MASTER-/DIPLOMARBEIT

Study on Amphibious Low-rise Flooding-adaptable Buildings

Significance of Amphibious Architecture in Flooding-prone and Floodplain Urban Areas of Metropolitan Cities

ausgeführt zum Zwecke der Erlangung des akademischen Grades eines Diplom-Ingenieurs unter der Leitung

Em.Univ.Prof. Dipl.-Ing. William Alsop

E253

Institut für Architektur und Entwerfen

eingereicht an der Technischen Universität Wien
Fakultät für Architektur und Raumplanung

von

Robert Tomić

1027870

TECHNISCHE UNIVERSITÄT WIEN
Vienna | Austria

Wien, am 3.11.2016

eigenhändige Unterschrift

Abstract de

Immer mehr Menschen sind mit Naturkatastrophen wie Überflutungen, Erdbeben oder Wirbelstürmen konfrontiert. Diese verursachen große Sachschäden, kosten Häuser und Menschleben. Eine Folge ist Umsiedelung. Überschwemmungen sind die gefährlichsten unter den Naturkatastrophen.

Trotz der Gefährdung von Architektur und Existenz im Überschwemmungsgebiet, konnte sich das Besiedeln an Ufer- und Küstenregionen aufgrund von historischer Notwendigkeit und kultureller Gewohnheit durchsetzten. Nicht nur Gebiete am derzeitigen Stadtrand sind betroffen: auch neu entwickelte Städte sind mit diesem Problem konfrontiert.

Amphibische Gebäude, amphibische Architektur, amphibischer Urbanismus sind neue Begriffe die in der Gegenwart nicht klar definiert sind.

Obwohl gestaltende Architekten und Stadtentwickler diese schwimmfähigen Methoden bereits anwenden, ist nicht klar wie sich unterschiedliche Arten von amphibischen Architektur unterscheiden, welche Typen es gibt, wie die Verbindung zum urbanen Kontext hergestellt wird und weiters wo sie ideal umgesetzt werden kann.

Diese Arbeit setzt sich zum Ziel, die vorherrschenden Lücke zwischen dem finalen urban-architektonischen Design und der technischen Ausführung von amphibischer Architektur zu überbrücken. Die genaue Definition schwimmfähiger Architektur als Gebäude oder Urbanismus wird anhand von Fallstudien analysiert und verglichen. Weiters wird die aktuelle (technische?) Umsetzung erforscht um Vorschläge, basierend auf erweiterter Recherche zu formulieren. Ein urbaner Entwurf für hochwassergefährdete Gebiete in Metropolregionen wird erarbeitet und in seinen amphibischen Parametern erforscht.

Keywords: amphibische Gebäude, amphibische Architektur, amphibischer Urbanismus, Chongqing Guangyang Isle, amphibische Auftriebssysteme, amphibisches Verhalten

Abstract en | ch

More and more people are being faced with a natural event such as a flood, earthquake, or hurricane that causes huge material damage and often loss of life and home, and results in displacement. Floods are one of the most dangerous natural disasters. Floodplains and flooding-prone areas are dangerous for buildings and living, but building and living next to water reflects our cultural habits and historical need for settlement next to a water source. Not only suburban areas are affected: newly developed cities are either facing the flood problem or lack of space that can be easily found in floodplains and flooding-prone areas.

Amphibious buildings, amphibious architecture and amphibious urbanism are new terms not clearly defined at the present time. Although architectural designers and urban developers are already dealing with all of them, they still have no clear picture about what kinds of buildings belongs to which kind and type of amphibious architecture, what exactly amphibious architecture is, and what its relationship to urbanism is, as well as where such architecture can be applied.

This thesis aims to close the gap that appears between the final architectural/urban designs and technical design of amphibious building, not only by defining what amphibious building, amphibious architecture and amphibious urbanism are or by doing different case studies for the purpose of comparison and analysis of the present solutions, but also by exploring the implementation of amphibious buildings by giving different kinds of suggestions based on extended research and an urban project proposal for the floodplains and flooding-prone urban area of metropolitan cities, as well as exploring the relationship between amphibious buildings, amphibious architecture and amphibious urbanism in such urban areas.

Keywords: amphibious buildings, amphibious architecture, amphibious urbanism, Chongqing Guangyang Isle, amphibious buoyancy systems, amphibious behaviour

越来越多的人正在遭受到洪水、地震、飓风等自然灾害的影响，这些自然灾害让他们家破人亡，最终导致了他们的被迫迁徙。其中洪水是最具破坏性的自然灾害之一。在洪水漫滩和易受洪水影 响的区域 进行建筑并生活在那里是十分危 险的，但生活在水域附近是我们的文化习俗，并且从历史角度来说，生活在水源附近是人们的根 本需求。对于洪水问题，以及由洪水引起的土地资源缺乏问题，不仅仅郊区受到其影响，新开发 的城市也同样深受其困扰。

两栖建筑、两栖架构，以及两栖城市化都是新兴的名词，但他们往往被人们错误理解。尽管建筑师和城市规划师 都在使用这些名词，但往往他们不能清晰的解释什么样的建筑属于哪一种类型的两栖构造，到底 什么是两栖构造，两栖构造和城市化有什么联系，以及两栖构造应该在哪些地方得到应用。

本论文旨在理清最终建筑/城市设计和两栖建筑设计的差别。本 论文不仅仅只是对两栖建筑、两栖构造、和两栖城市化进行定义，也不仅仅只是为了比较和分析 当前的解决方案做一些案例研究，而是在现有研究的基础上，通过对两栖建筑的探索，给出了不 同的建议，同时也为重庆市区的洪水区域提出了一个项目计划。与此同时，本文还进一步探索了 两栖建筑、两栖构造、两栖城市化之间的关系。

关键词：两栖建筑，两栖构造，两栖城市化，重庆广阳岛，两栖浮力系统，两栖行为

Acknowledgments

I would first like to thank my two thesis advisor Prof. William Alsop at TU Vienna and Prof. Ye Hai at Tongji University. The door to Prof. Ye Hai office was always open whenever I ran into a trouble spot or had a question about my research or writing. He consistently allowed this paper to be my own work, but steered me in the right the direction whenever he thought I needed it.

I would also like to thank the experts who were involved in the validation survey for this research project. Without their passionate participation and input, the validation survey could not have been successfully conducted.

Finally, I must express my very profound gratitude to Bojana, Aleksandar, Sanja, my parents and all other very good friends for providing me with unfailing support and continuous encouragement through the process of researching and writing this thesis. Furthermore I want to dedicate this book to my brother Alekandar. This accomplishment would not have been possible without them. Thank you.

Proofreading
Bojana Pavlovic

Illustration
Aleksandar Tomic

Table of Content

1. Introduction

Figure 1 | People dealing with floods, Doboj, Bosnia and Herzegovina

Research Motivation

More and more people are being faced with a natural event such as a flood, earthquake, or hurricane that causes huge material damage and often loss of life and home, and results in displacement. Floods are one of the most dangerous natural disasters. (European Parliament, Directive 2003/35/EC. 2007) Floodplains and flooding-prone areas are dangerous for buildings and living, but building and living next to water reflects our cultural habits and historical need for settlement next to a water source. People love water and waterfront, lakes and seas, waterfalls and fountains, etc.

Through the history, people have always tried to deal with water, to have some interaction and to use it as a productive mechanism to grind flour, produce electricity, transport heavy materials etc., with transportation use and leisure as one of two main activities. But, as water can bring many good things, there are bad things it can bring as well – such as flooding – that were present in many countries around the world through humans history and exist to this day. (i.e. In the year 1931, China suffered from the Yellow River floods. These were the floods that caused the most deaths in the past century, with around 3.7 million people dead.) Flooding continues to be one of the most effective, brutal and fastest demolishing mechanisms. Although they are not always prepared, people have to deal with flooding. They fight the water, try to block it, stop it and control it. Water is very strong and because of its demolishing power, many dwellings next to it are destroyed and to recover them and put them back in function, big money has to be invested. In any flooding disaster, money is not the only thing lost. Many people are dying from year to year.

Despite the fact that water is dangerous, people never stop interacting with it. There is a wish and a need for it, and the biggest evidence are all the historical settlements located just next to the water edge. People build a lot near to the river, sea and lake. Many big cities such as London, Paris, New York, Chicago, Vienna, Moscow, Dubai, Shanghai, Chongqing are located just next to a water source.

The biggest problem we are facing today is that people are trying to resist the water more and more. Sometimes they succeed, sometimes not. One main reason for this is that humans are changing the natural circulation of pre-existing water sources without taking into account that the nature will naturally resist such a change. This is where the things become a little bit more complicated – in spite of the fact that we understand 'how the thing works' and that 'we know how to fix it', we are not very good at mitigating the nature's pushback to our change of the natural waterfronts. Many floods present in all parts of the world are the best indicator of 'how well we can handle the nature'.

Water has played a main role in shaping not only many ancient settlements, but many present ones as well. **"In 20th century, the car influenced the way planning was established and the water is going to do the same in 21st century."** – *Robert Barker, Founder of Baca Architects*

The main problem is not only that 18th and 19th century cities are not designed to deal with a big amount of water, but very often new cities are designed to deal just with water amounts present at the time of their design and construction. They lack an 'adaptive design' crucial to combating flooding – they are not designed to last. If they were to be the only people habitats affected in this whole process, that would be the best outcome; but this is not the case. By influencing the natural circulation of water in nature so dramatically, big cities are harming the whole planet as well.

It is very hard to change big and complex things. It is a process requiring comprehensive preparation, many people with different kinds of relevant knowledge and interests, as well as money and support from both the government and massive companies. Nevertheless, every big step starts with a small one. Architects have a duty to try to develop solutions and systems that are acceptable, logical, economical, yet also 'attractive to the eye'. Although it is not an easy job, it has to be done and never ignored.

Mentioned above are the reasons why architects have to experiment with architecture every single day. Architects have to push the boundaries even though sometimes it sounds unreasonable and even impossible.

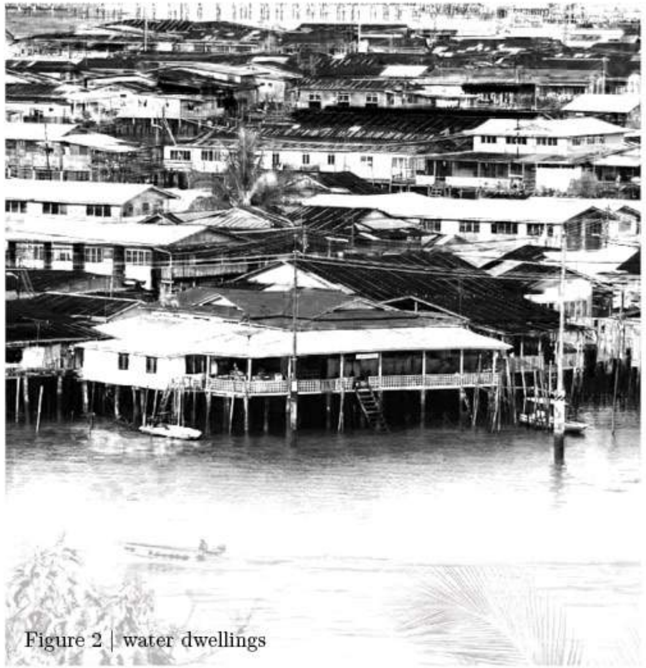


Figure 2 | water dwellings

Figure 3 | water dwellings

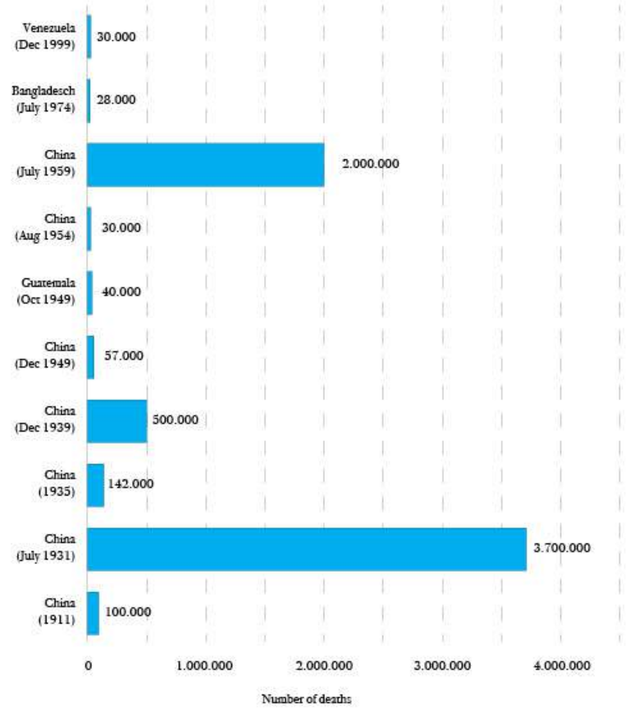


Figure 4 | number of deaths due to major floods from 1900 to 2015

"The 1931 Central China floods caused the most deaths due to a flood in the past century, totaling some 3.7 million deaths. Some 28 years later in 1959, the Yellow River flooded into East China killing an estimated 2 million people. The death toll due to this flood has been also associated with the Great sparrow campaign that arose due to the Great Chinese Famine that began in 1958. Citizens were told to kill sparrows and other wild birds that ate crop seeds which lead to an explosive increase in the population of crop-eating insects. This massive ecological shift, starvation, as well as floods and drought lead to the deaths of many living in China. More recently, a 1996 flood and 1998 flood in Yangtze, China caused some 30.7 billion U.S. dollars and 24 billion U.S. dollars in damage. In 2014, 38 lives were lost in the United States due to floods or flash floods. Since 1980, the two of the most significant natural disasters have been the earthquake in Haiti in January 2010, which caused 22,570 deaths and the 2004 earthquake and resulting tsunami which caused 220,000 deaths in countries like Thailand and Sri Lanka. Death tolls in Haiti were aggravated by poverty and poor housing conditions that many Haitians experience."

The Statistics Portal. 2016. Number of deaths due to major floods from 1900 to 2015. [ONLINE] Available at: http://www.statista.com/statistics/267746/number-of-deaths-globally-due-to-major-flooding/. [Last Accessed 12 January 16].

When I first started to deal with this topic, I asked myself: 'If the boat can float, why does the building not float when a flash flood appears, and why do we try to stop the water so hard instead of letting it go through?'. After that I took a large bowl and put a small bowl in it. I started to pour water inside the large bowl. It was more than clear that the small bowl would float, but the question was how much fruit could fit in small bowl while still floating during the water injection in the large one.

