Karen Paiva Henrique

(Re)Envisioning Architecture and Landscape Architecture in the Fluid Terrains of Flooding

> Today, flooding has become synonymous with the impact of global sea level rise, and the threat of rising waters has taken on a new sense of urgency. Studying the planar transformation that takes place during high-water events is an opportunity to reinvent and redesign the twenty-first-century city and consider new notions of urban and ecological development.[1]

1 Nordenson; Seavitt 2011: 44.

Human Settlements and Their [Evolving] Relationship with Water

Human populations have historically occupied the edge between land and water. The proximity to large water bodies assured humans with endless sources of fresh water, food, and highly productive land, which, rich in nutrients and biodiversity, created a perfect setting for communities to gather and thrive. Such fertile environments were always highly conditioned to their proximity to fluctuating water levels, which regularly deposited sediments and nutrients, continuously renovating the land.[2] In spite of the dangers posed by flooding, societies adapted to the recurrent presence of water and evolved using their strategic location as an asset for transportation and better connectivity.[3] With the growth of coastal settlements, however, floodplains have been increasingly developed and largely occupied, leading the natural condition of rising tides to become "major society disrupting disasters."[4]

2 van Beek and van Alphen 2006.

3 Hoornweg et al. 2010.

4 van Beek and van Alphen 2006: 11.

At the beginning of the twenty-first century, fifteen of the twenty world's megacities are located in areas adjacent to major water bodies, at risk from rising sea levels and coastal surges.[5] Thirteen percent of the world's urban population lives in low elevation coastal zones (LECZ), less then ten me-

5 Hoornweg et al. 2010.

ters above sea level and particularly susceptible to flooding.[6] This number is only expected to grow in the years to come, as settlements located in coastal low lands continue to grow rapidly, either by necessity or choice.[7] Add to this the current climate change projections and recurrent flooding from high tides and storm surges will become more acute. As temperatures increase, sea levels will continue to rise, and large storms will become more frequent and prolonged, leading to a higher incidence of flooding.[8]

Urban environments are already experiencing the consequences of such exacerbated climate conditions and their influence on rising tides. From 120 million people displaced worldwide between 2008 and 2012, seventy-four percent were forced out of their homes by flood events.[9] In Venice, a city traditionally affected by the phenomenon of *acqua alta* (high tide), the winter floods of 2012 reached 1.5 meters higher than normal, leaving seventy percent of its territory under water.[10] In that same year, cities in the United States and the United Kingdom also suffered from the devastating impact of flooding. In Brooklyn, New York City, twenty-five homes were completely lost and 825 badly damaged due to the rising waters that followed Hurricane Sandy.[11] In the United Kingdom, flood events affected more than 800 households before the end of the year.[12] Such examples testify to the fact that tidal flooding is becoming a severe rising threat of global proportions, asking for new solutions on how to develop and inhabit an increasingly fluid urban coast.

Making Room for Water: A Paradigm Shift in Urban Development

Recent flood events have intensified the debate on measures to prevent human and material losses due to the temporary, and usually destructive, presence of water. The construction of protective barriers for New York City, for example, is currently under analysis,[13] with precedents ranging from the 1982 Thames Barrier in London, to the currently under construction project MOSE in the Venetian Lagoon. Representing a traditional approach in the definition of boundaries to protect land from the impact of flooding, such hard-infrastructure projects are, however, increasingly challenged by researchers and designers. These "anti-barrier advocates"[14] argue against solutions that can be easily "overtopped by events outside their design capacities,"[15] profoundly affecting local ecologies,[16] and precluding a healthy relationship between urban populations and their surrounding water bodies.[17] They urge instead for the development of softer boundaries, replacing sea walls and storm-surge barriers with a flexible grade band to accommodate the in-and-out movement of the tides.[18]

6 McGranahan, Balk, and Anderson 2007.

7 McGranahan, Balk, and Anderson 2007.

8 IPCC 2013. *The Intergovernmental Panel on Climate Change Fifth Assessment Report* (IPCC 2013) projects that sea level will rise an average between 26 to 55 centimeters under a low emissions scenario, and 52 to 98 centimeters under high emissions, in the next century.

9 Yonetani 2013.

10 Knight 2012; "Venice Under Water" 2013.

11 Carcamo, Hennessy-Fiske, and Pearce 2012.

12 "More than 800 Homes Hit by Floods" 2012.

13 Gregory and Santora 2013.

14 Marshall 2013: 47.

15 Abhas, Bloch, and Lamond 2012: 32.

16 Anderson 2009.

17 Volner 2013.

18 Volner 2013; Mathur and da Cunha 2009.

Following these ideas, cities have started to rethink their coastal management approaches, introducing a softer edge that allows water to permeate the land. Initiatives such as "Room for the River Program" (2013) in the Netherlands and "Making Space for Water" (2013) in the United Kingdom, propose a resilient urban edge that allows water in, aiming to "improve the quality of the [river's] immediate surroundings,"[19] "while achieving environmental and social benefits."[20] Such initiatives signal a paradigm shift in the establishment of coastal urban environments, recognizing the "need [for] designs that can deal with changing circumstances,"[21] and embracing the ubiquity of flooding as an opportunity "to tear down the walls and create more integrated, livable communities instead."[22]

19 "Room for the River Program" 2013.

20 "Making Space for Water" 2013.

