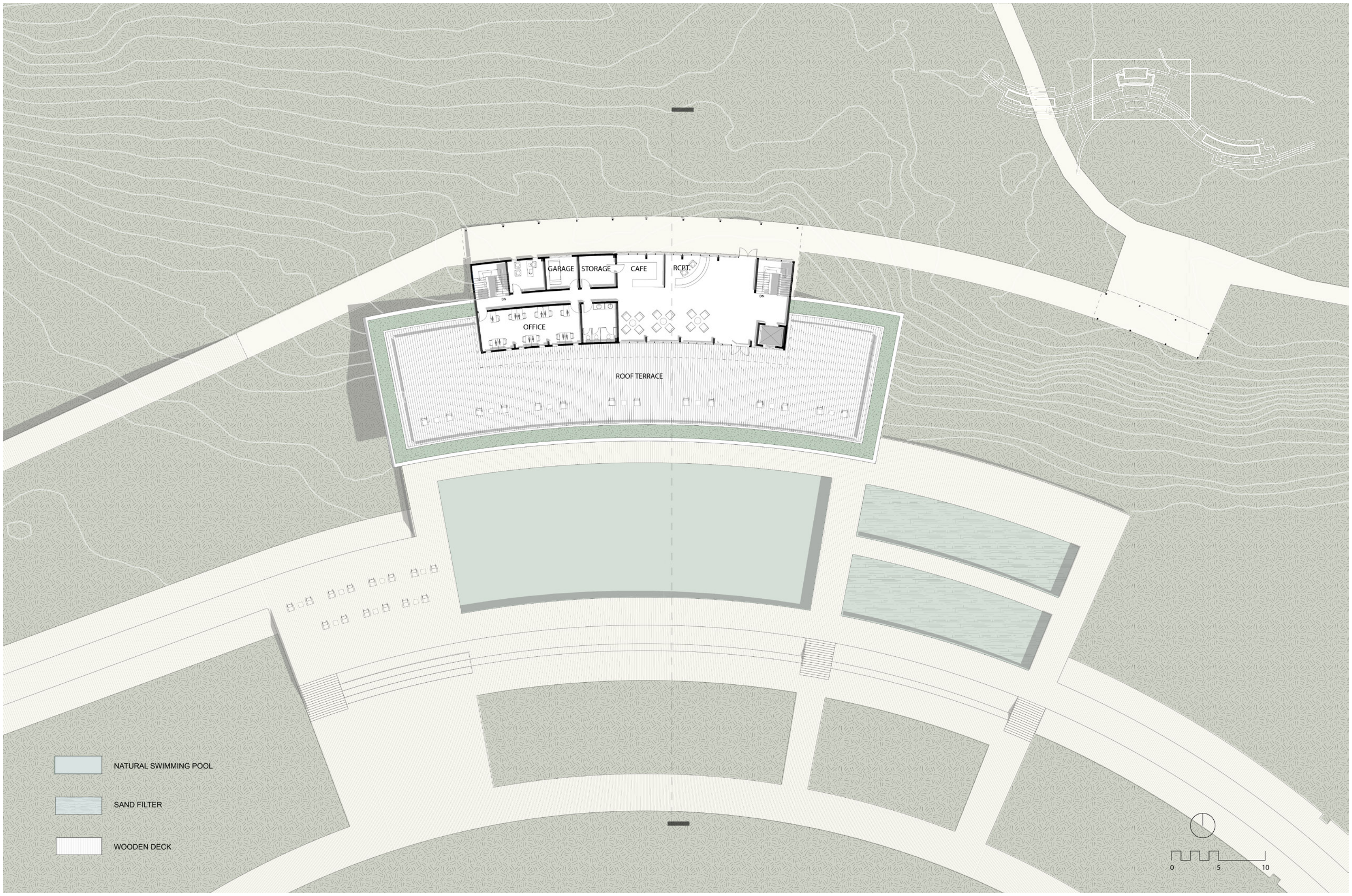


Section of the learning centre building.