Figure 5 | experiment

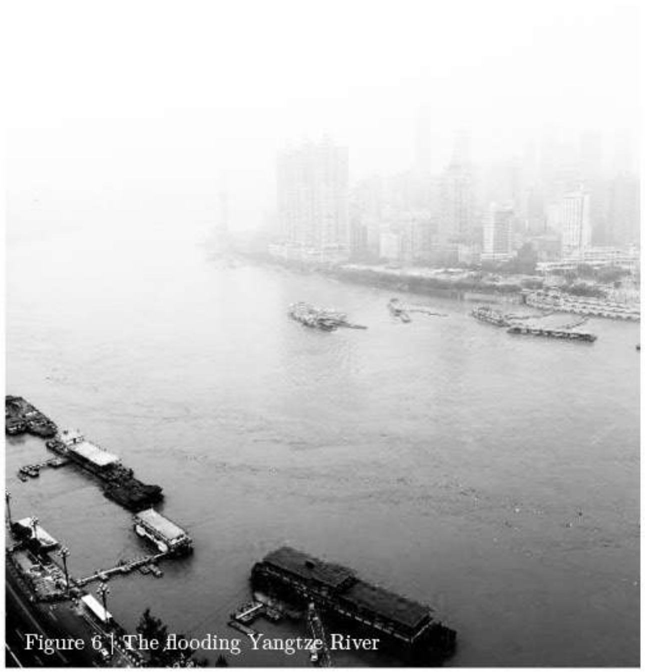


Figure 6 | The flooding Yangtze River

To make this small story clear, it was not any sort of discovery – such a knowledge is already obtained in primary schools – but in spite of having that knowledge, people never think to consider it.

When I talked with people around me for the first time and proposed my 'non-floodable' building model (at this time I had not known that many others were and are dealing with amphibious buildings and architecture as well), people told me with no thinking: 'No way! That cannot work!'. This 'No way!' is our biggest problem nowadays.

People rely on the things they are told and they never question anything at all. Many do not try to improve, they do not try to make it better and even less they try to invent and innovate.

After I conducted a detailed research, I found out that many builders and designers have long had ideas about amphibious architecture, and that are many still deal with it to this day. The very first International Conference on Amphibious Architecture, Design and Engineering, ICAADE 2015 was held in Bangkok, Thailand, on August 26-29, 2015, where many architects and architectural offices as well as architectural students sharing their interest in this matter sat together, analysed, discussed, presented existing stages and worked on improvement and implementation techniques of amphibious buildings as well as amphibious architecture.

Big and small cities are influencing one another. Things that people developing in small urban or non-urban spaces will very soon be reflected on the big urban environment. Vice-versa is also true.

Through time I had spent in China, I realised that flood and flash appearance of the water was not only the problem of the past. It is still presented in many Chinese cities. I started my journey in Shanghai (上海) and stopped in Chongqing (重庆), a 'wild urban jungle' (as my friend Antonella would like to say) where the Yangtze River (长江 'The Long River'), that plays a large role in the history, culture and economy of China, intersects with the Jialing River (嘉陵江 'jīalíng jiāng').

Although Chongqing is located on the hills around the river, it still faces water rise and flesh floods very often, as we can easily imagine that the Yangtze River is carrying many various tributaries from Geladaindong Peak (各拉丹东) to Shanghai. Chongqing is a big city that sits on one of the biggest rivers on the planet, which makes it a very interesting location for further development of an urban amphibious architecture.

Every big journey starts with a small step and so can this one. This thesis explores amphibious architecture and its origin, as well as amphibious architecture significance in flooding-prone and floodplain urban area.

Thesis Organisation and Structure

This thesis focuses on solving the flood problem in urban floodplains and flooding-prone areas from an architectural aspect and it consists of: 1) *analysis and comparison of present solutions*, 2) *a project proposal for the urban area of Chongqing*, and 3) *directions for future development and research of Amphibious Architecture.*

Amphibious urban project proposal in this thesis will, in response to the flood-facing problem, suggest an appropriate long-term design solution for floodplains and flooding-prone urban area of Chongqing. The solution will include: 1) *rehabilitation and adaptation of an existing potential urban area*, 2) *protection of vital sectors using water-repellent materials*, 3) *use of different building methods*, and 4) *implementation of amphibious flooding-adaptable buildings.*

The newly developed urban area would become an amphibious urban area and such an area would be able to give convenient, suitable and pleasant experience where: 1) *potential flooding risk of floodplains and flooding-prone areas is minimized*, 2) *extremely large costs caused by flood events are cut, and* 3) *the need for secure people displacement is prevented.*

Safety in floodplains and flooding-prone areas would be increased and a better way of living in floodplains and flooding-prone areas would be present. The health and wellbeing of inhabitants would be the biggest success, followed by the support for unobstructed further economic and cultural development.

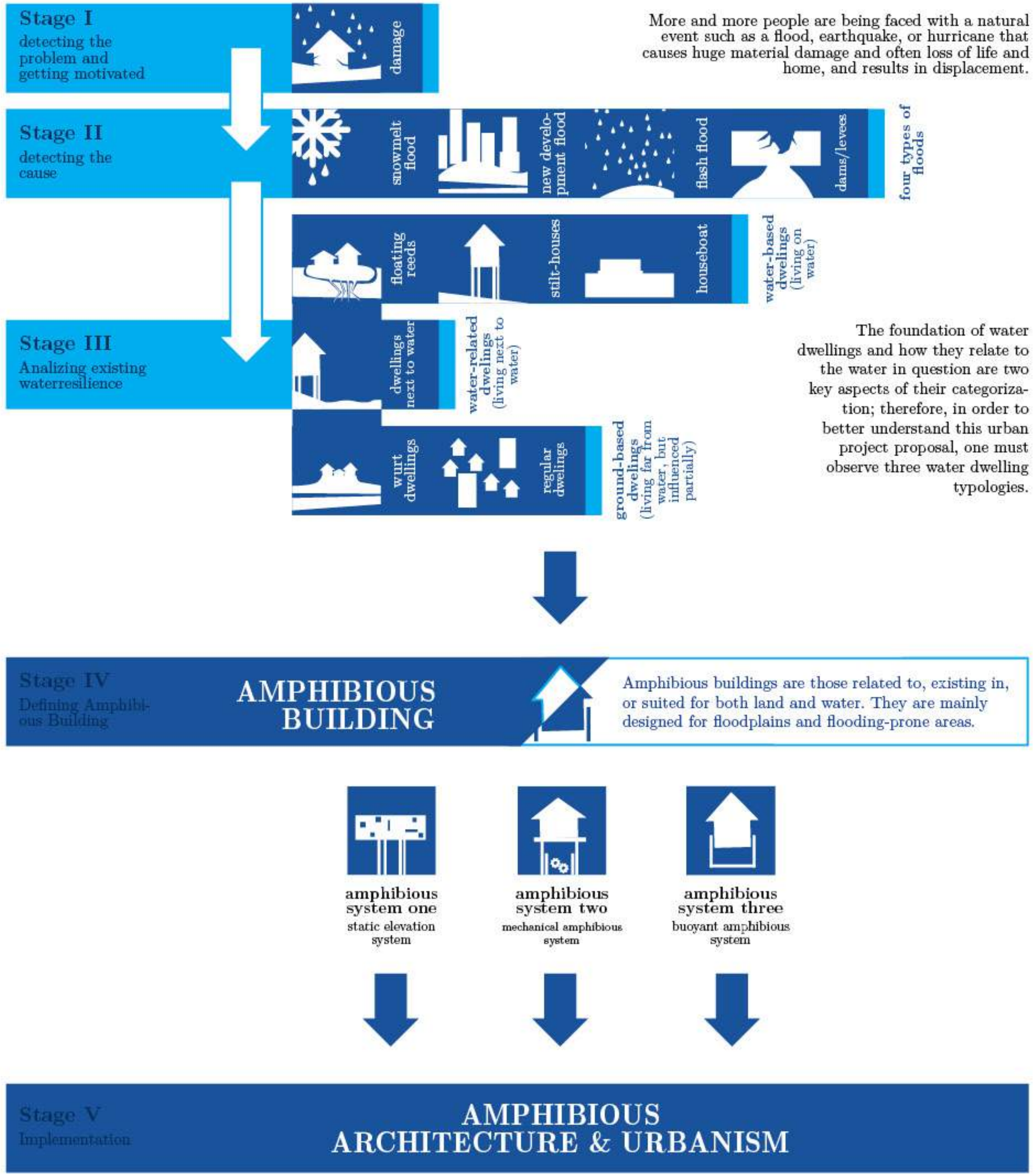


Figure 7 | Thesis Organisation and Structure | schematic diagram

This thesis is divided into six different chapters (**Introduction; Origin of Amphibious Architecture; Amphibious Buildings; Amphibious Architecture in Metropolitan Cities; Amphibious Urbanism of Metropolitan Cities; Final Words;**), starting with the Introduction that defines the existing flood problem and announces possible solutions through different methods.

This is followed by the second chapter - Origin of Amphibious Architecture, where, beside defining the flooding-prone and floodplains areas, the main focus will be on defining the three water dwelling typologies and analysing water dwelling systems through time. At the end of the water dwelling systems, a table that represents a summary of all water dwelling systems and their advantages and disadvantages will be presented. Furthermore, this chapter will introduce the process of amphibious buildings formation. This chapter is a key introduction to the following ones.

The third chapter, Amphibious Buildings, will focus mainly on amphibious buildings and their place in amphibious architecture. Here, present amphibious buildings will be briefly introduced and explained. This chapter consists not only of an extended description of amphibious buildings but also of different case studies necessary for better understanding of this matter. At the end of this chapter, a summary of all case studies will be presented.

The fourth chapter, Amphibious Architecture, will, as the name says, focus mainly on the significance of amphibious architecture in urban area. In this chapter pedestrian activities and movements would be analised and proposal for moving during flood would be presented.

The fifth chapter represents Amphibious Urbanism in Metropolitan Cities. Architectural concepts, plans, sections, and sketches will be presented, followed by the extended protocol and a set of suggestions on how to deal with this matter in the future. The fifth chapter is a result of all previous research that was conducted on amphibious low-rise flooding-adaptable buildings and Amphibious Architecture. The goal of this chapter is to present innovative architectural and urban solutions for a flooding problem that Amphibious Architecture is facing nowadays.

After fully understanding the problems and their origin, as well as how to effectively deal with them, in chapter six Final Words, final words will be presented together with the final Conclusion. This chapter is built from: results collected during amphibious case studies, results collected during the amphibious urban project proposal design, directions for future research and contribution to amphibious architectural development in urban area. The main goal of the sixth chapter is not only to end this thesis, but also to give a stable springboard for further research regarding amphibious architecture, the low-rise flooding-adaptable buildings and amphibious architecture urban desegregation.

Research Significance

In general, a study of selected matter is always there to help with better understanding of some specific topic or existing problem that calls for a solution. Only study without an action cannot be enough to solve a problem, but it can be a good start for necessary development.

The purpose of this work is to go through all necessary segments that can provide help to later researcher with this topic to better understand the flood problem, Amphibious Architecture and Amphibious Architecture urban desegregation. Amphibious architecture is still very new at this time. Sources are still limited. Things related to the Amphibious Architecture are happening now, as this thesis is being written, on Twitter, Facebook, WeChat, various personal blogs and various architectural web pages. The need for research in this field is necessary and worthwhile. China is one of the countries that has recognised that specific need and started to invest big money in similar topic. The so-called LID cities are very popular in China at present. The LID cities will be mentioned in this thesis as they are closely related to the matter, but they will not be deeply analysed, as they would demand a thesis themselves.

Furthermore, with the help of this thesis content, one should be able to understand, further analyse and improve suggested methods for dealing with the floodplains and flooding-prone areas presented in the urban project proposal in this thesis.

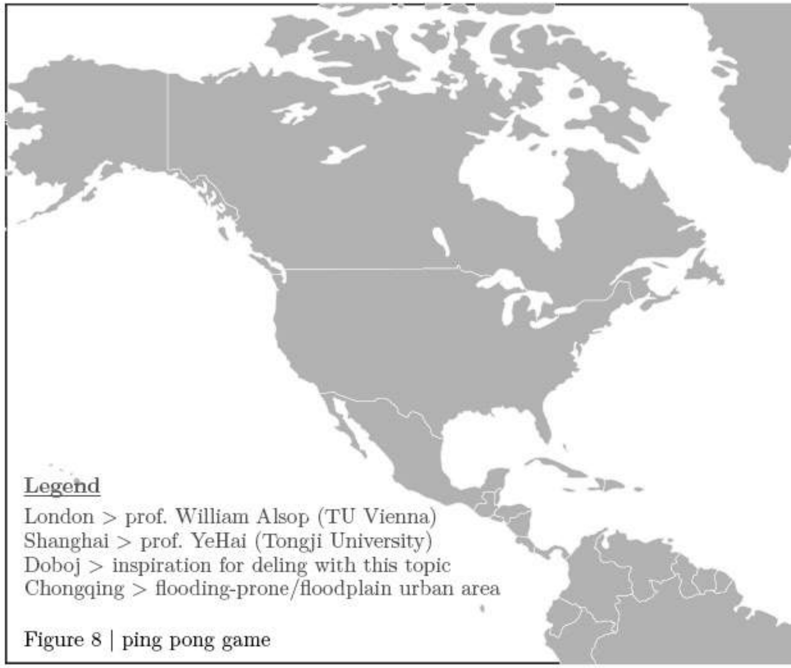
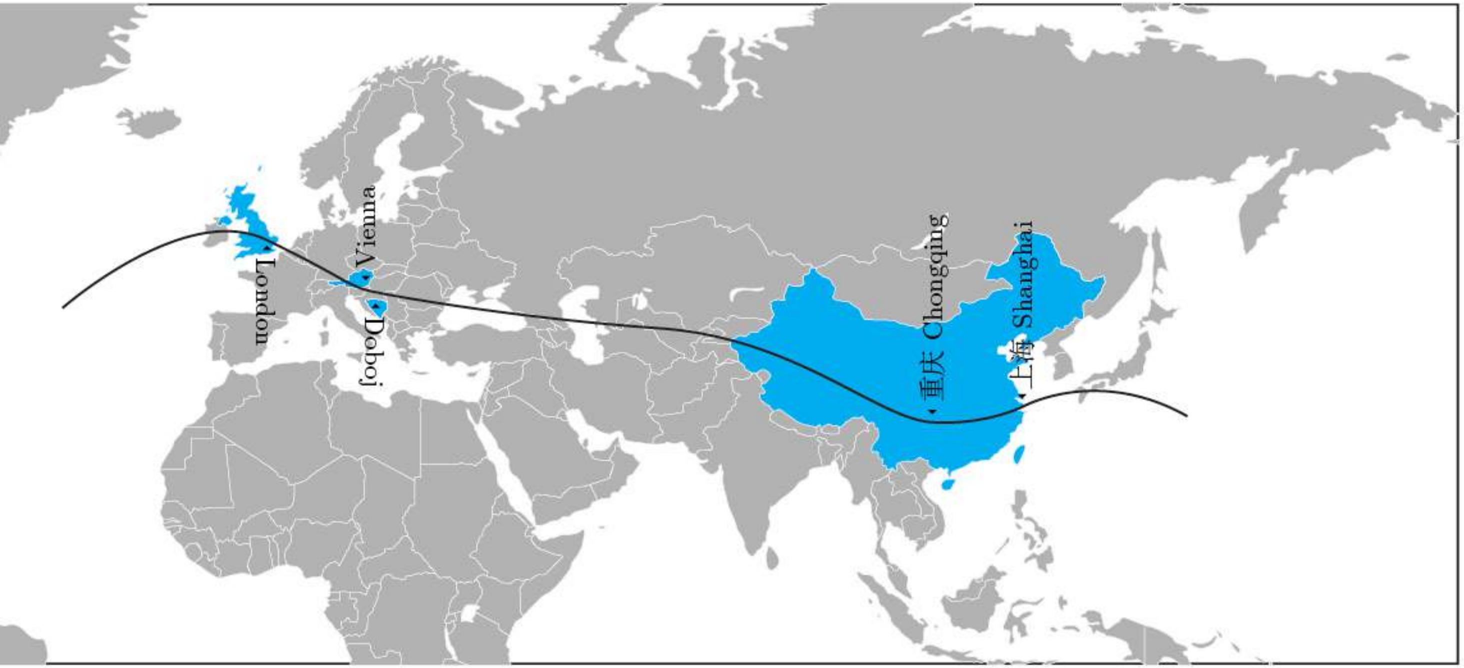