21 Ulam 2015: 109.

22 Anderson 2009: 66.

Building a New Edge: (Re)Envisioning Design for Flooding

Developing this new edge, however, requires buildings and landscapes to be reconceived in order to withstand the temporary and recurrent impact of rising tides. Competitions and design invitations for the development of areas prone to flooding have grown substantially in the past years, with strategies ranging in location, program, and scale. While some solutions focus on creating buffer zones in the form of wetlands and public green areas,[23] others focus on the protection of private property, often elevating structures above the flood line.[24] Such approaches, however, seem to define distinct roles for landscapes and buildings in safeguarding urban environments from the impact of floodwaters. While the first is responsible to protect the city from flooding through natural landscapes that hold and slow down rising waters, the second must protect residential development from floodwaters, often by keeping both apart. Approaches such as these raise a series of questions regarding urban development in the floodplain. Is it possible to develop the coast only for leisure in face of a continuously growing urban population?[25] What type of urban spaces can be created when only property safety is taken into account?[26] Can we create enjoyable and safe residential neighborhoods in face of the constant threat of flooding? Some contemporary proposals have taken on this challenge by merging soft-infrastructure with flexible residential design, creating resilient and livable urban environments that invite city dwellers to embrace the fluidity of the floodplain. This article focuses on such proposals, examining how buildings and landscapes are (re)envisioned to cope with the temporary and recurrent presence of water.

23 For examples of this type of project see "Water Proving Ground" (Bergdoll 2011: 80–89) and "Oyster-tecture" (Bergdoll 2011: 90–99).

24 A well-known example for this type of approach are the houses built by Make It Right Foundation in New Orleans after Hurricane Katrina. For more information, see "Architecture in times of need: Make It Right rebuilding the New Orleans' Lower Ninth Ward" (Feireiss 2009).

25 According to the United Nations Department of Economic and Social Affairs (2015), the world population is expected to increase 33 percent by 2050, reaching a total of 9.7 billion people. It is expected that 67.2 percent of these (6.5 billion people) will live in urban settings (Mitlin and Satterthwaite 2013).

26 Several critics have called attention to the lack of quality of public spaces created when designers choose to safeguard property against flooding, elevating structures above stilts. Such approach, they argue, often leads to the establishment of a barren public realm, characterized by "a network of passageways between parking spaces and gloomy undercrofts" (Anderson 2009: 6).

The article draws from the systematic analysis of four case studies developed for two competitions and one exhibition: "Amphibious Living" (2000), in the Netherlands; "Flood-proof Houses for the Future" (2008), in the United Kingdom; and "Rising Currents" (2010), in the United States. It uses a novel approach for the integrated analysis of architecture and landscape architecture, applying drawings as a tool for analysis. For each project, both building and landscape are examined through exploded 3D diagrams [27] and analyzed through a set of six parameters [28] — defined below — allowing for the examination of each design element individually and as part of a larger system.

The six parameters for analysis are:

- *Site* — Flooding conditions in the project's specific lot and forms of access to the property;
- *Structure* — Building's and landscape's supporting elements;
- *Skin* — Materials and building components that constitute the building's envelope and the landscape's surface. This category also accounts for strategies applied in the management and drainage of floodwaters, often defined by both building's and landscape's surfaces;
- *Program* — Different functions performed by the building and the surrounding landscape;
- *Infrastructure* — Basic infrastructure supporting the family's and the neighborhood's daily needs (for example: electricity, water, sewage systems, etc.);
- *Furniture* — Smaller scale objects designed with specific purposes, directly or indirectly connected to the condition of flooding.

It is important to highlight that not all proposals present the six elements clearly delineated in the design of buildings and / or landscapes. The analysis follows this constraint, excluding elements from the study when necessary. As the analysis will show, sometimes it is difficult to distinguish between building and landscape elements as these are often combined in the proposed scheme. Therefore, each case study analysis is followed by an examination of the relationship between architecture and landscape architecture in that particular design.

The result is a holistic understanding of design approaches engendered to cope with the recurrent and temporary presence of water. These, the research shows, go beyond the development of technical solutions for the management of floodwaters, redefining the relationship between inhabitants and their natural environments. The research also hints at a new relationship between buildings and landscapes, challenging the typical role assigned to architecture and landscape architecture in protecting urban environments from flooding. In all proposals, buildings and open spaces merge, creating a livable buffer zone that protects both inhabitants and property from losses caused by flooding, when unaccounted for.

27 According to Bernard Leupen in *Design and Analysis* (1997), "drawing the object as though it had been taken apart can bring out the relationship between components or aspects of the design" (19). Following this idea, the analysis implements exploded view diagrams for the study of individual parts and the relationship among parts in each proposal.

28 Such a framework is proposed by Stewart Brand in "How Buildings Learn: What Happens After They're Built" (1994), in which the author specifies the six elements that conform a building: Site, Structure, Skin, Services (Infrastructure), Space Plan (Program), and Stuff (Furniture) (Brand 1994: 13). For the purpose of this analysis, the six categories were adopted following Brand's definition, and were adapted for clarification, as noted in parenthesis.

Design Analysis – Case Study 1: Amphibious Unit

The “Amphibious Unit” (fig. 1) is part of a larger master plan for residential development in a zone highly susceptible to flooding in Barendrecht, The Netherlands.[29] The proposal aims to minimize the use of infrastructure currently keeping the area dry, planning for the pumps (normally operating around the clock) to be activated only when the water reaches one meter above average ground level. The master plan focuses on the occupation of the site over time through the creation of a temporarily flooded ‘amphibious zone’ developed for residential and recreational purposes. The “Amphibious Unit” combines the features of a traditional home to those of a housing boat, creating a structure able to float during a flood event and to rest on the ground during the ‘dry’ season,[30] thus continuously redefining the relationship between the building and its surrounding landscape. The dwellers inhabit their homes all year long, in spite of flooding conditions, supported by the unit’s self-sufficient systems.