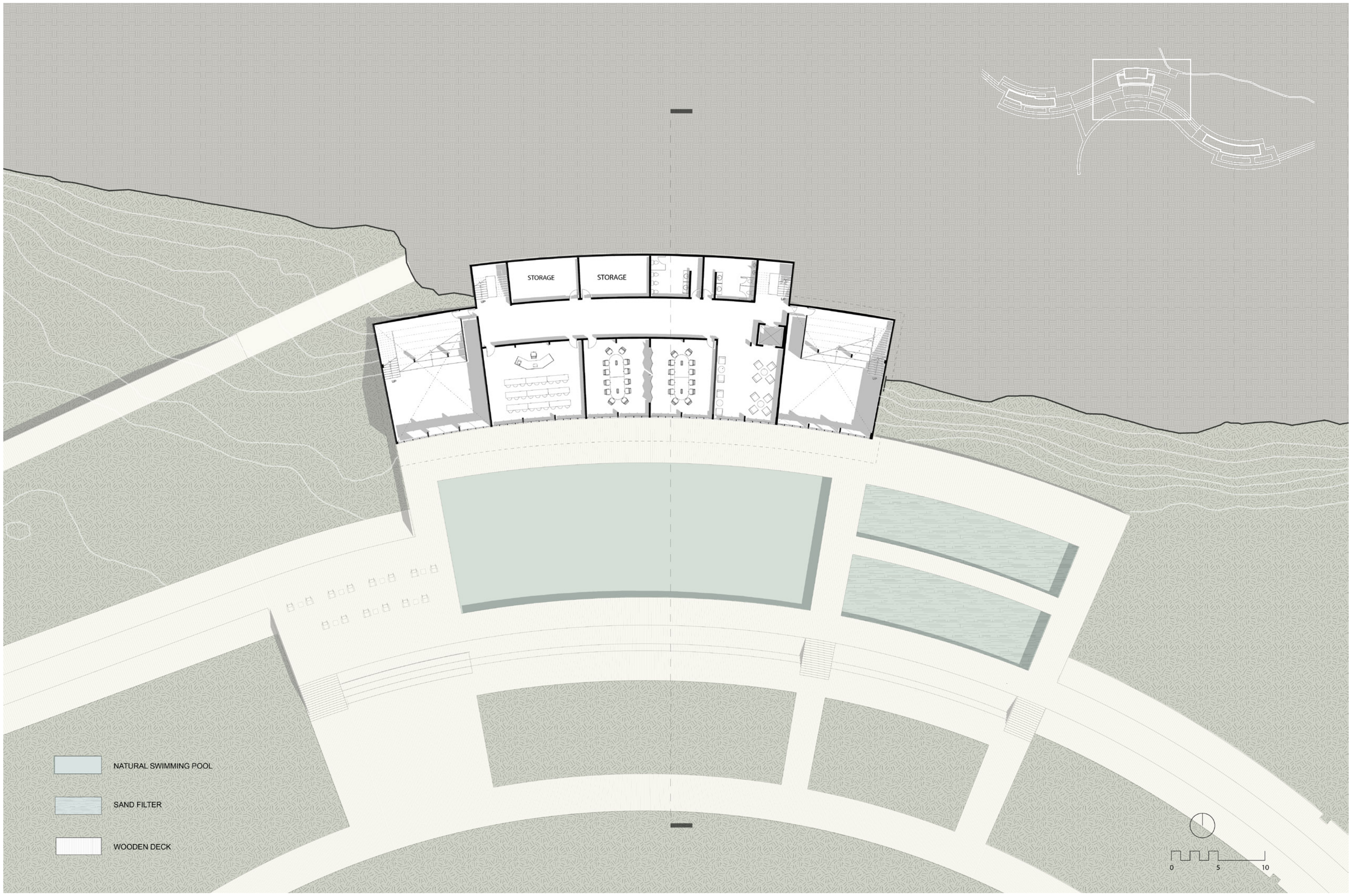
Interior perspective of the enclosed classroom.