Figure 8 | ping pong game

One of the main goals of this thesis is not only to point to the importance of new so-called 'amphibious architecture' as well as amphibious buildings and further on to amphibious communities, but also to help understand amphibious architecture and amphibious architecture urban desegregation, and finally present the appropriate way how to implement all this in an urban area. Amphibious architecture cannot wait any longer for people to start exploring it. Flood problems should be taken seriously. Amphibious architecture is the way to solve flood problems and prevent many economic losses, which is why amphibious architecture must be taken seriously and be further developed from day to day.

The floodplains and flooding-prone urban project proposal in this thesis will be conducted and designed in Chongqing, China, at the small island in downtown area that faces few huge city centres. Amphibious architecture aggregated with urbanism is an experimental design that is very important for a good understanding and further development of low-rise flooding-adaptable buildings and amphibious architecture



in flooding-prone and floodplain urban area of various metropolises. This urban project proposal should support amphibious architecture urban desegregation.

Research Methodology

The author is relying on a set of well-proven methodologies and scientific analyses to capture the current as well as the previous status of methods introduced in solving the flooding problem in urban areas.

First, all existing flood resistant systems in the past will be analysed and compared with a system at the present time. Necessary case studies will be conducted and after the accumulation of sufficient information, an experimental urban project will be proposed and analysed. During the experimental project, consultation and discussions will be conducted with qualified persons. Literature of the current and modern solutions will be used. The latest publications from universities will be followed and analysed. Different floodplains and flooding-prone areas will be visited and analysed in Asia and Europe, where necessary interviews with local people will be made to help better understand why people keep building and living in floodplains and flooding-prone areas.

Such analyses with tools mentioned above will be of great help in this research, which should later help urban planners and architects that are dealing with amphibious architecture during the future project planning and development.

Conclusively, necessary systems for amphibious architecture planning will be defined and organized so that architects and urban planners in the future can have a good starting point for urban development in the floodplains and flooding-prone areas.

They would be minutely advised how to plan and design in floodplains and flooding-prone areas for a new 'amphibious communities'.

Key Issues

As in the case with most research, here as well time presents a major problem. The flood topic is very extensive and it is important to not get lost in diffused details. The architectural path must be closely followed. Architecture is a very wide field, and in order to have a compact and coherent analysis, unnecessary discussion or demagogue will be avoided. Nonetheless, thoroughness cannot be ignored, as every step is a necessary link that must be completed before full understanding of the presented problem in this thesis can be achieved.

Language can present a problem, because the information distributed in this thesis is collected in four different languages: English, German, Chinese and Serbo-Croatian. Literature that is not available in the English must be translated and its interpretation can take away the extra time and require the expertise of qualified persons in the required language.

Due to the necessary consultations with mentors, one in Vienna/London, another in Shanghai, extra time for traveling will be invested, as well as extra time for visiting the site in Chongqing, China that is 1500 km away from Shanghai. The author will spend three months in Chongqing to observe urban behaviours and measure the importance of the the Guangyang Isle, an island on the Yangtze River, with an area of 6.4 km2.

The field of amphibious architecture is new and has yet to be more developed and perfected. Printed literature on this topic is limited or not accessible, but at the moment, the topic is very popular and a number of digital papers dealing with amphibious architecture are being published by various universities more and more. However, the literature about flooding, how to deal with floods and the wetlands architecture is very extensive.

All in all, the author does not consider the facts stated in above text as critical for the overall findings of this thesis. Possible issues might make a whole process somewhat harder, but not unsolvable.

Literature Review

The literature review focuses on three different aspects. First of all, topics such as water resilience, design for flooding, flooding and different kinds of studies about city infrastructures were investigated and analysed more closely in order to learn more about the tools and methodologies used to deal with water in urban area, wetland, floodplains and flooding-prone areas. Literature on amphibious architecture mainly consists of different scholars and scientific publications and all those serve as a theoretic background for investigating and truly understanding amphibious buildings and the potential of amphibious architecture. Literature collected from official web-pages and publications done by different architectural offices focuses on new brainstormed solutions and how to implement them in reality. Different case studies give a good base for comparison and understanding amphibious buildings. Finally, literature on urbanism and pedestrian activities in Chongqing provided by different architectural world-famous offices will serve as the necessary step needed for better understanding of how to deal with amphibious architecture in urban areas as well as how to implement it and make it pedestrian-friendly.

Although literature tagged by words amphibious house, amphibious design, amphibious architecture and amphibious urbanism is limited and still not very widespread considering that we have only begun to take this topic seriously and globally deal with it, there is still extensive literature available that deals with water and the impact that water has on architectural design.

In the matter such as this, it is important to know where to begin and definitely the best start is understanding water and its behaviour and significance in nature. [see Figure 9 & 10] Our planet is a planet of water [see Figure 11], and everything that happens on Earth has to do with water. Although it does not look so serious, the position of water is one of the most important in our daily life and any architectural design.

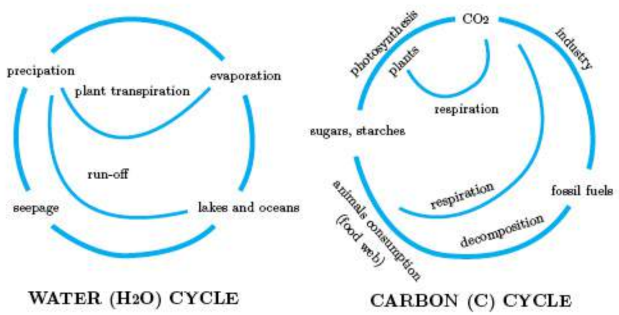


Figure 9 | The water cycle and the carbon cycle are impacted by changes in the land.

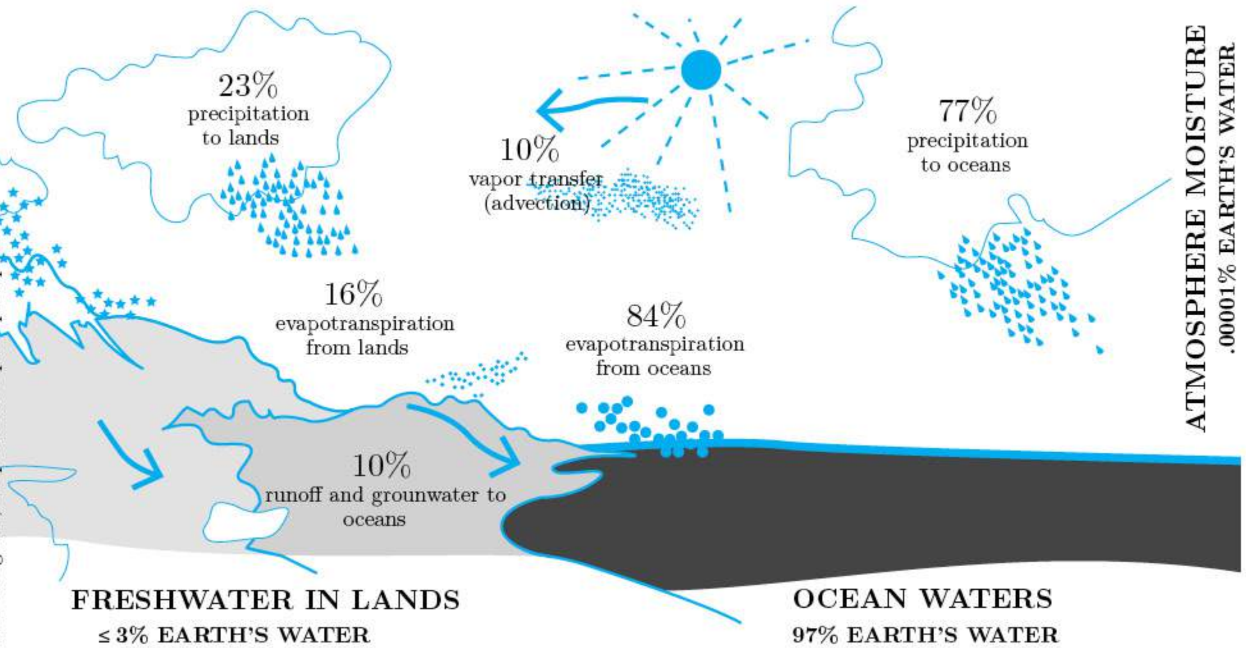


Figure 10 | The hydrologic cycle at global scale: Averaged over the globe, evaporation equals precipitation.

'Design for Flooding; Architecture, Landscape and Urban Design for Resilience to Climate Change' by Donald Watson, FAIA, and Michele Adams, P.E. is a nice start when one is new to the topic such as amphibious architecture. According to Daniel Williams, FAIA, author of 'Sustainable Design: Ecology, Architecture, and Planning', "Design for Flooding defines the need and opportunity for planners, architects, landscape architects, engineers, and conservation biologists to work together to develop the mix of inland and coastal flooding solutions required for a comprehensive response to climate change," where Carol Franklin, FASLA notes that "Design for Flooding should be a major tool for the design professions, for public agencies, and for civic activists, indeed for everyone who wishes to bring a genuinely 'intelligent' design for water to their communities. It is a call to action and demonstrates that we have the knowledge, the tools, and the capability to better manage the water system on which we depend." This book covers technical and institutional issues along with new designs in floodplains and flooding-prone areas such as: fundamentals of climate and weather; stormwater and floodplain management; best practices of flood-resistant design and adaption to sea level rise; multidisciplinary design that integrates sound ecological and engineering principles and innovative design and construction to protect and improve water security. Notwithstanding that Design for Flooding lists only one amphibious project in its case studies, it is still a very good place to start proper research about amphibious architecture. Buoyant foundation project, mentioned and analysed in Design for Flooding [see Figure 12], is designed by Dr. Elizabeth English, University of Waterloo and School of Architecture Cambridge, Ontario and it is part of The Buoyant Foundation Project – a non-profit research initiative that was created as a response to Hurricane Katrina at Louisiana State University Hurricane Center in 2006, whose main function is to design and create buoyant foundations for 'shotgun' houses, to be retrofitted in New Orleans. Design for Flooding presents practices and lessons to create buildings and communities that

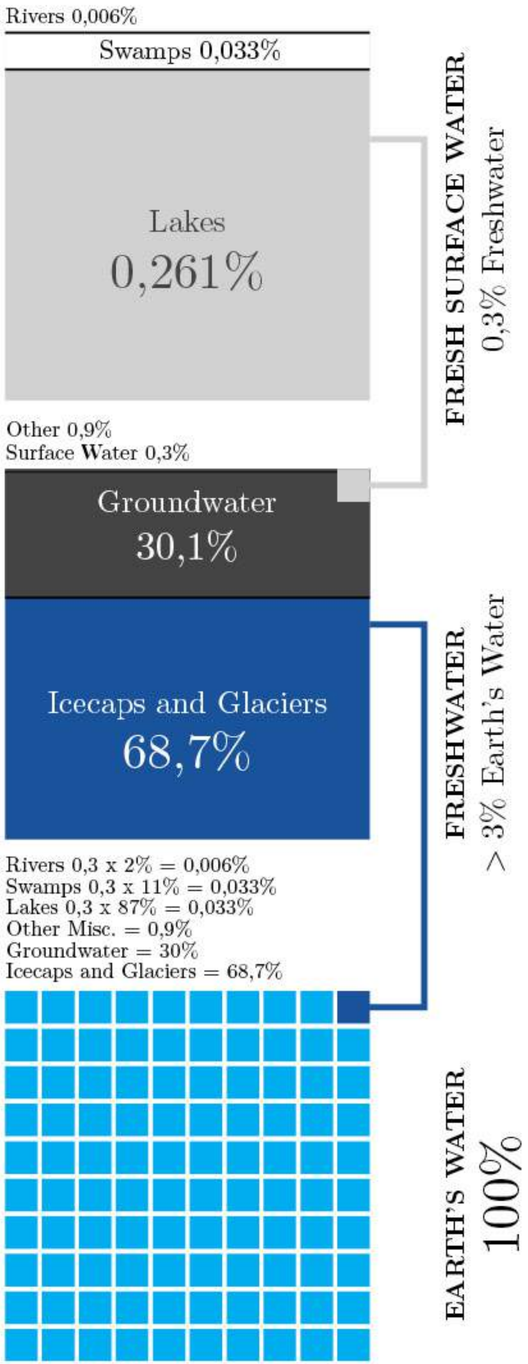


Figure 11 | Global water resources.