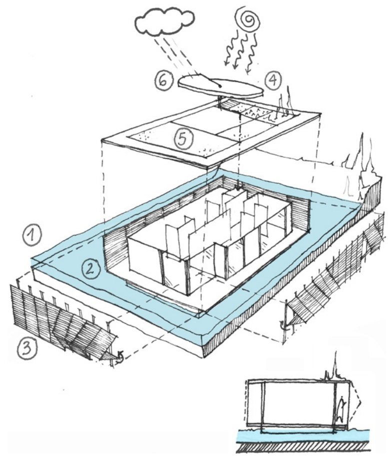

Fig. 1 Amphibious Unit. (1) Site: Temporarily flooded; (2) Structure: Floating base; (3) Skin: Operable shutters; (4) Infrastructure: Sustainable systems; (5) Program: Green roof; (6) Furniture: Water/solar collection element

Site—The plot in which the “Amphibious Unit” rests is not defined. The house is envisioned as a free floating or standing object able to move within the polder in accordance to the dweller’s preferences and needs. The structure is conceived to float freely during the high tide, resting anywhere in the neighborhood’s ground when the floodwaters recede. The only limitation imposed by the project is the number of homes that can be located within the polder at any given time, taking into account other amphibious community structures, such as churches, community centers, and sports fields. Residents access their houses through floating paths (‘wet’ season) and existing roads (‘dry’ season). In this proposed arrangement, the relationship between site and house becomes more fluid. The residential unit is conceived as one of the many elements of an always-evolving landscape.

29 Project name: Amphibious Unit
Competition: Amphibious Living
Location: Barendrecht, South Holland Province, Netherlands
Year: 2000
Concept Manager: Lucas Verweij, Schie 2.0
Implementation Manager: Dennis Moet, Bureau Park
Workshop Participants: (1) Tom Mossel, MG architecten; (2) Martjin Schoots; (3) Rob Bonneur, Jolanda Faber, Tanya Trapp, Van Velzen La Feber Bonneur Architecten (4) Liza Mackenzie, Neil Davidson, Future Lifestyle Innovators
For additional information on the “Amphibious Unit”, see “Amfibisch Wonen=Amphibious Living” (Venhuizen 2001: 197–219).

Structure—The “Amphibious Unit” consists of a pre-fabricated home, assembled from a catalog of parts that can be selected according to the user’s preference. The building’s primary structure defines a framework within which façade components and inner partitions can be arranged in various ways. Two sets of secondary structures are attached to the building’s primary structure and support a double façade system, analyzed below. This prefabricated unit rests on a floating platform completely detached from the ground, allowing dwellers to move their houses during the high tide, positioning it closer to other structures.

30 Throughout the analysis the terms ‘wet’ and ‘dry’ are used to define periods when the site is and isn’t flooded, respectively.

The dwellers’ ability to reposition their homes according to personal preference has the potential to strengthen community bonds and / or personal alliances (one can choose to relocate his or her house closer to friends). Furthermore, the act of moving the building between seasons can improve the connection between inhabitants and their surrounding natural environment. The polder's dwellers will become constantly aware of its natural processes, with their houses rising and falling according to the movement of the tides and being constantly repositioned within an always-evolving landscape. As a result, the entire polder becomes everyone's backyard to be protected and nourished.

Skin—Each unit's relationship to nature and to neighboring structures is mediated by a double façade system. The outer skin offers a dynamic exterior through a set of shutters that can be completely opened, enhancing the connection between dwellers and their surroundings. At the same time, the inner skin encloses the interior space, adopting a more conventional façade made of opaque panels and glass. Lightweight materials (osiers, bamboo, clay, hemp, and coconut fiber) are used on both facades, assisting with the house's floating properties. Each unit presents a green roof, guaranteeing its inhabitants access to open space throughout the year. This elevated landscape is organized in sections with different functions, such as, small gardens for filtering rainwater and production of food.

Infrastructure—According to the designers, acquiring an "Amphibious Unit" would ask the inhabitant to adapt to an amphibious existence, unbound by the traditional provision of infrastructure. In order to float freely, the house is conceived as a self-sufficient unit in terms of energy, water, and sewage treatment. Energy is harvested from the sun and stored into a battery system. Water is collected from the rain and filtered on the roof garden to be later used in the toilet and in the shower. The sewage is treated in a composting station located inside the house.

The proposal achieves environmental and economical sustainability at two levels. First, its reduces neighborhood energy consumption by deactivating water pumps, which are no longer kept constantly functioning in order to keep the entire area dry. Second, each individual house is able to provide basic infrastructure to its inhabitants, minimizing their dependency on fossil fuels and providing for a more self-sufficient existence.

Program—Each house is programmatically organized as a typical home, with the exception of two crucial design components: a double-façade system and a productive green roof. The double façade system provides a one-meter wide buffer zone that operates similar to a traditional porch, creating an outside private space that can be enclosed, providing the residents with privacy when different dwellings drift closer together during the high tide. The green roof acquires the function of 'backyard,' guaranteeing a private (dry) open area for the house's occupants even when the polder is flooded.

Furniture—The roof garden presents elements that are perhaps the most dramatic in the unit's design. The integrated water or sun harvesting cell stands apart from the structure otherwise orthogonal lines, calling attention to its unique sustainable features. This serves as a remainder of the inhabitant's choice to live an alternative life, more in tune with what nature has to offer.

Relationship between Architecture and Landscape Architecture—The "Amphibious Unit" main design strategy is defined by a fluid relationship between building and landscape. Such fluidity is not only expressed by the site's fluid nature, which varies between a 'dry' and a 'wet' season, but more importantly by the movement of the houses within an open and shared landscape. The proposal offers a bold alternative for human occupation of space (the position of the house is not only redefined during the high tide, as the house can occupy a different position every time floodwaters recede), creating a neighborhood in which all inhabitants become stewards of one shared landscape. When this common wetland floods, however, the houses inevitably become islands, but still remain connected to their individual elevated green spaces.

Case Study 2: Turnaround House

The "Turnaround House" (fig. 2) is a flexible two-story home designed to adapt to flooding conditions by allowing floodwaters to infiltrate the house's first floor.[31] The house is planned to endure the persistent contact with floodwaters and is designed for a maximum flood elevation of 0.6 meters, within which the property won't be damaged. The proposal allows inhabitants to remain inside their homes during flood events by providing continuous access to the surrounding neighborhood and to basic utilities.