The Reception Building

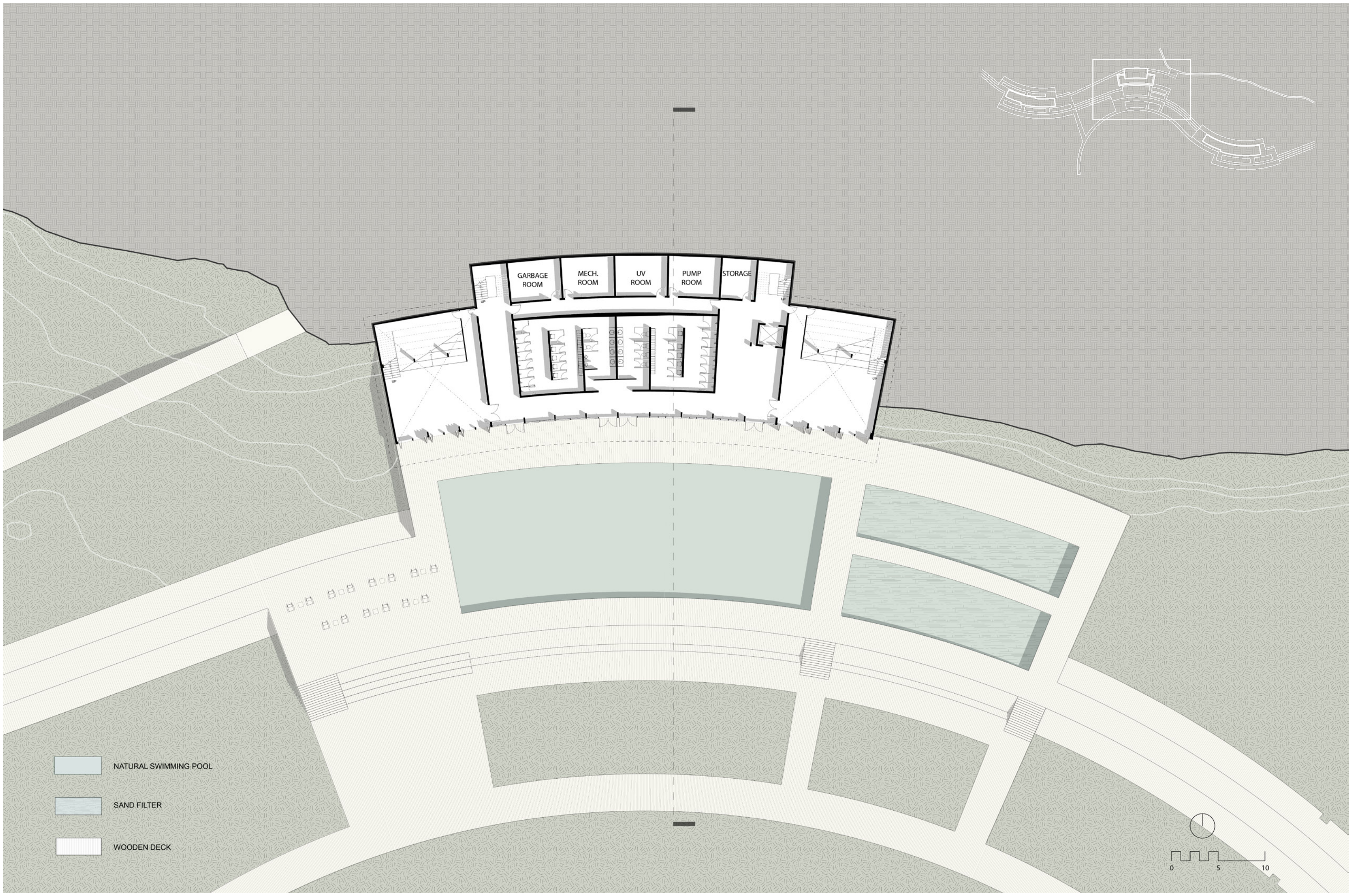
The reception building is a complex three-story building constructed against the hill. From top to bottom, there are the reception level, the conference level, and the changing room level. The top level is directly accessible from the path in the middle. After getting in, there is the visitor centre and the cafe. From there, visitors can choose to go to the terrace to enjoy the scenery of the water garden. On the east side of this level, there are the offices for the garden’s administration department. The management team will mainly work in these offices. Moving down, the second floor is designed to host various types of conferences and lectures, especially about sustainability and hydrology topics. Storage spaces are provided at the back of this level to keep the furniture and facilities. On the lowest level, the spaces are mainly designed for the natural swimming pool. Changing rooms are at the front so people can go directly to the pool after putting on their swimming equipment. The garbage, mechanical, pump, and UV fertilization rooms are located at the backside. At both ends of this level, there are two double-height studios. People can have yuga, dance, and even aerial circus classes there. Spanish steps at the back of the studio allow people to rest, wait, or watch their friends doing exercises. The top of these seating areas is accessible to the upper level. Storage rooms are set under the seating areas and provide sufficient spaces for training equipment. Opening the folding door of the studio, the breeze from the water will cool down the whole room during the summer. There is a large deck zone to the east of the natural swimming pool where swimmers can relax and enjoy the sunlight at the intervals of swimming.