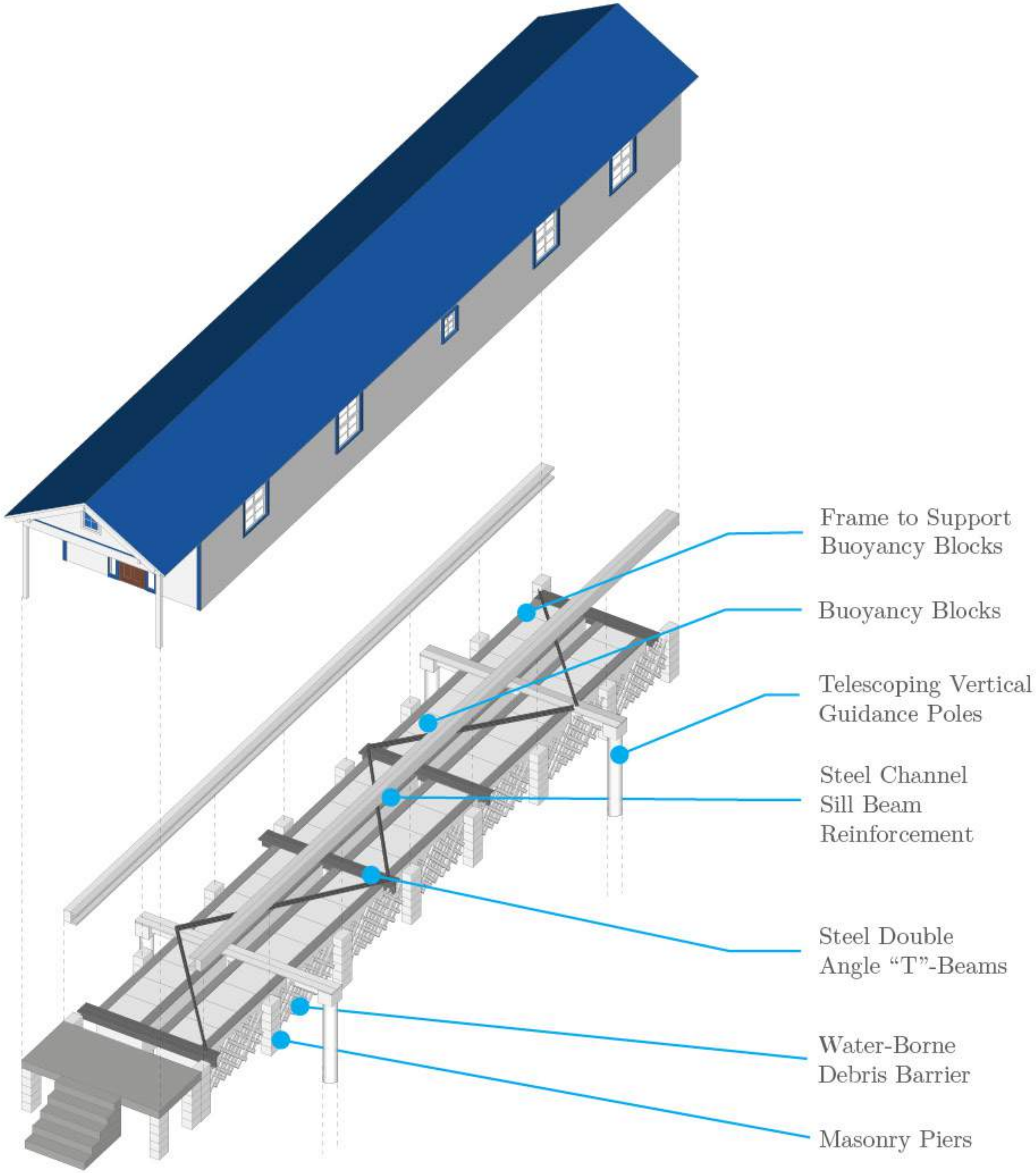


Figure 12 | Buoyant Foundation Project is developing options for each of the components of amphibious construction.

Figure 13 | Channel construction in the neuwaldegger street in the former Neuwaldegg municipality, starting in 1884

are resilient to water, climate change and rising sea level. All this is very useful for amphibious architects and urban planners.

An extremely important aspect of architecture and urban planning related to amphibious architecture is the way that various kinds of naturally-occurring water is handled within the design of a city's infrastructure – by this are meant not only rivers, lakes and other waterfronts, but also stormwater, snow-melts, hurricanes and other non-regular weather occurrences that may result in a high volume of water entering the city.

In order to analyse the way that this is handled, a good option to begin would be 'Vom Bach zum Bachkanal' by Christian Ganter, that covers the historical development of Vienna's sewer system. [see Figure 13] Different sewer systems and the processes of their establishment are mentioned in 'Vom Bach zum Bachkanal' in a city that has changed a lot in last 100 years, but still managed to keep the quality and comfortable living conditions for its inhabitants. This book covers the relationship between public transport and city sewage systems. A more technical description about different canals and their proper construction is provided in the book 'So baut man Kanäle' by Obersenatsrat Hans Stadler, published in Vienna in 1966, that covers topics such as the pre-construction of canals; the structure realization of canals and special canal structures. To understand why city infrastructure is built and what the cultural background of our development is, a good start would be 'Expedition in die Kulturgeschichte des Abwassers' by Heinz Krajci, published in Vienna in 2004, which covers the cultural history of sewage systems from their earliest-known primitive forms (such as were found in Ancient Rome) to today's modern systems.

This literature is important for a proper understanding of the importance of amphibious architecture and amphibious urbanism in future development, given the fact that in these segments of the profession, water and architecture are inextricably linked.

More and more young architects and architecture students recognise the importance of amphibious architecture, leading to a rise in extensive research on amphibious architecture in search of possible solutions for the present and the future. Many works by up-and-coming architects that deal with amphibious architecture are available in digital form online and in universities libraries as a paper print, such as the master thesis 'Amphibious Architectures: Living with a Rising Bay' done by Heather Christine Anderson and presented to the Faculty of California Polytechnic State University in San Luis Obispo in 2014, as well as 'Amphibious Architectures: The Buoyant Foundation Project in Post-Katrina New Orleans' done by Elizabeth Victoria Fenuta and presented to the University of Waterloo, Ontario in Canada in 2010 that was supervised by Dr. Elizabeth English, Associate Professor at University of Waterloo School of Architecture in Canada. Dr. English wrote a paper on amphibious architecture and presented it at the International Conference on Urban Flood Management in Paris, France in 2009. Her paper, 'Amphibious Foundations and Buoyant Foundation Project: Innovative Strategies for Flood-Resilient Housing', clearly shows that a better alternative to permanent static elevation in situations where the rise of flood waters is slow rather than fast are amphibious foundations, as these are resident friendly and very cost-effective.

Figure 14 | Personal flooting experiment with water bottles, Tongji University, Shanghai 2016

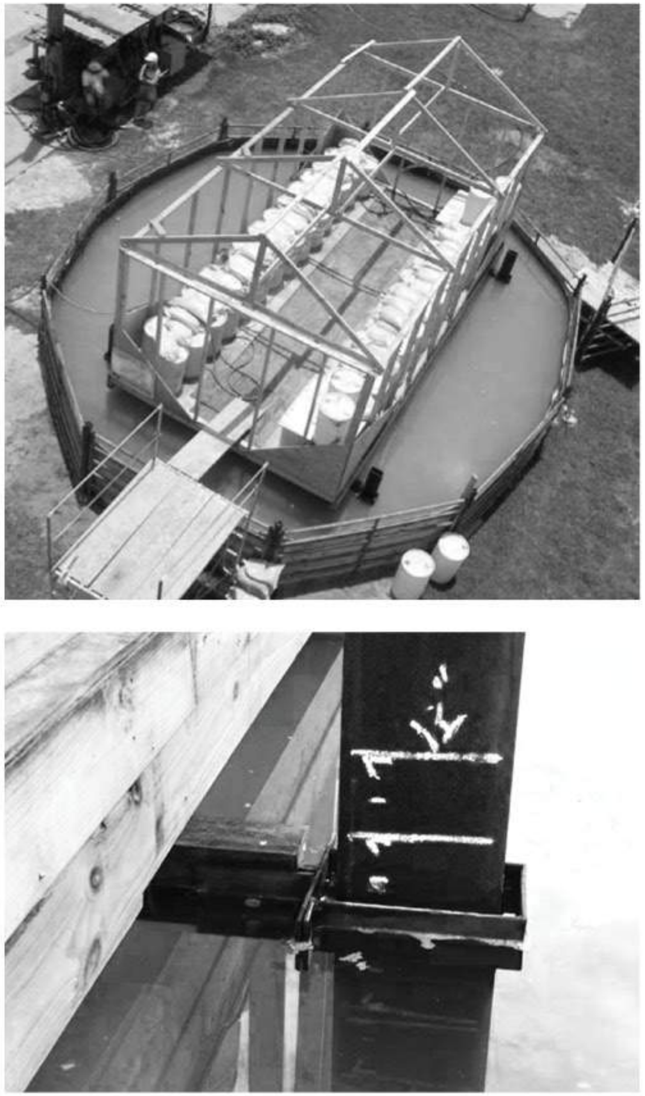


Figure 15 | Full-scale testing of prototype buoyant foundation system.

In her paper, she demonstrated numerous examples of this principle.

'Amphibious House, a Novel Practice as a Flood Mitigation Strategy in South-East Asia' by Mohamad Ibrahim Mohamad , Mohammad Ali Nekooie and Zulhilmi Bin Ismail points out that the destructive impact of flood as a natural disaster has risen to alarming levels and that the need for expansion of urban development and concerns about land value are some of the reasons for living afloat. This paper explains the calculations as well as the technical knowledge necessary for the functionality of amphibious architecture.

'Living on Water: A floating town on an unsinkable foundation complete with gardens, streets, and squares', a technical report from Delft University of Technology by Marion De Boo, points out the severity of the existing problem that the Netherlands has been facing in the land loss to the rising sea level in the last 100 years. According to hydrologist Prof. Dr. Ir. Cees van den Akker of Delft University of Technology, the Dutch will be forced to leave the Netherlands within a century if they do not find a solution to deal with this issue. Ir. Ties Rijcken goes even further with his opinion that "it's not a question of keeping the water out or getting on top of it. It's about keeping it out and getting on top of it." Rijcken focuses on floating houses, streets and islands. "If the island is large enough, you wouldn't even be aware that it was floating," Rijcken says, "And it's best to make the banks as long as possible. People like that." Rijcken's design relies on the foundation being strong enough to support everything that should lie on it [see Figure 16], and emphasises the belief that architects of floating houses should not need to have any concern in this respect aside from making sure the house remains within the weight limits of the foundation (for instance, using timber instead of bricks).

His area of focus can be applied in certain ways in amphibious architecture as well, as the systems he proposes could be used as a basis of amphibious buildings. These common points between amphibious buildings and floating buildings are important because both of

Figure 16 | Rijcken Floating Module

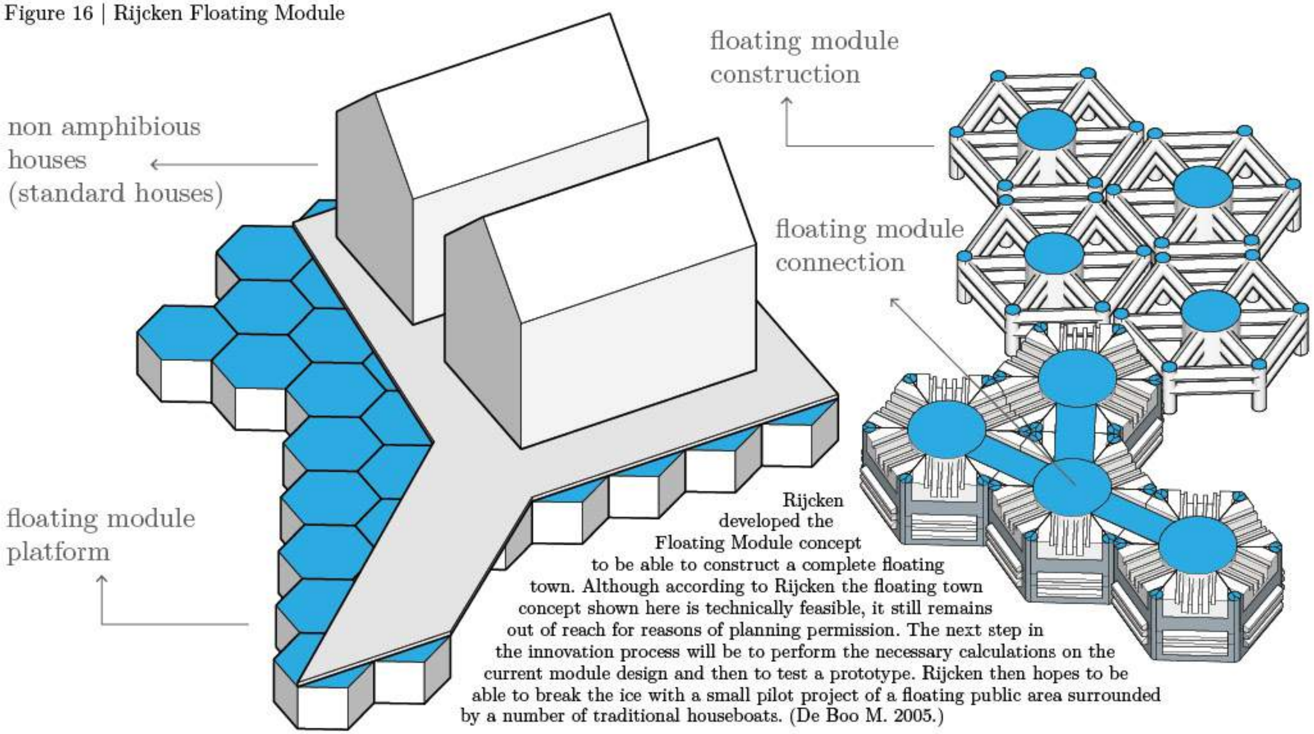


Figure 17 | A boy evacuates his dog after a rainstorm floods his hometown in Bijie city, Southwest China's Guizhou province

these designs will become more and more important in the future.

The International Conference on Amphibious Architecture, Design and Engineering (ICAADE) was established to promote the development of amphibious architecture, including the collection and defining of various amphibious systems, the consolidation of literature on this topic available in many different forms including digital papers and university publications, published books, social networks, official web pages, etc. Its goal is to allow for the evolution of innovative and useful ideas in this area.