Site—The "Turnaround House" withstands 'dry' weather conditions for most of the year, generally performing as a traditional house. During periods of flooding, however, the house is reconfigured, guaranteeing the safety of the property and its inhabitants, while promoting a continued relationship with the surrounding community. In order to achieve this, the house presents an elevated garden adjacent to its main façade, which provides a permanent green space for its inhabitants and becomes an elevated street during a flood. The elevated gardens of different houses are connected by timber shutters located on the second-floor of each house which fold down from the building's façade, creating a continuous raised pathway between neighboring structures. It is envisioned that such pathway could connect individual houses to other neighborhood amenities (such as hospitals and community centers), allowing for the dwellers' daily-lives to continue without any disturbance before, during, and after a flood.

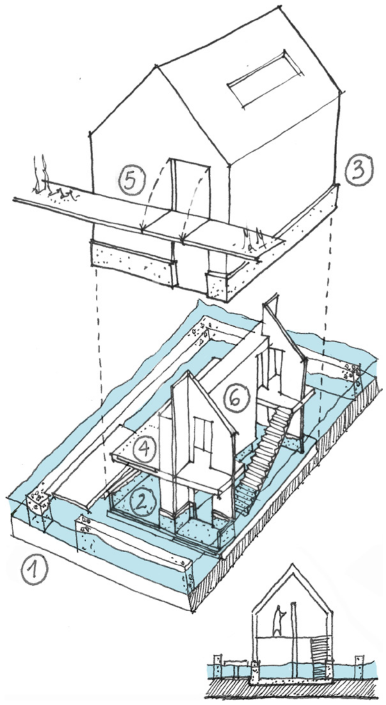

Fig. 2 Turnaround House. (1) Site: Temporarily flooded; (2) Structure: Concrete dado; (3) Skin: Various materials adopted according to their proximity to water; (4) Infrastructure: Water storage space; (5) Program: Elevated pathways connected by fold-out shutter; (6) Furniture: Grand storage wall.

31 Project Name: Turnaround House
Competition: Flood-proof Houses for the Future
Location: Floodplain, United Kingdom
Year: 2008
Size: Single-family house 150 m², plot 270m²
Team: Nissen Adams LLP (based in London, United Kingdom)
Consultants: Mendick Waring Ltd
For additional information on the "Turnaround House", see "Flood-proof houses for the future: A compendium of design" (Norwich Union and Royal Institute of British Architects 2008: 6–7) and "Water Level-fighting Houses" (Dah-young and Jung-ouk 2009: 102–103).

Structure — The house presents a traditional structure, composed of a concrete foundation and prefabricated insulated walls. The concrete foundations extend beyond the slab on the ground floor, creating a one-meter-high concrete dado, which provides resistance and easy maintenance of the structure during and after a flood. The house's main structure is generally static with one exception: a floating concrete pontoon, located on the garden, which rises together with the water in order to protect the family's car. The elevated gardens are supported by the building's façade and a gabion wall that surrounds each individual plot.

Skin — All surfaces in the house located below the flood line are built with concrete for durability and maintenance purposes. Above the flood line, however, different materials are adopted (such as plaster and wood), differentiating surfaces that are endangered from contact with floodwaters from those that are not. The staircase, for example, is made of concrete up to the 0.6-meter-line (flood line), with wood implemented above this limit. This allows for the location of drawers in each step to maximize storage space. Besides fulfilling practical purposes related to the building's exposure to floodwaters, the different materials applied in accordance to the flood line also serve as a constant reminder of recurrent flood events taking place in the environment where the house is situated.

The proposal's landscape presents an overall typical palette for a residential neighborhood. Each house is surrounded by a garden with a small wooden deck for outside gatherings, a few shrubs and trees. Two exceptions are made to this rule: the use of gabion walls around the site — preventing the entrance of flooding debris into the housing property — and the floating concrete pontoon. The proposal gives preference to the use of vegetation over impervious pavement, reducing water runoff and providing a more livable open space for a house situated in a predominantly urban environment. The management of floodwaters is not, however, restricted to the pervious landscape composition. The building also assists with water drainage, offering an open space underneath the ground floor designed to allow low floodwaters to flow under the structure without entering the house's livable space or causing any disturbance to the inhabitants. This space also serves for drainage purposes after a flood, directing the water to exit the house on its rear portion.

Infrastructure — All electrical components (wires and outlets) are located above the flood line. Water provision is assured by the storage of potable water on compartments located on the second floor slab and a water tank located above the bathrooms, which maintains the toilets' flushing capacity. Such design strategies assure the continuous provision of utilities to the house throughout the flood event.

Program—The house's program doesn't follow a typical distribution; this model places bedrooms on the ground floor, and kitchen and living room on the second floor. This unusual arrangement is made in order to protect larger appliances (such as refrigerator and stove) from contact with floodwaters. When the flood warning is issued, all activities on the ground floor are relocated on the structure's upper level, including the house's main entrance. For the duration of the flood, the house can be accessed through the elevated gardens that interconnect for that period of time and function as a public street. This elevated street is one of the main features of the "Turnaround House," sustaining neighborhood connections and community support that would be otherwise hindered at the time they are needed.

Furniture—The "Turnaround House" utilizes furniture as a main design component for the house's adaptation to periodically rising waters. In order to protect personal belongings from damage, several storage spaces are designed throughout the house (such as inside the second floor slab, and within the steps of the staircase). The house's central wall is planned as a grand storage wall, with fold out tables, shelves, and diverse storage compartments ranging in scale. During a flood, residents often raise their personal belongings in order to protect them from direct contact with the water. The "Turnaround House's" furniture design allows dwellers to protect small and large objects from the damage caused by flooding in an organized manner.