Plan of the reception building level 3 (top level).



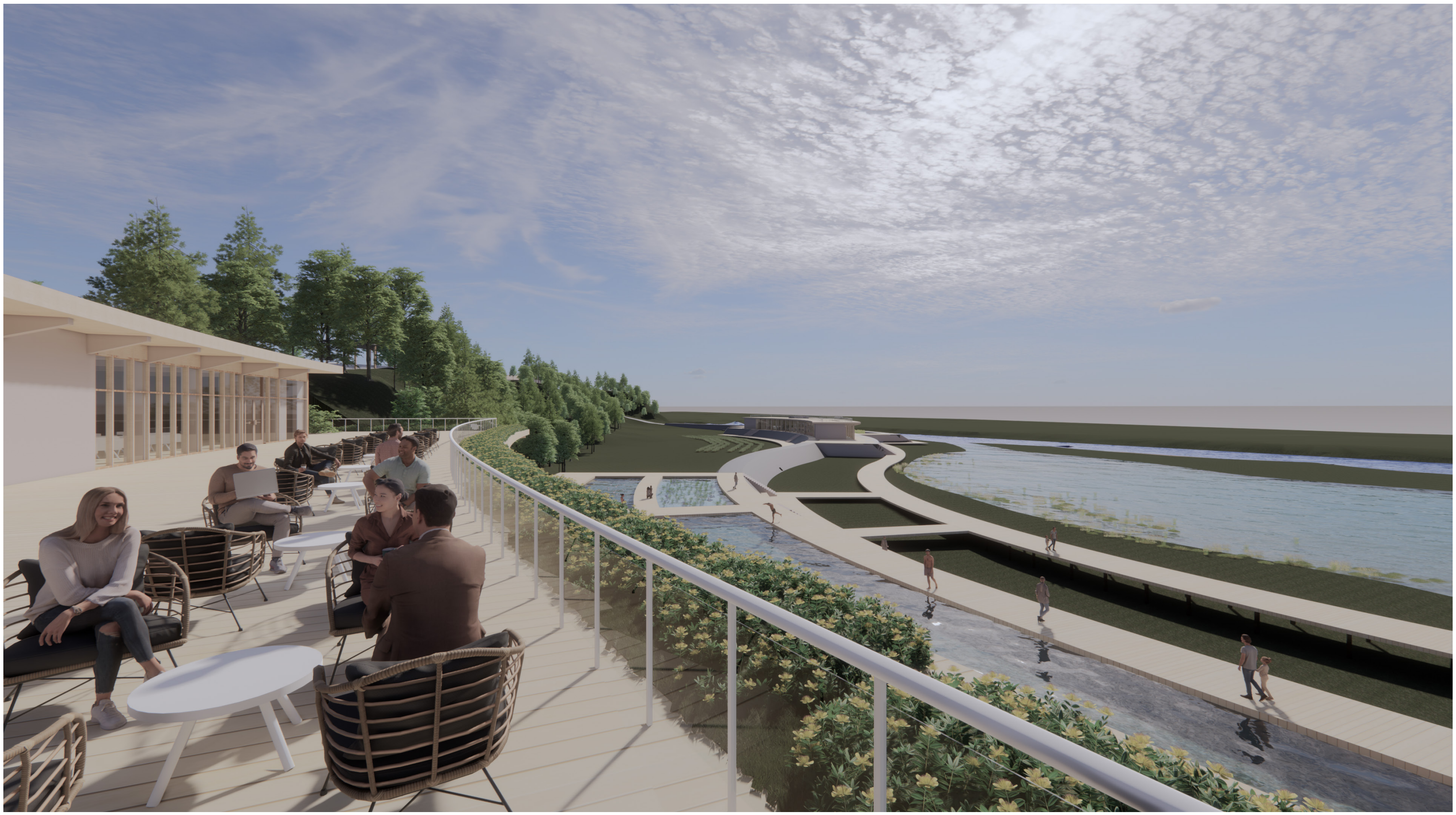
Plan of the reception building level 2.