To conclude, there are still many official and unofficial places where one can read and follow the development of amphibious architecture. Amphibious design has been present for a very long time and many countries and costal cities have been using it without being fully aware of it. Amphibious architecture has been better defined and improved every day. Many architectural offices, as well as individual architects and architectural students, are pushing amphibious architecture and development of amphibious architecture. Literature on amphibious buildings (such as 'Amphibious House, a Novel Practice as a Flood Mitigation Strategy in South-East Asia' by Mohamad Ibrahim Mohamad, Mohammad Ali Nekooie and Zulhilmi Bin Ismail as well as many other publications) mainly focuses on the technology behind the building and proving in detail that and how amphibious systems works. Amphibious architecture, however, is not mentioned a lot. Some master theses (such as 'Amphibious Architectures: Living with a Rising Bay' done by Heather Christine Anderson) deal with different variations of amphibious buildings, analyse them and give suggestions where those buildings can be implemented and how; they provide a various number of proposals for new urban structures as well. However, clear theoretical statements and declarations as well as classifications of what amphibious really is and what kinds of amphibious architecture we are dealing with nowadays stay very often hidden. There is a gap between technical appearance of amphibious buildings and existence of those buildings in reality. 'What is amphibious architecture, amphibious building' and 'how important is the role of amphibious urbanism in the future' are some of the questions that are being answered every day, but they all are still unclassified and one can easily get lost and confused when doing research about this topic. For instance, a typical mistake of this kind is that a houseboat is the same as an amphibious building. Furthermore, when an amphibious building is being differentiated from a houseboat, there is no clear awareness that amphibious buildings exist in different forms and such forms are used in different urban contexts. It is not only small buildings that can be amphibious – large buildings can have amphibious behaviour as well, though it does differ from the behaviour of small ones.

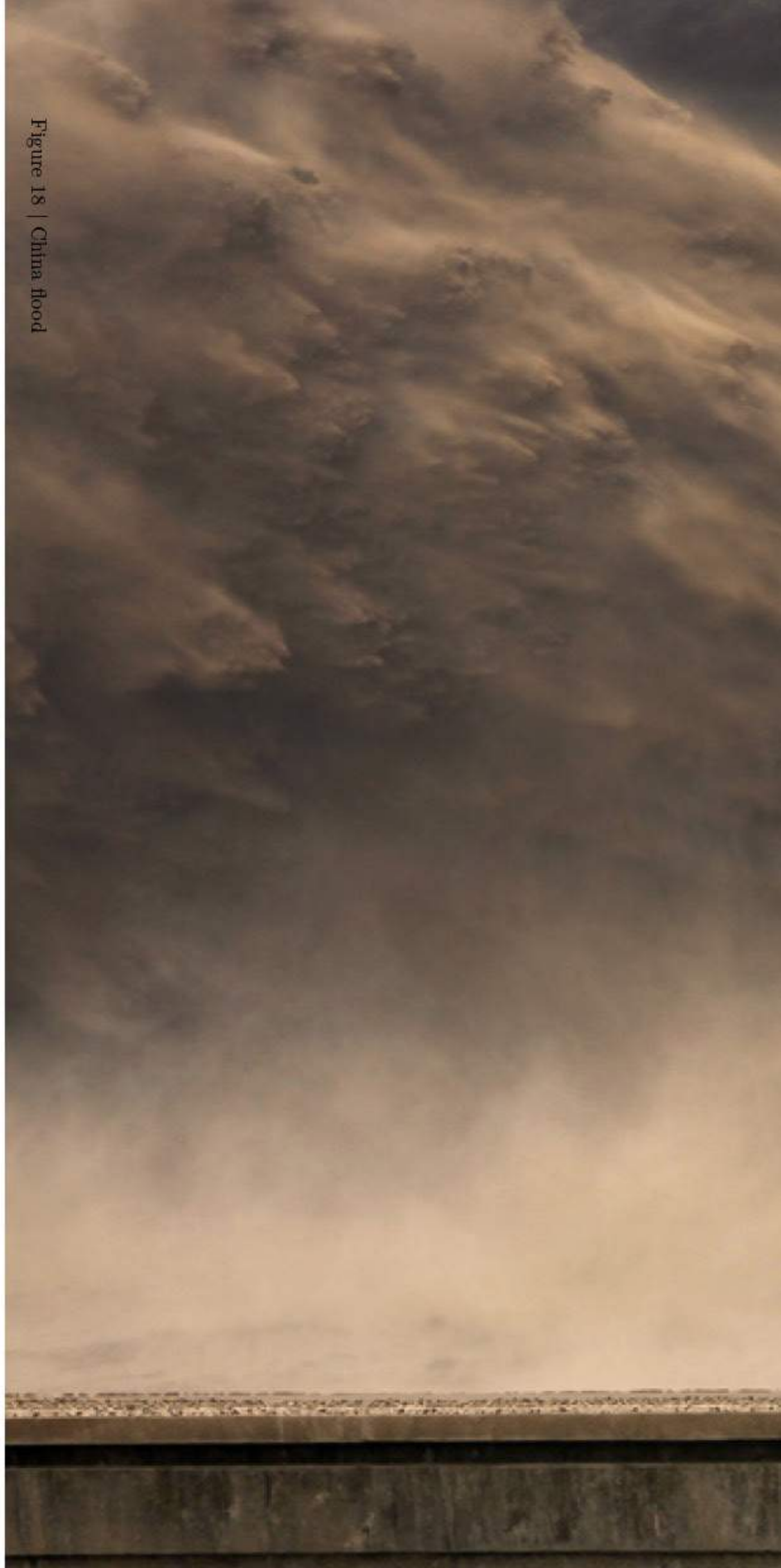


Figure 18 | China flood

2. Origin of Amphibious Architecture

Figure 19 | Uros floating reed islands in Peru


Figure 20 | Venice, water city

Why We Build on Water?

Living next to the water is literally something rooted in human history for thousands of years. People do not build next to water or on water because cities are located at the low-lying area, but because of a need for water that is a source of life, transport and trade, and energy. In the past, humans realized the importance of a water source and then started developing different kinds of inventions, such as would then use water mechanical power to run the water mills, and evolving to today's hydroelectric power stations. Where there were water mills, there were humans, and where humans gathered, there were by necessity settlements as well. Water is just so important that all the great cities in the world have been built around water.

London is located at the Thames River, Paris has the Seine, New York has the Hudson River, Chicago is on Lake Michigan, Vienna has the Blue Danube, Graz has the Mur River, Sarajevo has the River Miljacka, Moscow has the Moscow River, Dubai is located on the Persian Gulf, Shanghai has the Huangpu River (黄浦江) and the Yangtze River (长江), Chongqing has the Yangtze River (长江 'The Long River') and the Jialing River (嘉陵江 'jīalíng jiāng'). All those and countless other cities sit next to water or even on top (such as Venice in Italy [see Figure 20] or many cities in the Netherlands) because water has always been very important.

Old cities had used river channel systems to protect themselves from enemy attacks, as a food source, for hygiene maintenance through bathing and clothes washing, disposal of faeces and so on. It does not matter if the water source is a river, a lake, or an ocean, communities and cities were founded near the water sources. Through time technology and engineering allowed cities to move further inland away from large sources of water and the need for direct proximity of water has become less and less but there is still something pushing people back to water. People have desire to live near the water, to have a nice view, to listen the water circulates through the channels and similar. Because of that particular desire many buildings are built next to the water but not adapted to the water and that is the reason why very often that desire brings many humans and buildings in danger. Those sequence of events affect and week local economy effectively.

Donald Watson and Michele Adams note in their book 'Design for flooding; Architecture, Landscape, and Urban Design for Resilience to Flooding and Climate Change' that Earth is a water planet and that human beings have become one of the most significant forces misusing water. The premise of their book is that water is a resource and not a problem, and that many small, distributed projects are always better than one big, concentrated solution. (Watson D, FAIA and Adams M. 2011.)

On the other hand, a separate truth has to be acknowledged: constant battles with floods worldwide have resulted in the humanity's 'love and hate' relationship with water and significantly influenced the formation of towns and settlements through time.

Regardless of this, it is a known fact that water (in any form) is a great place for vacation, relaxation and fun. That fact brings us to the inexhaustible number

Figure 21 | Floating Seahorse Villas: A New Level Of Luxury

Figure 22 | A child in fear of floods

of games on the water or next to the water, as well as the formation of new so-called luxury water dwellings (houseboats).

Many new inter-disciplinary approaches are being developed and implemented to help and support 'living with water' rather than fighting against it. All these approaches require amphibious architecture urban desegregation. New thinking must be developed and implemented. Urban planners, architects, flood managers and many others related to this topic need to work together and find ways of creatively integrating urban planning and flood risk assessments together with the water cycle management planning. The Common goal should be understanding the importance of this topic and perfecting it.

That all brings us to the importance of amphibious architecture, a very young but increasingly more popular branch of architecture in world. This chapter covers the Overview and analysis of water dwellings systems and points out how we arrived to the amphibious architecture. It will present the previous systems from the past, as well as the existing systems at the present time. After a brief introduction to the water dwellings systems, one will be able to understand the occurrence of amphibious buildings as well as amphibious architecture and the need for amphibious architecture urban desegregation.

Why Do We See Flood as a Treat?

A flood is defined as an overflow of a large amount of water beyond its normal limits, especially over what is normally dry land. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water.

> *Floods have the potential to cause fatalities, displacement of people and damage to the environment, to severely compromise economic development and to undermine the economic activities of the Community. [...] It is feasible and desirable to reduce the risk of adverse consequences, especially for human health and life, the environment, cultural heritage, economic activity and infrastructure associated with floods.* (European Parliament, Directive 2003/35/EC. 2007)

Flooding is not a new thing. It was always present. Some of the floods are natural and some of the floods are outcomes of bad planning, i.e. the so-called fast development. Flood is a disaster for society because we build around floodplains and flooding-prone areas. Floods can bring benefits (such as irrigation, water accumulation, etc.), but they are usually threats because they are not considered in community planning and building design. Lack of appropriate planning must eventually bring consequences where flood is a threat to the life and property of the inhabitants. [see Figure 22]

Floods can occur almost anywhere. They are not limited to coastal areas or to devastating tropical storms. They happen more often and in more locations then we may realize. They are the most common natural disaster. (FloodSmart.gov. 2010.)

We distinguish four types of floods: snowmelt flood, new development flood, flash flood and dams/levees.

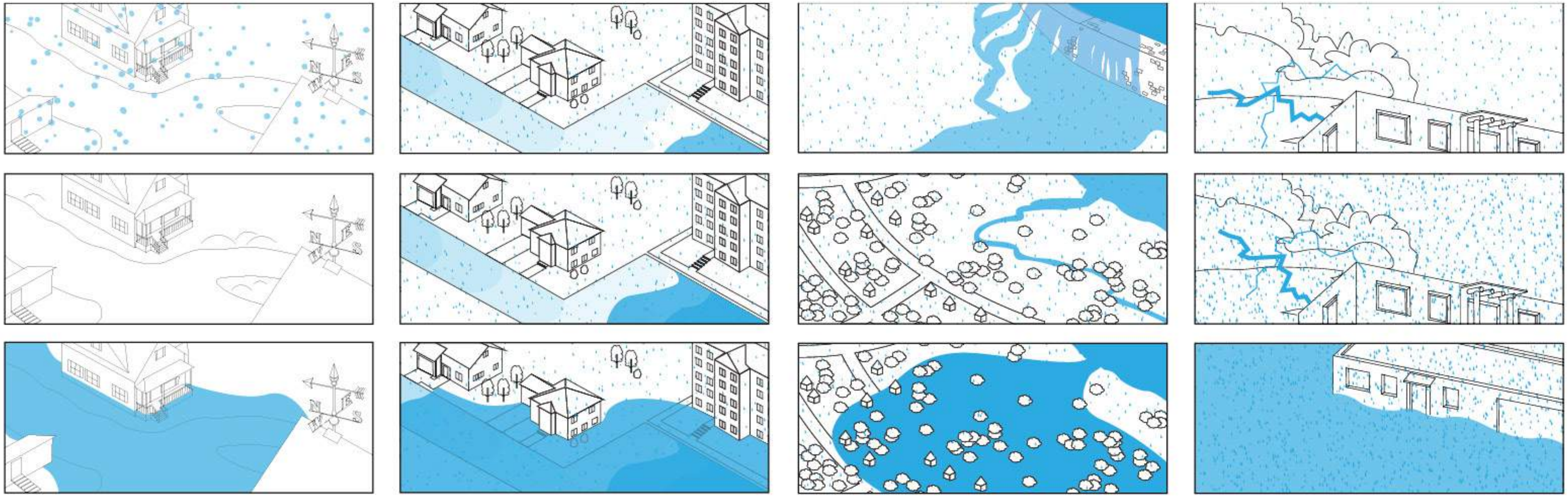


Figure 23 | Flood types as followed: snowmelt floods; new dewelopment flood; dams/levees break; flash flood

Flood Types

Snowmelt floods

Snowmelt flood occurs after a sudden snow melting. It is characteristic for places that accumulate large amounts of snow during the year. Those are places mainly in the valleys of the mountains, places that have four seasons. They can be foreseen. Safety measurements are removing massive amounts of snow from places that could be targeted. The snow is mechanically transported to other areas.

Common mistakes are throwing snow in the river.

New development floods

New development floods occur after rapid development. Lack of appropriate planning is the biggest problem here, namely the fact that massive areas are being covered with asphalt and concrete. Earth behaves like a living organism i.e. has a 'skin' that needs to 'breathe' with respect to water – it absorbs and evaporates water. New materials that cover the surface are not ready to absorb sufficient quantities of water at a given moment, which results in the ecological system being affected. Cities and inhabitants are protected from those floods by protective dams or, if there is a river nearby, an artificial river channel. The problem is that those kinds of floods cannot be solved by building a dam from year to year. Dams are only temporary solutions, because while they can protect a building or a city, they often have to be very large.

Flash flood

Flash floods are usually caused by heavy rain. When rain falls continuously every day without stopping, it is able to bring large amounts of water, which eventually become serious floods. Flash floods can be distinguished from any other flood by a timescale of less than six hours. With excessive rainfall, they can occur within minutes. (National Weather Service Weather Forecast O ice. 2008.)

Flash floods must not only be caused by heavy rain. Watershed of the river can be overwhelmed and peak, generating flash floods.