Relationship between Architecture and Landscape Architecture—The "Turnaround House" features unique building and landscape components designed not only to protect the house from the damage caused by flooding but also to guarantee the continuity of its inhabitants' daily lives. This is achieved through the uninterrupted provision of utilities and a permanent connection to the neighborhood. While the building and landscape's individual solutions envision new ways to apply common construction materials used in residential design, thus guaranteeing the proposal's economic feasibility, the effort made to maintain neighborhood connections (perhaps the most important feature in this design) only becomes possible when the architectural object is merged with its surrounding landscape. In the "Turnaround House" the building façade folds-down to become landscape surface, giving rise to a web of elevated pathways that (temporarily) convert the families private garden into public space. As the water invades the house and the building envelope unfolds into landscape, the lines between architecture and landscape architecture become blurred. Thresholds separating the house from its surrounding open space are redefined, momentarily transforming the building from an island surrounded by an urban garden to an active object connecting a network of landscapes suspended above water.

Case Study 3: Flood Resistant House

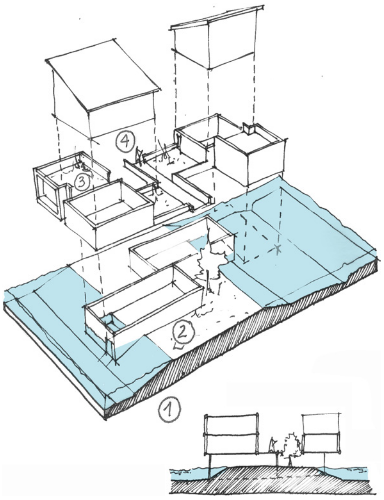

Fig. 3 Flood Resistant House. (1) Site: Temporarily flooded; (2) Structure: Traditional structure with engineered brick foundation; (3) Skin: Pervious open spaces; (4) Program: Elevated pathway.

The "Flood Resistant House" (fig. 3) is part of a comprehensive proposal for residential development in flood-prone zones, presenting a set of integrated solutions that combine individual homes, neighborhood streets, and city blocks in the management of floodwaters.[32] The proposal is based on landscapes designed to retain and redirect excess water, minimizing runoff. Water is kept outside the house up to 0.3 meters, partially infiltrating the building structure beyond this limit. The individual houses are connected to each other both at the street level and through elevated pathways, offering a permanent evacuation and rescue route for the event of a flood.

Site—The "Flood Resistant House" is envisioned for areas with temporary and recurrent flood events and it is designed to perform during both 'dry' and 'wet' seasons. The ground floor of each house is designed in a split-level arrangement made possible through a cut and fill intervention on the terrain. The front part of the house sits on a 0.3-meter high plateau, while its rear part is located 1.2 meters above street level. This design strategy protects most of the house from flood events while still connecting the structure to the street through a lower entrance space that becomes partially submerged in the event of a flood. Based on such topography play, the house makes use of multiple terraces, maximizing the building's connection to open spaces and allowing for natural light to permeate every room in its interior. The houses are organized back to back, with individual ground floors covered by a private garden, connected to a permanent elevated pathway. In each neighborhood block, a group of elevated pathways merge into an elevated road that guarantees safe evacuation in the event of a greater or more prolonged flood event.

Structure—The house presents a traditional brick structure with a few modifications made to assure its resistance to floodwaters, such as, the adoption of engineered brick foundation. The multiple terraces, located at different levels, and the elevated pathway are all supported by the house's main structure.

Skin—The house presents raised door thresholds that prevent water from entering the structure below the predefined 0.3-meter limit, guaranteeing the inhabitants enough time to move and protect their personal belongings before the water reaches higher levels. In sections of the house where water is allowed to enter, surfaces are protected from their exposure to flood waters by flood resistant materials, such as ceramic tile floors. Similar to the "Turnaround House," the "Flood Resistant House" material palette also serves as a remainder of recurrent flood events in the area where the neighborhood is located. In this case, however, the building is responsible for only a small fraction of floodwater management, which is predominantly

32 Project name: "Flood Resistant House"
Competition: Flood-proof Houses for the Future
Location: Flood plain, United Kingdom
Year: 2008
Size: Single-family house 150 m^2, plot 270m^2
Team: Eleena Jamil Architects
For additional information on the "Flood Resistant House", see "Flood-proof houses for the future: A compendium of design" (Norwich Union and Royal Institute of British Architects 2008: 8–9) and "Water Level-fighting Houses" (Dah-young and Jung-ouk 2009: 100–101).

undertaken by the proposal's extensive pervious surfaces. These are distributed through an intricate composition of open spaces that convert all open horizontal surfaces (both public and private) into areas for absorbing and slowing down water runoff down.

Infrastructure—The design focuses on water management and accessibility for rescue and evacuation with little detail given on the provision of utilities before or during the flood event. It is assumed that adequate measures would be taken to protect infrastructural systems (such as electrical and plumbing) from the exposure to floodwaters.

Program—In order to allow the ground floor to be partially submerged during a flood, the "Flood Resistant House" presents a specific program arrangement. A multipurpose room is located next to the house's entrance at street level and it is proposed to be emptied in the event of a flood. In order to safeguard larger appliances, the kitchen is located at the higher portion of the ground floor, together with the living room and a small courtyard. On the second floor, the house presents a set of bedrooms: one master bedroom, connected to a more private open green space, and a set of single bedrooms, connected to the outdoor patio that leads to the elevated pathway. This patio provides a second connection between the house and its neighborhood (the first located at the street level), providing an open green space that works as a permanent point of entrance throughout the year. While proposed to provide a secure elevated point of egress in the event of a flood, the elevated garden and pathway also multiply the connection between each individual house and the neighborhood, an approach that can certainly foster the establishment of community ties among neighbors.

Furniture—The proposal doesn't specify furniture components for the building and landscape.