Plan of the reception building level 1 (dyke-top level).

Section of the reception building and the natural pool.

Section of the reception building, the natural pool, the Ducks Unlimited Lake, and the Salmon River.



Perspective from the roof terrace outside the reception.

Perspective of the sand filters and the natural pool.

Perspective of the double-height exercise studio.

The Green Project

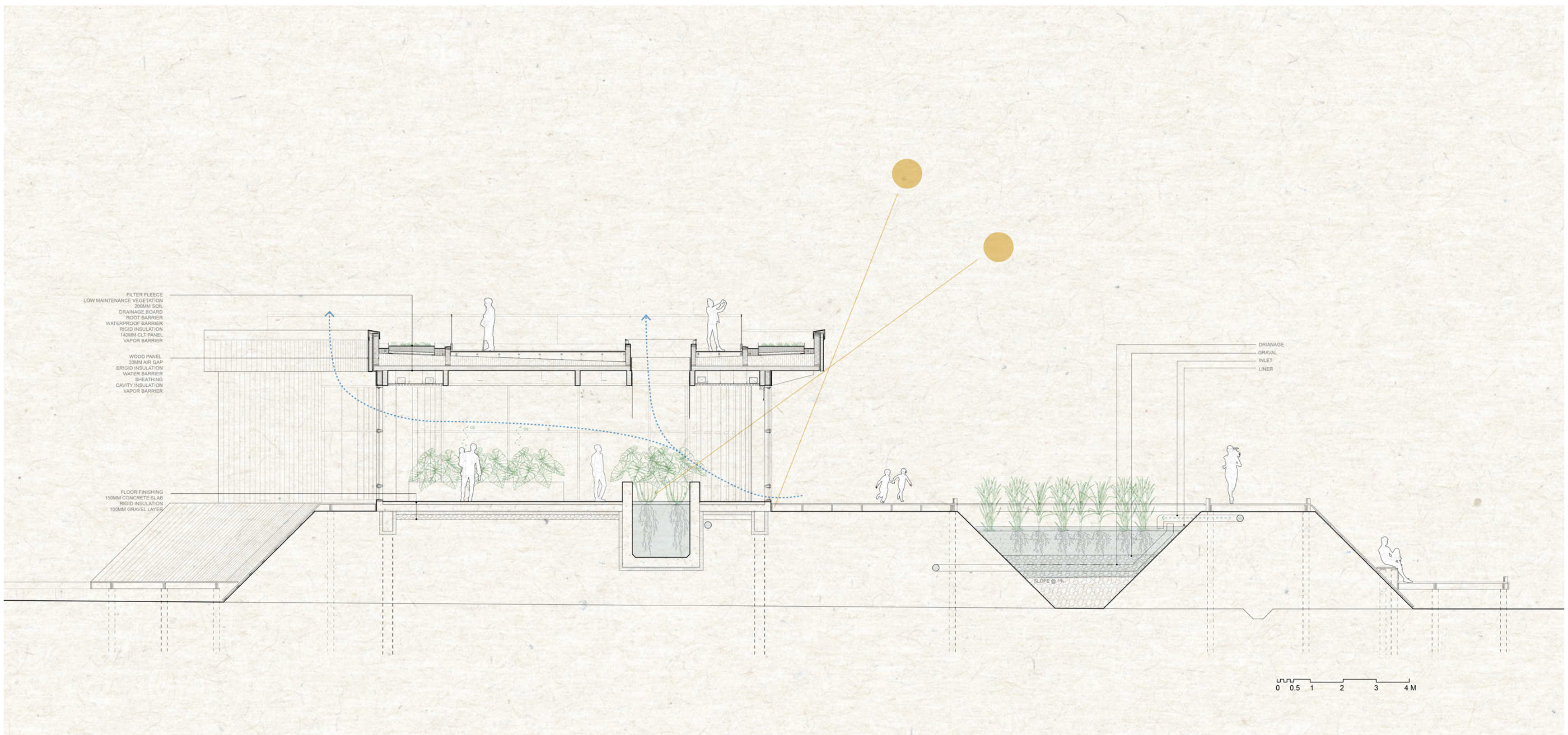
Designing a sustainable project is an important principle behind the water garden. The eco-friendly aspects are mainly shown in three elements: natural water treatment, natural materiality, and energy conservation.