Dams/Levees break

Dams and levees create a problem when they break. They are barriers that provide a significant resistance to water. As they are acting opposed to the nature, when pressure reaches its critical level, they can be overloaded and break, letting the enormous amounts of water flood across the area.

Dams are barriers that enclose water or underground streams. They are very old techniques of collecting water. Stored water can later be distributed between locations.

Levees are an embankments built to prevent the overflow of a river. They can be natural or artificial.

Floods in the world

In the year 1931, China suffered from the Yellow River

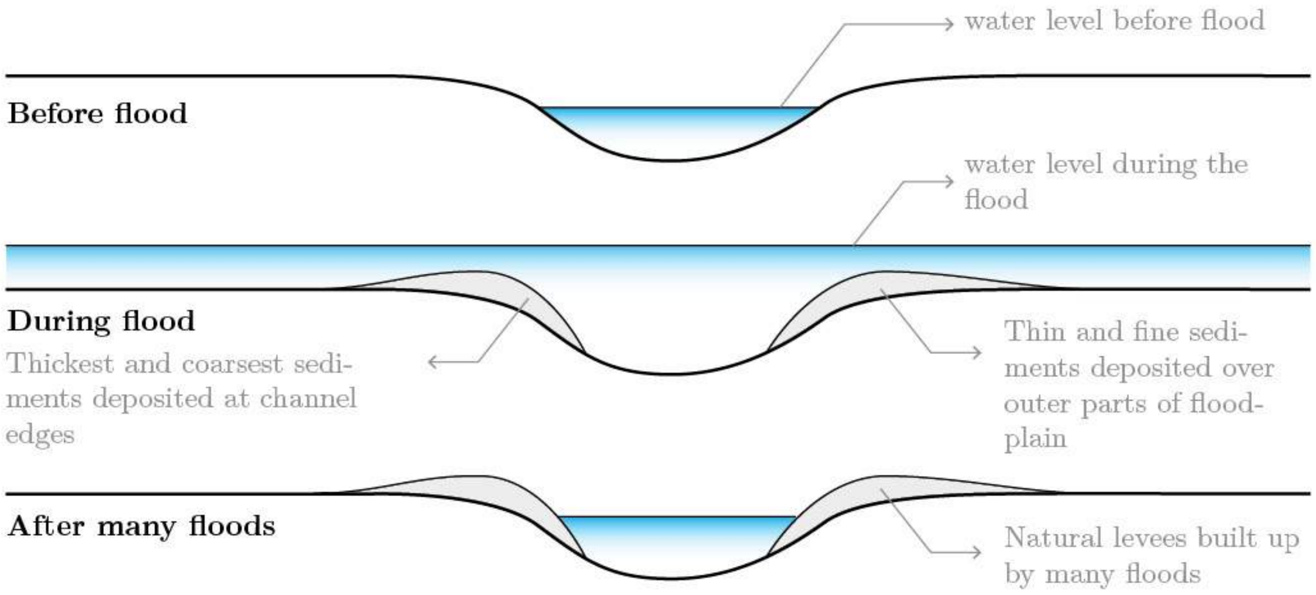


Figure 24 | Natural "levees"

Figure 25 | Yellow River floods

floods. [see Figure 25] These were the floods that caused the most deaths in the past century, with around 3.7 million people dead. Not as big as the Yellow River floods, Europe has also had serious problems with flooding through the history. Not all countries suffer the same amount of damage. Some European countries, like Austria, are well prepared, while others, like Bosnia and Herzegovina, are less so.

Vienna, the capital city of Austria, has an old but a very effective system for protection – the Danube Canal [original name: Donaukanal] which has existed since 1598. (AEIOU Encyclopedia. 2001.) While Vienna has been protected from floods by the channel system [see Figure 27] for more than 400 years, some other cities in neighbouring countries, like Doboj in Bosnia and Herzegovina have serious problems.

In the year 2014, Croatia, Bosnia and Herzegovina and Serbia were seriously ruined by flash floods. Many people in those countries have lost everything. According to CNN international news, floods and rains in 2014 were the heaviest in last 120 years. (CNN international. 2014.) People from those countries are usually badly prepared for dealing with floods. Instead of planning for the future, they wait until the problem appears and then they try to solve it. They usually invest their whole lives and everything they own in a single family house which is built on a floodplain or flooding-prone area. [see Figure 26] After catastrophic disasters, people are forced to accept displacement, take loans and different kinds of support offered by the government, because they have nothing left. Doing so they weaken first themselves, then their city and after that the economy of whole country.

The importance of a secure home is very high. Home is the starting point of living. It is the main place of safety for its residents. Without a proper home, people can hardly do any other activity. Home must be secure, safe and continuous. To lose a home is very painful for anyone, especially small children.

All in all, flash floods are the most dangerous of the four kinds of floods. They often appear too fast and the inhabitants as well as government are not ready to react properly.

To conclude, fighting the nature is not the best solution. If flooding were to happen, buildings in the vulnerable area should be able to correspond to the flood – move up or down or simply be able to adapt in any way. The flood threat should be turned into an opportunity to explore new designing solutions, to improve water resources and to help people develop even further, not oppose something that is an unstoppable force.

Flood Types Summary

The table presented below is there to help identify types of floods one is dealing with and to allow an easier understanding of the semantic differences of the four flood types. It is a summation of the previous chapter that shows the most important characteristics of certain flood types.

When dealing with amphibious architecture and amphibious urbanism, one should first define the flood type that is happening at a specific site, after which

Figure 1 | A wrong place to build

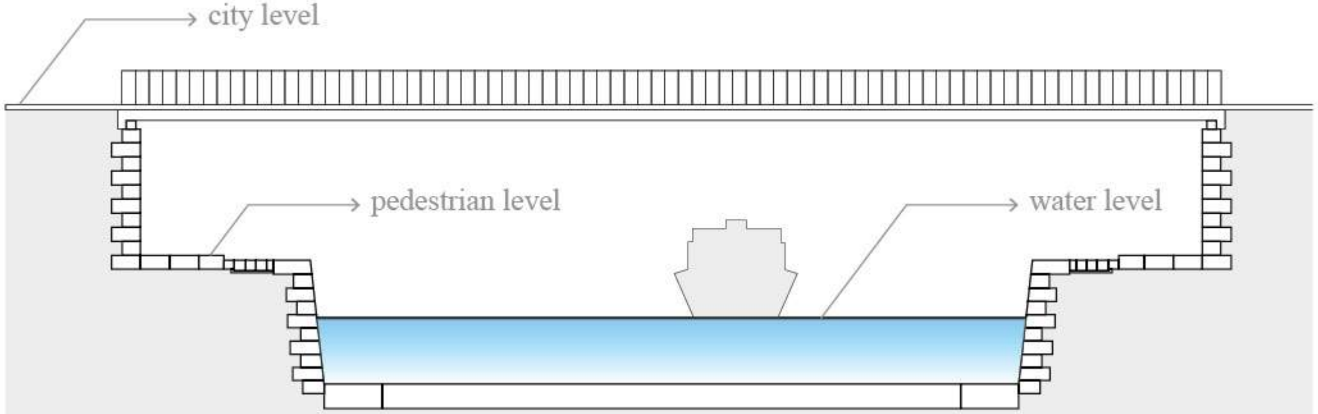


Figure 26 | Artificial "levees" – Vienna Danube Chanel [not to scale]

one can extend their research in a specific direction to fulfil the required questions (such as how high and how fast the water would rise at specific site, and how long the flood would last).

Table 1 | Semantic differential of four flood types

	Snow-melt	New devel-opment	Flash flood	Dams/ levees blow
When does it occur?	after a sudden snow melting	after rapid development	after heavy rain or overwhelmed river	when they reach critical pressure
Where does it occur?	valleys of the mountain	new urban areas	riverside; areas prone to rainfall	where the water level is the highest
Existing safety measurements	mechanical transport	dam, water channel	dam, water channel	evacuation
Common mistakes	throwing snow in the river	overloading of dams causes break	overloading of dams causes break	overloading of dams causes break

Overview and analysis of water dwellings systems

Living and building in flooding-prone and floodplain areas is not a new discovery. People have lived and built in flooding-prone and floodplain areas for hundreds of years – often it is a choice, but it can be a necessity as well. Through time, different types of flood control have been discovered, used and developed. In the past, people used to build different types of water canals, not only to protect themselves from the flooding, but also to irrigate fields. While building levees was popular among people from flooding-prone and floodplain areas for centuries, elevating houses on piles (so-called stilt-houses settlements) [see Figure 28] was extremely popular among many tribes in the past. (Alan W. 2008.) They would build elevated walkways and use them together with boats for infrastructure. Additionally, with this infrastructure, they could also protect themselves from attacks. In the past, certain remains of settlements in the Ljubljana Marshes (Slovenia) and at Mondsee and Attersee lakes (Upper Austria) led archaeologists to think that these were artificial islands, similar to those the Irish and Scottish Crannogs built. Nowadays, the belief is that these were built on lake shores, with the lakes later expanding and pushing their shores further out to give the impression of island dwellings. (Menotti F. 2004a.)

The foundation of water dwellings and how they relate to the water in question are two key aspects of their categorization; therefore, in order to better understand this urban project proposal, one must observe three water dwelling typologies:

1. water-based dwellings *(living on water);*
2. water-related dwellings *(living next to water); and*
3. ground-based dwellings *(living far from water, but influenced partially).*

Water-based and ground-based dwellings are very radical if observed through the constructions methods, while water-related dwellings are a combination of both, usually badly interpreted by designers.

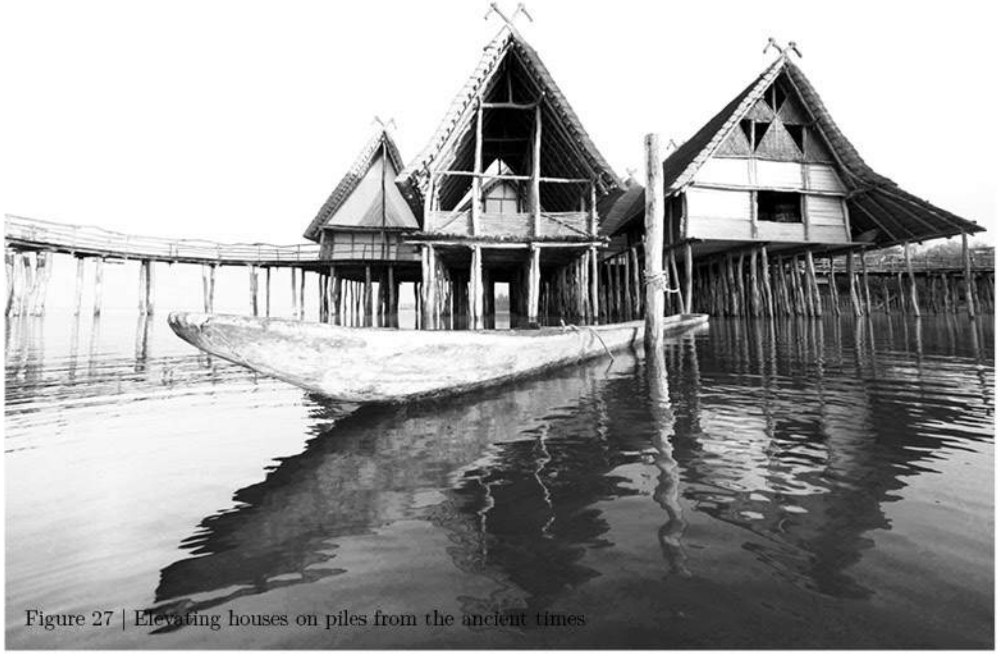


Figure 27 | Elevating houses on piles from the ancient times

Table 2 | Three building typologies designed to interact with water

Stationary buildings	Floating buildings	Mobile buildings
- building elevated on column - building on elevated platform - building on elevated island	- amphibious buildings - boat building - floating platforms	- boat building - floating platforms - floating islands
	Advantages	
easy to design; low costs; almost any building can be "attached" to the base; infrastructure integrations presents no problem	ability to move vertically – rise with the change of water level; connected to the coast through a bridge; project itself can be partially built on land	ability to move horizontally across the sea or river; flexible urban figure
	Disadvantage	
focus lies in the design of the base which support the building and if the base collapses, the whole building collapses; usually creates inappropriate environment	horizontal movements are not possible; they are stationary in their location; usually high construction cost	moving costs; maintenance of the engine room; possible breakdowns
	Problems	
if water rises above expected levels, serious problems occur	have direct contact with water (also possible to observe as opportunity)	legal issues (China: 不动产 immovable property – House cannot be moved!)

Water-based and ground-based dwellings are very radical if observed through the constructions methods, while water-related dwellings are a combination of both, usually badly interpreted by designers.

Those who build and live on the water from the very beginning are used to water. They approach building from a unique point of view. Construction techniques they use are different from the ones on the ground. Materials are light and flexible. In the past, the building material was various kinds of wood. One example are old stilt-houses on Austrian lakes, which rested on a supporting framework that was secured on the lake floor using pegs. There are cases where the elevation of the floor was only 20-30cm. Wooden construction elements combined in various ways allow for a large number and type of possible constructions. (Menotti F. 2004b.)

To make it clear, three building typologies, which are designed to interact with water, must be distinguished – stationary, floating and mobile buildings. [see Table 2] There is also 'the fourth one' – one which is not designed to interact with water but is located at flooding-prone and floodplain areas and very often faced with different kind of water rise. 'The fourth one' is the most problematic and this thesis will mostly deal with this one and how to solve its problems.

There are dozens of ways to deal with water rise and every day, new technology is developed. Living on water or next to water is more and more secure. Floating houses are very popular as luxury cottages. (The Architectural Review. unknown.) Many people enjoy these kinds of temporary living houses they use for vacation, and not only do they exist in modern times, they also existed in the past. Many tribes used to live in floating houses and some used to live even on floating islands. Interesting is that some of those floating societies still exist. There is a tribe in Peru called Uros, whose people build dwellings that are unique in the whole world. (Sumitra. 2013.) They are a type of special man-made floating islands [see Figure 29, 30, 3 and 32], and are called floating reeds. The Uros tribe was forced to develop special techniques which they use while building floating islands and their homes attached to them. From them we can learn how location is an important factor for not only for building methods, but also for building materials. The base on which they build (water) demands a light and flexible material which allows the island to bend and move along with the waves of water.