Relationship between Architecture and Landscape Architecture—The "Flood Resistant House" presents a unique neighborhood arrangement achieved through an ingenious play of topography that gives form to various elevated gardens. These are able to protect dwellers and their personal belongings from floodwaters, while slowing down water runoff and redirecting the flood to a more natural collection and discharge system. This approach generates a variety of open spaces with different levels of privacy (a courtyard on the ground level partially connected to the street, an elevated backyard connected to a neighborhood pedestrian pathway, and a private roof garden accessible only from the master bedroom), creating a composition in which the building is sometimes juxtaposed and sometimes merged with its surrounding landscape. Through this play of topography, the "Flood Resistant House" makes use of a temporarily flooded environment to create unexpected spatial experiences (the master bedroom, for example, becomes a ‘suspended room’ floating above water during a flood), proving that the soft-infrastructure of basins and swales, increasingly adopted to protect cities against flooding, can certainly incorporate human inhabitation as long as the design of both landscape and building is carefully revised.

Case Study 4: Aqueous Neighborhood

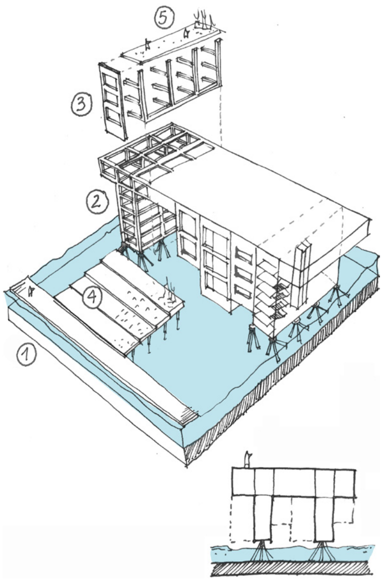

Fig. 4 Aqueous Neighborhood. (1) Site: Permanently flooded; (2) Structure: ‘Double-T’ bridge resting on stilts; (3) Skin: Distinct materials applied per unit; (4) Infrastructure: Treatment wetlands; (5) Program: Shared green roof.

The “Aqueous Neighborhood” (fig. 4) is a multi-family housing development, part of a master plan that envisions a more resilient coast for the city of New York.[33] The proposal defines that any building located less than six meters above mean sea level is at risk from flooding in a Category 3 Storm. Rather than safeguarding the coast as a leisure zone, however, the proposal combines residential structures (elevated above stilts), and floating landscapes (including wetlands and wave-attenuating piers), in its approach to coastal development. As a result, the proposal extends New York’s vibrant urban environment into the city’s waters while protecting both individual property and the city as a whole from the impact of flooding. Permanently situated above water, the entire system is resilient to both sea level rise and storm surges.

Site—The “Aqueous Neighborhood” is located above water, in an area adjacent to the city’s mainland. The water level is expected to vary while the multi-family housing structure remains unaffected. The structure is connected to the rest of the city through a system of floating pathways and treatment wetlands, which rise and fall with the movement of the tides. These serve two main functions: they guarantee public access to the waterfront, and they create a system to protect the city against storm surges. A garden roof, located at the top of the neighborhood structure, provides permanent access to an elevated open green space and functions as a safe haven for the rescue of dwellers in the event of a larger storm.

Structure—The “Aqueous Neighborhood” consists of a ‘double-T’ structure, similar to the structure of a bridge, from which all individual buildings are suspended. The structural system is composed by one horizontal truss supported by two vertical supports that rest on stilts above water, the latter housing elevators and stairs. Each individual building is hung above the flood line, with the distance between building and water defined by the area’s flood risk and the owner’s desire to locate her or his unit near the water level. By implementing such an unusual composition for a residential structure, the proposal explores the exceptional conditions of the site to create a unique spatial experience. Rather than resting on the ground, the houses are suspended above water allowing their inhabitants to witness its fluctuating levels as part of their daily lives. The bridge structure also sup-

33 Project name: Aqueous Neighborhood
Exhibition: Rising Tides
Location: Bronx, Brooklyn, Jersey, Manhattan, Queens, Palisades, and Staten Island, New York, United States
Year: 2010
Consultants: Ed Purver, Anuradha Mathur and Dilip da Cunha, Arup New York
Team: Eric Bunge, Mimi Hoang (Team Leaders) Julia Chapman, Noah Levy, Seung Teak Lee, Meir Lobaton, Sanjukta Sen (Core Team Members). With nARCHITECTS office: Dominique Gonfard, Stephen Hagmann, Hubert Pelletier, and with: Andre Guimond, Juliana Muniz, Teo Quintana, Rebecca Garnett, Tyler Velten and Brett Appel
For more information on the “Aqueous Neighborhood”, see “Rising Currents: Projects for New York’s Waterfront” (Bergdoll 2011: 100–109) and “MoMA Rising Currents” (nARCHITECTS 2015).

ports a public garden roof, which provides an elevated vantage point from which to observe the entire composition.

Skin—The proposal suggests the use of lightweight materials for the buildings' envelope, thus minimizing the load on the main structural system. It is expected that each individual building will present a different material palette, following individual owners' preferences. As a result, the entire composition alludes to the image of a traditional street, here, reinterpreted to the local condition of rising tides. Besides the green roof, the bridge structure is also connected to a set of floating wetlands at the ground level, which functions both as public green space and water filtering station, while also minimizing water runoff.

Infrastructure—The "Aqueous Neighborhood" is a sustainable structure able to purify and convert almost all its waste into energy. At the neighborhood scale, the floating treatment wetlands process the liquid waste of the housing complex (thirty seven square meters are dedicated to a household of four). The treatment wetlands are designed as barges and connected to flexible piers, rising with the movement of the tides. Because of its function, the entire system is designed to resist contact with floodwaters. At the individual household scale, micro anaerobic digesters, located inside the neighborhood's vertical supports (together with the elevators and the stairs), treat the solid waste, generating gas to fuel the houses' cooking appliances.

Program—The "Aqueous Neighborhood" public green roof transfers activities that would usually take place on the ground floor to the structure's upper level. In the process, the upper floor becomes the "public street", to which all the different residential buildings are connected, creating a shared space for community interaction. This large green roof also serves to extend the city's green areas beyond limited city space, giving form to a series of landscapes elevated above water.

Furniture—The proposal doesn't specify furniture components for the building and landscape.