Each day, the water garden can process 60,000 gallons of water, which meet the demand of the whole campus. Compared to sequencing batch reactors, the water treatment process is natural-material-based. The solar aquatic system reverts the water filtration process in nature. Instead of being a cold plant, it is a valuable teaching resource to the school children and the public. The greywater is not treated as waste and discharged. It is reused as valuable resources. Moreover, these living machines, reed wetland, and aerated lagoons are beautiful adornments to the site and the building, adding great visual pleasure to the project.

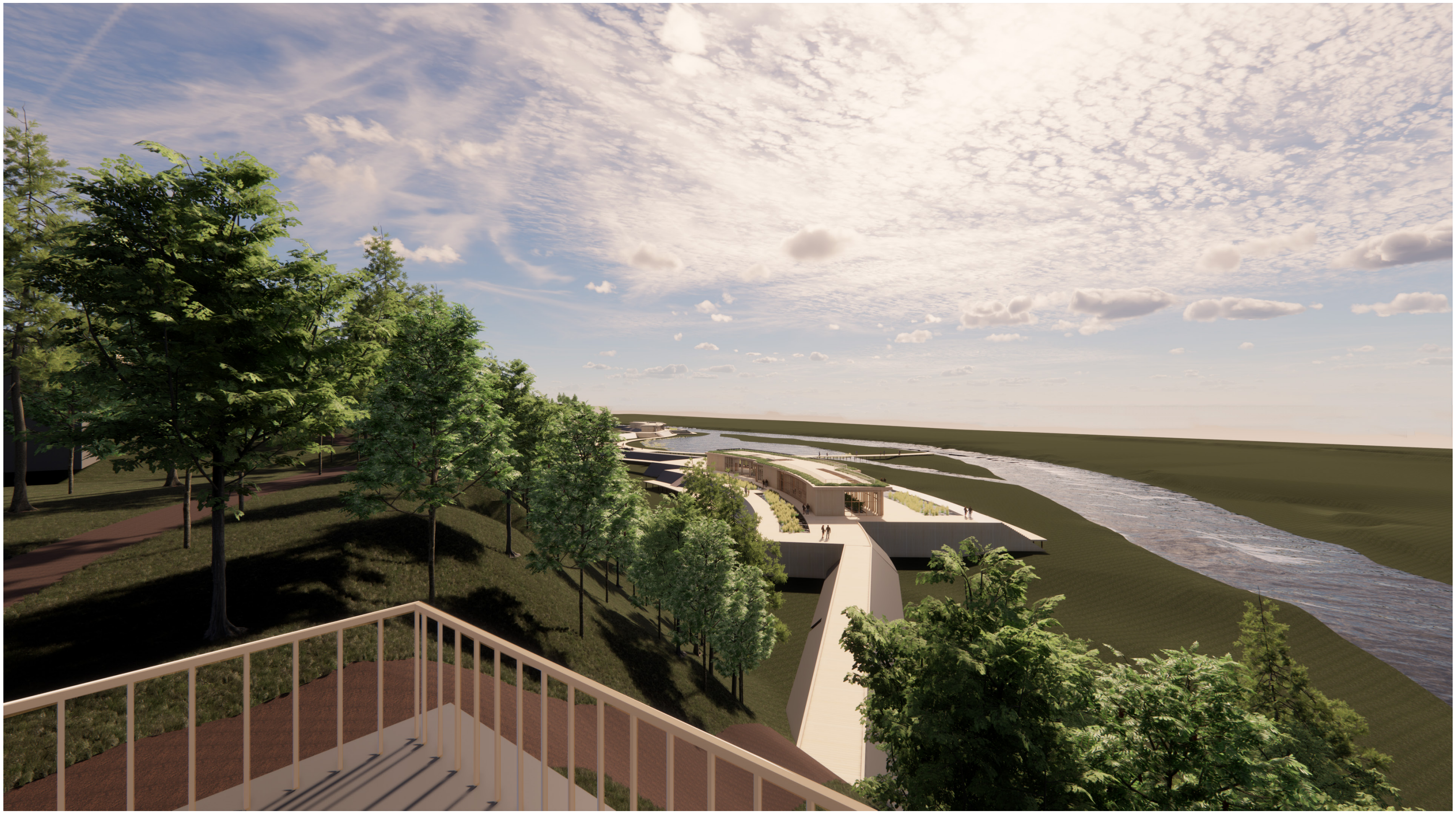
As for materiality, the project adopted as many natural materials as possible from the inside out. Using mass timber can reduce carbon emissions in construction phases. Wood materials themselves also cost much less energy to produce than metal. The wood siding and the rock finish on-site indicates the admiration for local materials, which also save energy in transportation.