On the other hand, those who build on the ground, because of the building base, usually have the possibility to use very heavy and stiff construction materials. Ground buildings can exist for themselves without too much concern for the surroundings and, like all other kinds, these kinds of buildings also reflect the inhabitants and their habits and culture. Unfortunately, these habits and culture have impacted the living on the water as well. Nowadays people literally elevate buildings that are designed to be built on the ground and far away from water on column structures [see Figure 33]. This way, they separate the ground levels of the building from the ground area, and in some cases, they even put those buildings on barges so that the buildings can float on water if necessary.

This is not only a reflection of bad design, but bad


Figure 28 | Uros floating reed islands in Peru


Figure 29 | Connection between floating islands


Figure 30 | Uros people


Figure 31 | Inside Uros home

taste as well. Such buildings look like computer 'hardware plugin' that is not plugged like it should be. The space under the house is unused and lost. While on the one hand, they appear dramatic, on the other, those kinds of structures are nothing but skeletons without flesh and skin.

In architecture, all elements are interdependent of each other, and once properly arranged, they form the correct architectural composition. That composition is especially important in floodplains and flooding-prone areas because if it is not present, the problems inherent in the building area (e.g. rise of water) can produce serious damage and affect not only the building itself, but also the local economy and wellbeing.

Not to be mistaken, offsetting a building is not a bad concept; however, the way that the building is designed can be. This is primarily what reflects the quality and value of a specific building. The beauty of architecture is that 'there is no generic building'. A building cannot be copied from e.g. Asia to Europe 1:1 without being adapted to the site. Almost every building site demands a custom design only for itself, and only when those demands are followed, the harmony can be established – only then will function, form, design and logic be in balance.

The Teahouse is the project of the Chinese Pritzker Prize architect 王澍 (Wang Shu) located in the East lake scenic area next to the water. The building site is about 3.000 m^2. His design reflects traditional mountain building. The function of this building is mainly the painting and calligraphy exhibition and cultural studies. (AoWeiBang. 2014.)

If the water level rises, the building will stay protected by the elevated structure. The building is designed so that the offset from the ground is big enough to protect it from the high level of water. The water rise in this case was studied and calculated so that the building offset can be big enough. When the water level is at its normal position, the space underneath the Teahouse is considered not only as part of a pretty design, but also as a space used to protect the building from overcooling in the winter and overheating in the summer. Not only acting as protection and isolation, the space is usable and has a function.

Figure 32 | Elevating houses on column nowadays

The beauty here is that by pushing the building up off the ground level, the architect did not only solve some of the natural problems, but also amplified the importance of the building itself.

Water Dwellings Systems in the Past

When working with flood resilience, modern society can learn much from historical examples of many different strategies used to very often prevent a problem even before it happened. In the distant past, people from rural areas have utilized early amphibious solutions to overcome intermittent flooding and protect their property, different approaches towards combating flooding appeared. Some of the solutions proved to be very effective while others did not, and some of them still exist in new and developed forms. This chapter will cover the ones relevant for amphibious architecture urban desegregation. The following dwellings systems were stimulators for further development of architecture in floodplains and flooding-prone areas and through time effective building model suited for both land and water that we today call the amphibious building.

Wurt Dwellings

A Wurt, also known as a woerd, terp, or warf, is an artificial dwelling mound.[see Figure 35] The main function

Figure 33 | Teahouse, 王澍 (Wang Shu)

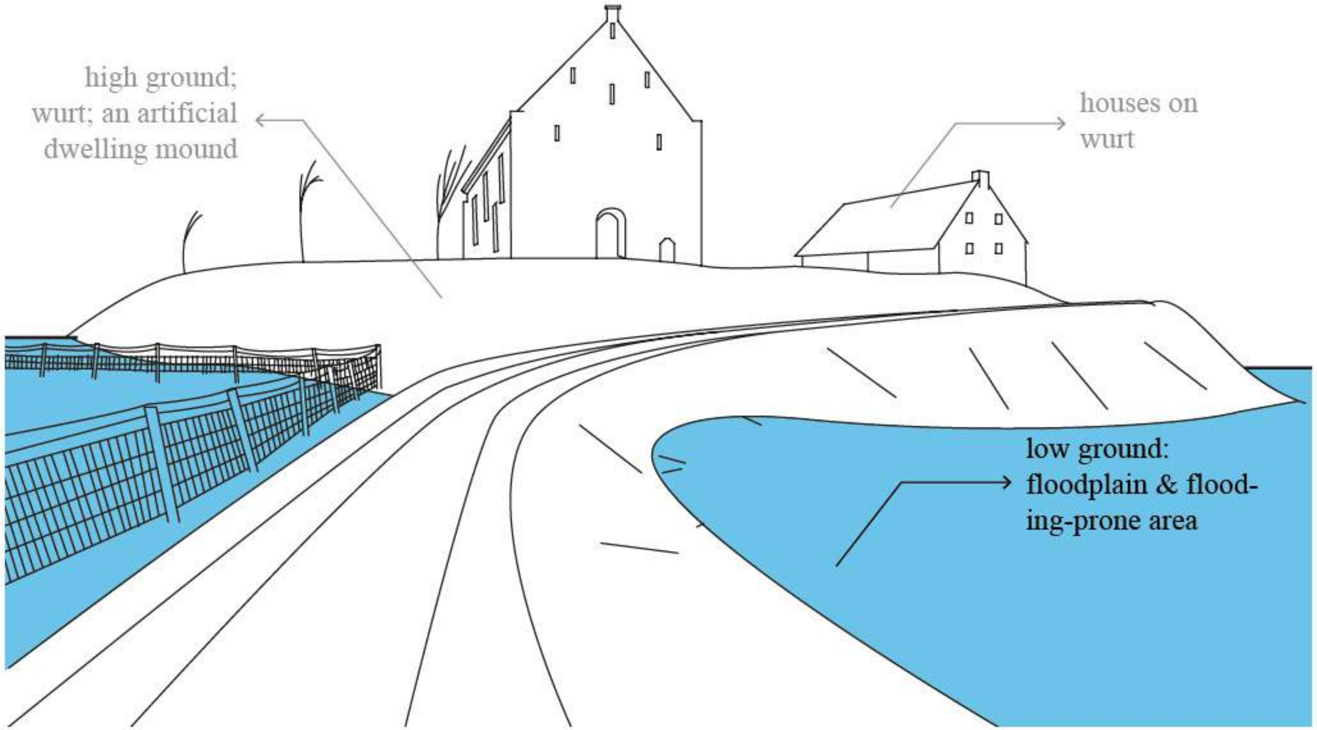


Figure 34 | Wurt dwellings

of the wurt is to provide safe ground during heavy storms, high tides and sea or river flooding. It can be found on the North European Plain (in the coastal parts of the Netherlands, in southern parts of Denmark and in Germany). An artificial dwelling mound in the Dutch province of Friesland is called terp.

Historical settlements were built on artificial mounds up to 15m high. By doing so, those settlements were protected and safe from the floods. The first wurts were built in between 500 BC and 1200 AD.

Floating Reeds

Reed, a tall, slender-leaved plant that grows in the water, is used by Uros people as a construction material. Uros people live on lake Titicaca, which is the largest volume-wise in South America, and is a good protection in itself because it is located about 3000m above sea level. However, throughout history, Uros people needed even more protection from other tribes. Therefore, they created a system of floating domiciles that can quickly move away from the mainland in case of the emergency – the so-called floating islands. [see Figure 36] In order to protect themselves from other stronger tribes, Uros people have lived on these floating islands for many years in past. Today they still live on them, not because of protection, but because of tradition. (Sumitra. 2013.)

Reed is a proven flexible building material. Uros people were able to hammer it or press it into shape without breaking it or cracking it. They used local materials to construct and build different kinds of structures such as floating platforms, houses, boats, accessories and so on.

By twisting the reed together into a dense mass called 'root', Uros people developed floating islands on a layer about 2m thick. [see Figure 36] The stability of the floating island is achieved by attaching the ropes from one side of the floating base to the base of the lake.

Because reed leaves rot quite quickly, maintenance is constant. They must be replaced four times a year, while the floating structure itself can last for up to 30 years. (Kaushik. 2011.)

Because of all the things they are doing to survive and the way they are doing them, Uros people have learned to live in great harmony with their surroundings. They can be called a 'perfect community'. Furthermore, because of their way of life, they make no negative impact to the surrounding and nature. (travelshorts. 2012.)

Stilt-houses in Past

The stilt house is one of the oldest forms of housing that existed even at the time of the beginning of agriculture. It comes from the tropical regions of both southeastern Asia and North and South America. Its primary feature is a very effective way of fighting the humid tropical climate by creating a natural cooling system using verandahs, large openings for windows and doors, raised design and roofs that are ventilated. It can also be built so that parts of it can be moved without destroying them, which is very useful in regions that have rotational agriculture and so require people to move from one agricultural plain to another. These stilt houses are the forerunners of stilt bungalows primarily accommodated for the use by Europeans. (James, H.P. & Tufts University. Department of History. 2001.)

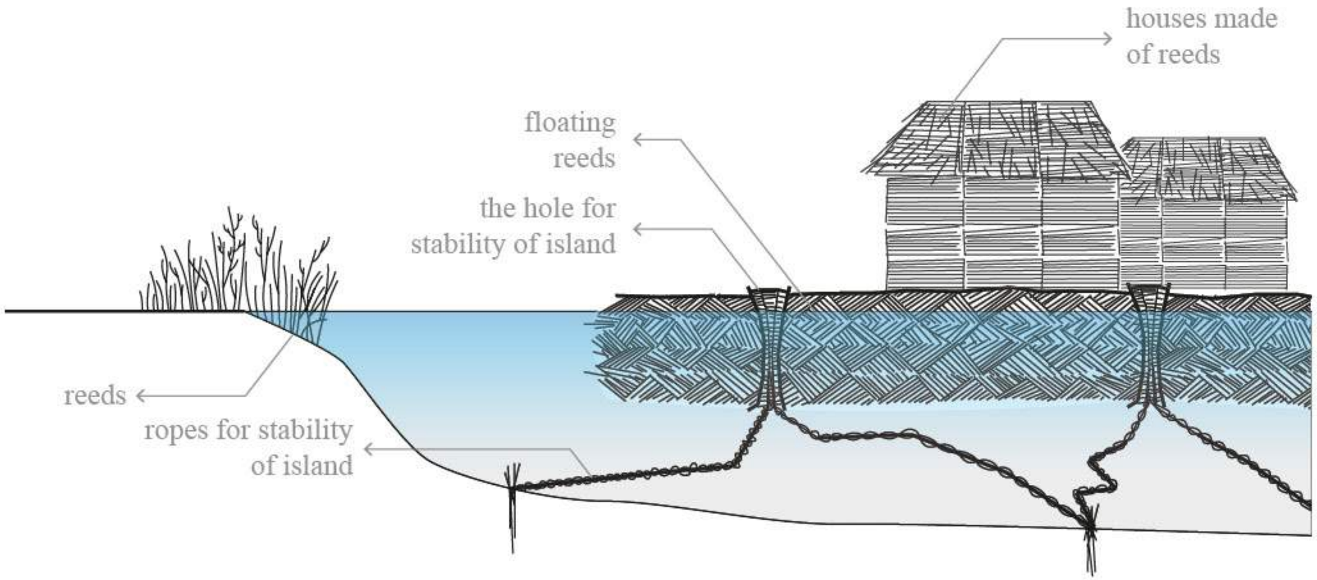


Figure 35 | Floating reeds – island section [not to scale]

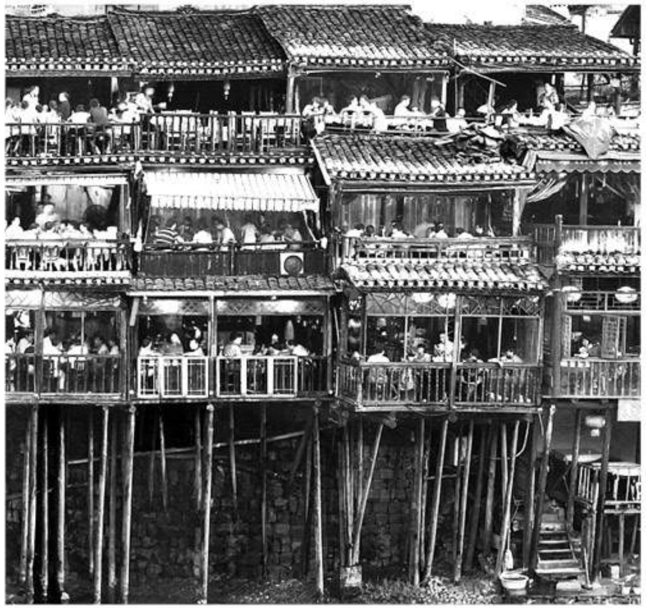


Figure 36 | Stilt house (diaojiao house) along the River, Fenghuang Ancient Town

Water Dwellings Systems in The Present

At the present time, different systems such as static elevation, houseboats [see Figure 38], buildings on barges, floating platforms, amphibious buildings and low-impact development (LID; in China: 'sponge cities'), can be found. Some of them are very simple and cheap, however very advanced systems are also popular and just as effective.

Static Elevation and Open Ground Floor

Static Elevation is a common system for flood-protection. It can be defined as an evolved version of

Figure 37 | Floating Houses Ijburg

stilt-houses. [see Stilt-houses in Past] It is only effective when the offset from the ground is higher than the highest possible rise of water. The building is elevated from the ground by lifting the house and building anew; extending the existing foundation below it; or leaving the house in place and either building an elevated floor within the house or adding another floor.

Such examples can usually be found as solutions for very large buildings located next to the sea where the appearance of the tsunami is a possibility. Those kinds of buildings belong to the super-category of so-called tsunami-proof buildings. [see Figure 39] What both have in common is that the first level can be flooded, which allows an enormous amount of water with big pressure to go through the building without destroying the structural parts of it.

More words on static elevation will be in the next chapters.

Stilt houses nowadays

Stilt houses (also known as pile dwellings or palafitte), as already mentioned in text before, are types of buildings that are raised on top of wooden, concrete or steel column structures. [see Figure 40] Even though they are a very old system from the past, they have persisted into modernity. (James, H.P. & Tufts University. Department of History. 2001.) Before the modern technology was invented, the methods and equipment used to construct stilt houses were simple and time-consuming; with the advance of technology, the methods and equipment that have been developed are precise and very quick, with contractors specialising in installing driven piles safely and adequately. (Arafati N., Fazli A.H., Mousavi S. M., Rouzmehr F. 2012.)