Relationship between Architecture and Landscape Architecture—The "Aqueous Neighborhood" offers a solution to occupy areas prone to flooding, introducing an alternative for residential development through the careful composition of buildings and landscapes. The combination of static residential structures (suspended from a 'bridge' built above stilts) and floating landscapes (a series of pathways and wetlands that rise with the movement of the tides) serves as a constant reminder of the fluctuating water levels in which the entire scheme is based. The landscape is more fluid, changing position as required by the surrounding environment, but always connected to the static building structure, which is kept apart from the movement of the tides. If at the street level, building and landscape are connected by pathways that constantly mediate between their different vertical positions, at the structure's uppermost level, building and landscape merge into one single space. This elevated semi-public space functions as a safe haven for rescue, while providing a unique vantage point from which to observe the natural processes that shape the neighborhood and its relationship to water.

Lessons Learned

The four case studies analyzed conceptualize residential urban development designed to resist periodic inundations. All the proposals accept the fluid nature of their surroundings, incorporating specific elements to cope with the recurrent and temporary presence of water. The solutions can be generally classified in accordance with their overall structure: built on stilts, above a buoyant platform, or with a permeable envelope.

Nevertheless, the research shows that beyond technical solutions, structurally able to withstand flooding, all the houses are the result of an intricate composition of various elements capable of producing new relationships between humans and their natural surroundings, and between architecture and landscape architecture. When studied in comparison, the four cases analyzed introduce five important lessons for the development of housing in zones prone to flooding:

1 — Flood-resilient design is part of a multi-scale approach that embraces flooding. Flood events usually affect entire communities, rather than a single household, often extending beyond the initially affected area to other parts of the city. Well-integrated planning approaches accept flooding in one place in order to contain floodwaters from invading others. Following this idea, all four projects accept the fluidity of their terrains, creating a buffer zone to protect the rest of the city from flooding. The research shows, however, that allowing for the presence of water in residential sites can also have a positive impact on the way populations inhabit space and relate to their natural surroundings.

The direct contact between floodplain dwellers and their surrounding waters can certainly lead to a higher sense of stewardship toward their natural environment. One would care to preserve the quality of the water in direct contact with her or his residence, especially when it is expected that floodwaters will enter one's home. The "Amphibious Unit" and the "Aqueous Neighborhood" further embrace this new relationship and propose buildings and landscapes that work as filtering stations, directly improving the quality of the structures' surrounding waters. Such approaches challenge the desire to create soft-infrastructure in the form of pristine green areas (kept apart from human populations), by proposing buildings and landscapes that become active elements in protecting their natural sites. As a result, urban dwellers gain closer contact with the processes of the floodplain and are invited to nurture a natural system that protects others from flooding.

2 — Buildings and landscapes are detailed to physically withstand flooding. Following the specific conditions of flooding presented by each site (such as length and recurrence), buildings are designed to physically withstand the forces of water. To that end, the houses are either kept apart from the water level (elevated above stilts or on floating platforms), or allow water in, incorporating specific materials and methods of construction to protect property from contact with floodwaters. When water is allowed inside the housing structure ("Turnaround House" and "Flood Resistant House"), a clear line is created dividing lower impervious surfaces, constructed of long-lasting materials (such as concrete and stone), supporting lighter surfaces, more fragile to water (made of wood, metal, and plaster). When applied across an entire neighborhood, the combination of various materials according to the flood elevation line goes beyond the practicality of maintenance, creating a strong awareness of flooding.[34]

34 It can be argued that a similar awareness is created by elevating houses above stilts, as seen in elevated structures built in New Orleans' post Katrina. The solutions devised by the "Turnaround House" and the "Flood Resistant House," however, create more enjoyable environments, inscribing the possibility of flooding into the building envelope.

Contemporary natural-hazard's resilience advocates emphasize "the notion of 'living with risk.'"[35] According to them, adaptation "is attained through social memory, the lessons that have been learned from past disasters, from accumulated experience and hazard knowledge."[36] The "Turnaround House" and "Flood Resistant House" create neighborhoods that constantly remind their inhabitants of the possibility of flooding through multiple 'water-level checks,' produced by surfaces that adopt different materials in accordance with varying water levels.

35 López-Marrero and Tschakert 2011: 229.

36 López-Marrero and Tschakert 2011: 230.

3 — Buildings and landscapes are designed with continuous access throughout the flood event. As important as the capacity of a housing structure to physically withstand flooding is to maintain its resident's ability to move to and from the house during a flood event. Three out of the four proposals examined offer solutions that allow for the permanence of affected populations during a flood by providing multiple neighborhood connections located above the flood line. Such an approach guarantees inhabitants' access to other parts of the city, food supplies, emergency provisions, and, occasionally, rescue when these are most needed.

In addition to sustaining continued access to provisions, the elevated and floating pathways proposed by the "Turnaround House," the "Flood Resistant House," and the "Aqueous Neighborhood" also provide a unique framework for community flood resilience. Flood risk is rarely experienced individually, since flooding usually affects entire communities instead of single homes, "so community solutions usually offer best protection."[37] As unexpected flood events can drive populations apart, planning for rising waters can bring populations together, as suggested by these examples.

37 Anderson 2009: 59.

4 — Infrastructure is adapted to resist and operate during a flood. In order to allow for the permanence of families inside their homes during the flood event, the infrastructure responsible for water, electricity, heating, sewage collection, and communications (telephone and internet) must be adapted to remain functioning during the inundation. While some examples locate infrastructural systems above the flood line, others offer their inhabitants a more self-sufficient existence. In the latter, buildings and landscapes are composed by sustainable systems that collect water from the rain, harvest energy from the sun, and utilize filtering gardens and composting stations for the treatment of water and residues. The idea of a self-sufficient home is closely related to the notion of "working together with nature, instead of against it."[38] The adoption of sustainable features enhances the connection between inhabitants and nature, especially when these are emphasized through design.