Lastly, the building itself conserves energy. The overhanging roof blocks sunlight during the summer while maximizing natural heating during the winter. Glare reflectors aligned with the skylights help guide the natural light to be utilized by the indoor vegetation. Natural ventilation allows air to flow through the low window on the south wall. The air rises and is exhausted from the skylight and the high window on the north wall and cools down the spaces. Green roof belts absorb heat as well. The plants in the lagoon absorb carbon dioxide and produce oxygen during the day, which helps to relieve the workload of the air circulation system (see the detailed section on page 69). Besides, vegetation could reduce indoor noises.

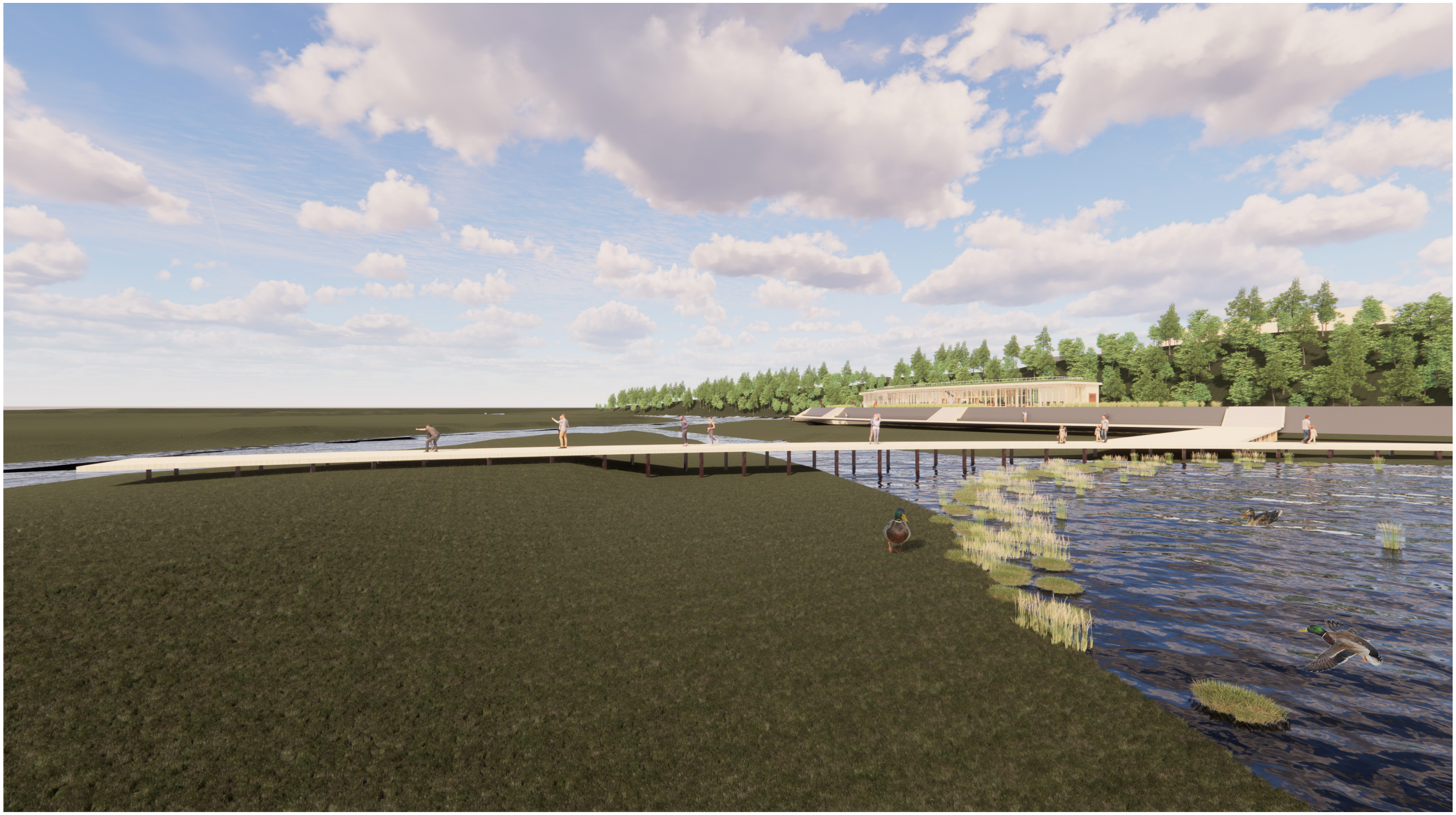
This project intends to showcase nature’s power and processes. It lets people witness that nature could do its everyday job gently and elegantly. It also asks people to face more and more severe climate problems.



Detailed section of the learning centre building.



Perspective from the tank-top view platform at the east entrance of the project.



Perspective of the project on the floodplain.

Perspective on the deck-top walkway in a flood event.

Chapter 6: Conclusion

The thesis is based on exploring the idea of how people can coexist with nature in harmoniously. Due to the special location of Truro, it is in a complex environment. The tide of the ocean and the river flow shape the town's past and future. As climate change intensifies, the tide and the river system are predicted to cause floods in this area more frequently.

This thesis takes water as the theme and discusses the solution from an architectural aspect in terms of floodwater management and water treatment. The dyke system is the foundation of the program, which protects the agricultural area from flooding, forms the base of the buildings, and provides walkways to the public. The dyke also connects the water treatment facilities of the solar aquatic system in the project. Seeded from my personal love of vegetation, the project eventually developed a living water purification machine. The project also advocates the concept that, instead of being single-mission directed, modern public education projects should serve as multi-activity spaces.

Occupying a fragile ecosystem like a tidal floodplain, in this project, is not to disturb the environment. Instead, it opens a window that allows people to closely observe and experience nature and directly face the environmental phenomena that will happen more often. Evoking people's attention by inviting them to an ecosystem is the driving force behind this project. The project becomes an extension of an existing university and enriches its research capability in submergence tolerance in rice. It takes diverse user groups in the community into consideration and reintroduces nature to people's lives in a gentle and respectful way. The use of local and natural materials minimizes influences on the site. This thesis aims to indicate that people could engage with nature with respect and enjoyment. A similar module could be introduced to other locations to help to build a better relationship between humans and nature.

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