38 Marshall 2013: 81.

Resilience depends both on the capacity to adapt existing structures to current and future climate scenarios, and on the ability to mitigate the factors influencing the probability of further changes in our climate.[39] Similar to adaptation, mitigation strategies can certainly be implemented in residential design. The sustainable systems applied in individual houses, reduce their inhabitants' dependency on fossil fuels, decreasing the amount of greenhouse gases released in our atmosphere. When combined, individual efforts can have an ameliorating effect on earth's temperature, reducing the meltdown of icecaps, and the frequency and intensity of storm events, inevitably influencing flooding.

39 Washburn 2013.

5 — The relationship between architecture and landscape architecture is (re)envisioned to create a livable and resilient urban coast. All solutions aforementioned can only be implemented through an integrated approach for the design of houses and open spaces. Each proposal not only (re)envisions the design of buildings and landscapes individually, they present a careful composition between both — suggesting a new relationship between architecture and landscape architecture. This is governed by the temporary presence of floodwaters and propose buildings and landscapes to become increasingly intertwined.

Regardless of the form that design for flooding undertakes (either floating, raised above stilts, or permeable — or a combination thereof), all cases merge buildings and landscapes, even if temporarily, creating a habitable buffer zone. Green areas and pathways are multiplied, floating aside and/or blended into the building structure, conforming unique flood-resilient neighborhoods that promote livable indoor and outdoor spaces all year long. As a result, almost all proposals challenge the now ubiquitous image of houses surrounded by floodwaters, in which urban dwellers become isolated from everything and everyone else, creating unique arrangements that result in urban spaces significantly more connected than their traditional (permanently dry) counterparts. Furthermore, all solutions promote the idea of a common landscape for all dwellers, who work side-by-side to protect and nourish their natural environments.

Conclusions

> It is time for a new approach that is sustainable from an environmental, technical, and economic standpoint, and that also has the potential to improve the quality of urban life.[40]

40 Nordenson; Seavitt 2010: 45.

Flood events have become a pressing condition affecting numerous cities throughout the globe. While historically deemed a vital natural phenomenon responsible for replenishing the world's fertile lands, flooding increasingly threatens human populations established near water. Flood events are currently regarded as the most common among all natural disasters, and this condition is expected to worsen in the years to come. According to the IPCC 2013 Report, temperatures will continue to rise, intensifying precipitation, raising sea levels, and increasing the incidence of flood events.

Following the already ubiquitous incidence of flooding, researchers and designers have started to argue against hard-infrastructure projects designed to keep the sea or river out, which often preclude a healthy relationship between human populations and their water bodies, potentially dislocating the problem somewhere else. They defend, instead, the construction of more fluid environments, able to buffer rising waters, while bringing inhabitants closer to the urban coast. Following these ideas, all proposals analyzed embrace the presence of water, engendering building and landscape solutions designed to cope with the temporary and recurrent condition of flooding.

Even if representing a small sample, the four cases analyzed propose a series of principles for the development of buildings and landscapes in the floodplain. These correspond to a series of design solutions that safeguard both property and inhabitants from the impact of flooding. Buildings and landscapes are raised above stilts, floating platforms, or are permeable to floodwaters. Building envelopes are detailed to resist the persistent contact with water, while landscapes are devised to drain and redirect its excess, optimizing the transition of the terrain from wet to dry. Landscapes are carefully devised to keep humans at a safe distance from varying water levels, and work together with infrastructural systems to guarantee uninterrupted access to the neighborhood and basic infrastructure, thus minimizing the impact of flooding on those affected. Furniture design also becomes an important element in different compositions, allowing for the organized protection of personal belongings during a flood event.

However, the research shows that beyond resisting the damage caused by flooding, the application of these various strategies lead to a new relationship between humans and their natural environments. Such relationship is defined by a greater sense of stewardship towards nature, an enhanced awareness of flooding, and stronger community ties. As the analysis shows, all three are instrumental not only in minimizing the impact of current flood events, but also in reducing the incidence of flooding in the future. Nevertheless, the application of such strategies (and the consequent relationship between humans and nature) are all contingent upon an integrated approach between architecture and landscape architecture. Each proposal presents an intricate composition of enclosed and open spaces, which often merge (even if temporarily) in the creation of more livable urban environments that are capable of coping with flooding. Through this combined approach, all four proposals challenge the typical role assigned to landscape architecture and architecture in protecting the city against flood events, which often reduce flood-resilient design to uninhabited buffer zones and houses elevated on stilts above the flood line. By introducing residential development in urban spaces designed to allow water in, the proposals prove that areas prone to flooding don't need to be approached as unsuitable for living. They should rather be perceived as a possibility to reinvent buildings and landscapes and to generate unique spatial experiences shaped in and around the recurrent presence of water.

The establishment of more integrated communities in closer contact with nature, is not, however, limited to environments affected by rising tides. The solutions here presented can undoubtedly serve as inspiration for architects and landscape architects working with various site conditions, prone or not to flood events. They invite designers to consider a combined approach between architecture and landscape architecture for the development of vibrant communities with a deeper contact, and care for, their natural surroundings in any given site. This integrated approach can certainly be expanded to include other disciplines, incorporating engineering, regional and city planning, and ecology standpoints, to name a few.

While the article focuses on residential architecture and landscape architecture, the methodology presented can certainly be used in the analysis of building and landscapes designed for other functions in areas prone to flooding. Further work is needed in order to expand the analysis, including not only residential, but also commercial, leisure, and institutional buildings and open spaces. This will enrich the list of strategies to be applied in the development of urban environments both resilient to flooding and able to provide for their population's diverse needs. One lesson learned through this study, however, applies for the design of any environment affected by flooding, regardless of its function. That is, floodwaters offer a unique opportunity to rethink the relationship between architecture and landscape architecture, and consequently between humans and their natural environments, inviting all to (re) envision the way people inhabit space in the fluid terrains of flooding and beyond.

Author

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Figure List

Fig. 1–4 Karen Paiva Henrique

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