Stilt houses can be found in low water, coastal areas, or lakes, where fluctuations in the water level can easily be predicted. The living area is offset from the base level (ground or water) 1,5m to 5m on average. Not only can the Stilt houses resist floods, they also allow house owners to build on rocky, steep or unstable land. This way of building also keeps animals and vermin out, provide ventilation under the house and minimize the footprint of the house. Several types of columns,

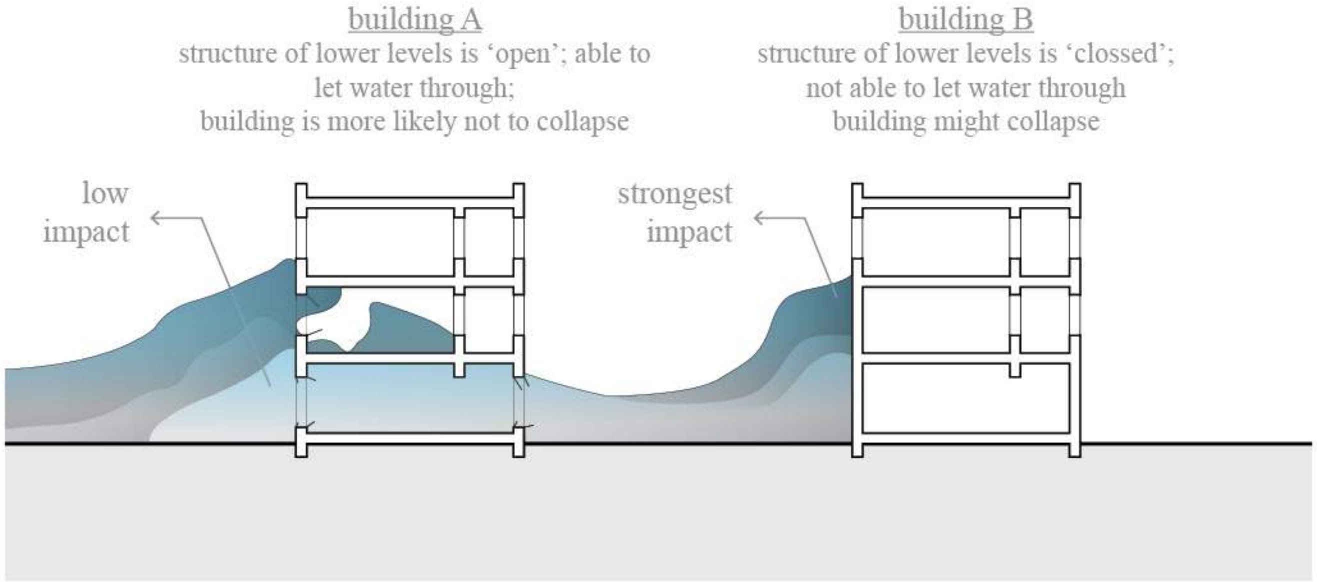


Figure 38 | Static elevation [not to scale]

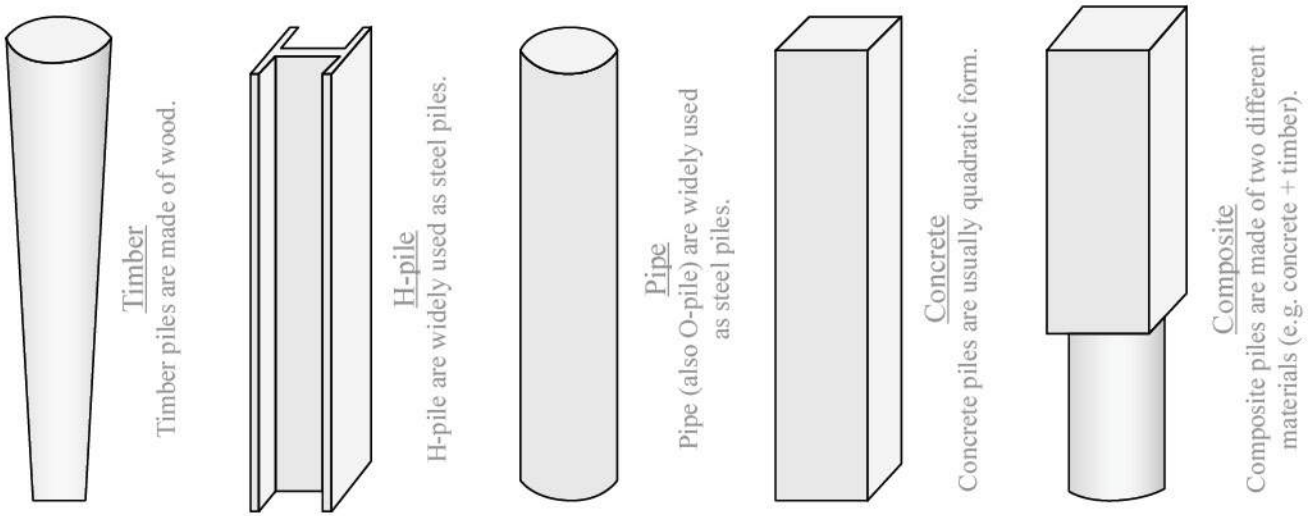


Figure 39 | Pile foundation [own illustration] such as timber, h-pile, pipe, concrete and composite foundation, are used frequently in the construction of stilt houses. [see Figure 40]

Timber pile foundation has been in use for about 6000 years and, because it has been proven to be a very convincing foundation structure, it is one of the most usable types. Timber pile foundation is a sustainable system with renewable resources. Wood is a light material, which means that the timber pile is light also, which gives it an advantage in transportation. When timber piles are used as underwater foundations, they are expected to last thousands of years according to the U.S. Federal Highway Administration. The part above water, when properly prepared and treated, can last more than a hundred years. (James G. Collin, PH.D., P.E. The Collin Group, Ltd. 2015.)

Concrete pile foundation is either prefabricated or built at the site. It can be reinforced, pre-stressed or plain. Concrete pile foundation is often recommended over the steel piles due to their high corrosion risk. They are affordable and convenient because of their long lifetime.

Steel pile foundation is very practical for building – multiple steel pile foundations can be easily joined one to another. Their lifetime is up to 100 years, but they are prone to corrosion, especially when they are partially planted underwater.

Houseboats

Houseboats started with the adaptation of ships and fishing boats into living units. From the outside, they usually look like a normal house on land. The difference is that these kinds of buildings either float on water or eventually move horizontally on the surface of water base. There are two design types: boats adapted to everyday living and regular buildings with a boat-like base. The second type is usually built on a barge (a flat-bottomed boat built mainly for river and canal transport of heavy goods), but it can be built even without a barge under the building structure. [see Figure 42]

Houseboats are usually built from wood, but they can be from concrete as well – UHPC (Ultra High Per-

Table 3 | Pile foundation features (James G. Collin, PH.D., P.E. The Collin Group, Ltd. 2015.)

Pile Type	Timber	Steel H-Pipe	Steel Round Pipe	Pre-Cast Pre-Stressed Concrete	Cast-in Place Concrete Mandrel Driven Shell	Cast-in Place Concrete Shells Driven Without Mandrel
Typical Length (m)	5-25	5-30	10-35	10-15 (Precast) 15-35 (Prestressed)	3-35	4,5-25
Typical Axial Design Loads (kips)	35-150	100-400	200-500	100-250	100-300	100-300
Advantages	- low cost - renewable resource - easy to handle - easy to drive - pile length variations easily accounted for - tapered section provides higher resistance in granular soils than uniform piles - use as friction or end bearing pile	- easy to splice - high capacity - small displacement	- open ended good against obstructions - high load capacity	- high load capacity - corrosion resistance obtainable	- initial economy - trapered sections higher provide higher resistance in granular soils than uniform piles - can be inspected after driving	- can be redriven - shell not easily demaged
Disadvantages	- dificult to splice - low axial capacity	- vulnerable to corrosion - not recommended for friction pile	- displacement for closed end pipe - open ended not recommended as friction pile	- vulnerable to handling damage - high breakage rate - high initial cost	- difficult to splice after concreting - thin shell vulnerable during driving - considerable displacement	- difficult to splice after concreting

Figure 40 | Watervilla De Hoef — The Netherlands

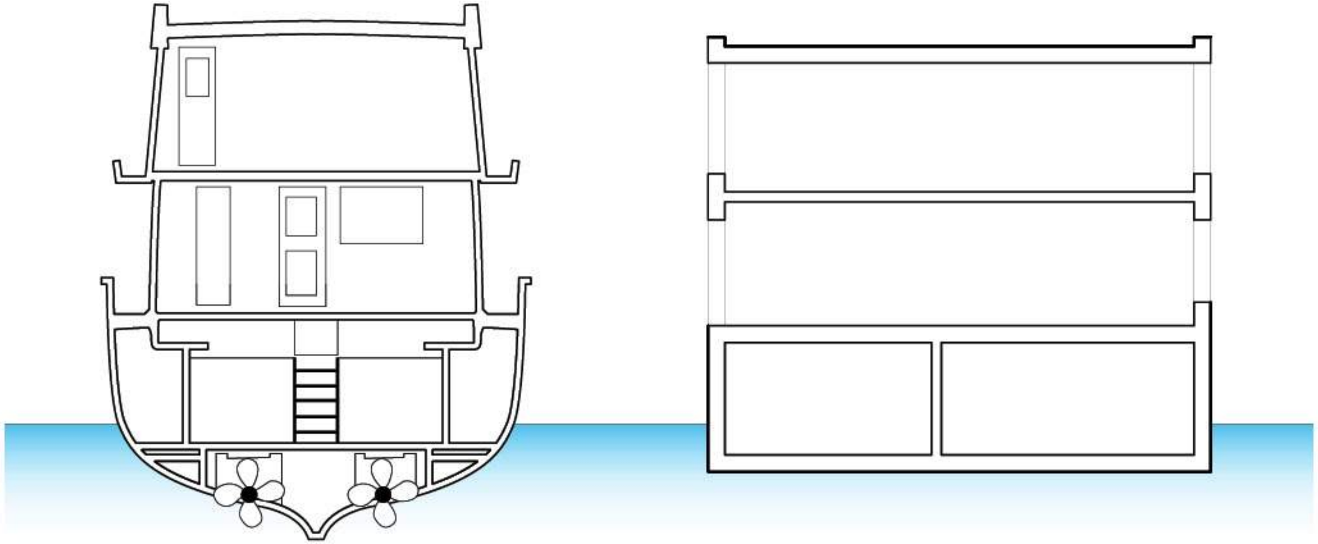


Figure 41 | houseboats – two main types [not to scale]

Figure 42 | Adol Floos at the Danube, Vienna [TU Wien]

formance Concrete) that is distinguished from normal concrete due to its increased compressive strength and durability (h1arch. 2015.), has been proven to be the most convenient concrete type. UHPC was developed in Europe in the 1980 (TAKTL. 2016.) for applications that demand superior strength and corrosion resistance. Compressive strength of UHPC is bigger than 150 kPa.

In the year 2015, an architectural student group from the Technical University of Vienna, together with Manfred Berthold, Karl Deix, Johannes Kirnbauer, Peter-Michael Schultes and Jürgen Hennicke conducted research on experimental building construction with UHPC in a project 'Betonkanuregatta', where they tested UHPC in the field. A concrete (UHPC) boat ('Adol Floos', name given by TU team) in 1:7 proportion (width 70cm to length 4,9m), weight of 34 kg, density of 2000 kg/m3 was built and tested by the team, which the author was a part of, on the Danube river. [see Figure 43]

From the experience the author had at the Technical University of Vienna, he was able to conclude that concrete is absolutely capable of floating and carrying things on the water and that it is not the material but the shape, proportion and design which define if the constructed structure will float or not. So, with all this presented, the fact that a concrete building is floating on water can be easily accepted and a building such as Arctia Headquarters in Katajanokka, Helsinki, Finland from K2S Architects (K2S Architects. 2013.) (Architect in Charge: Kimmo Lintula, Niko Sirola & Mikko Summanen; Construction Designer: Eero Kotkas) does not look unrealistic anymore. [see Figure 44]

More than 2,000 years before the first concrete boat was successfully made, the Greek scholar Archimedes discovered, according to traditional storytelling, the so-called 'Archimedes' principle':

> *"Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object." —Archimedes of Syracuse*

This principle is utilized in the design and construction of all boats, including concrete boats and of course in

Figure 43 | Arctia Headquarters, Helsinki

houseboats as well.

These days, houseboats can be found all around the world. Sausalito, a city just north of San Francisco, is famous for being one of the region's primary aquatic living centres, with many marinas acting as mooring locations for houseboats of people living various lifestyles. Often, people who live in houseboats are of the type who prefer a do-it-yourself (DIY) lifestyle. (PROVIDENCE Journal. 2015.)

The following are examples of some interesting houses from different parts of the world. [see Figure 45, 46, 47, 48, 49, 50, 51 & 52]

Figure 44 | Houseboat in Coimbra, Portugal

'This beaut of a houseboat, known as the Floatwing, was created by a group originally affiliated with the University of Coimbra. The group has since rebranded as Friday, though it's still comprised of the same naval architects, engineers, and industrial designers as before. The team specializes in the very specific niche market of personal submarines and prefabricated floating homes, and constructs made-to-order houseboats that vary between 33 and 59 feet in length. While some of the more deluxe Floatwing packages include a solar-powered motor, even the regular homes are built to be self-sufficient for at least a week. Personal BatSub sold separately.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift. [ONLINE] Available at: http://peppermunch.com. [Accessed 1 September 2016].

Figure 45 | Butt's Clermont Houseboats — Lake Dal, India

'The four Butt's Clermont Houseboats, however, are arguably the most famous. Beyond the intricate woodwork and the breathtaking views of the Himalayas, the laundry list of former celebrity guests who've briefly called the houseboats home is quite impressive.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift. [ONLINE] Available at: http://peppermunch.com. [Accessed 1 September 2016].

Figure 46 | Port X — Prague, Czech Republic

'This unique houseboat comes courtesy of the ambitious Port X project. The "C"-shaped design helps create the floor, roof, and rear wall of the structure, and a glass facade encloses the building with an unobstructed view of the River Vltava. The sleek, modern design also serves as a wonderful contrast to the surrounding rotunda and Romanesque architecture of the city, while its intuitive design allows for easy assembly, deconstruction, and relocation.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift. [ONLINE] Available at: http://peppermunch.com. [Accessed 1 September 2016].

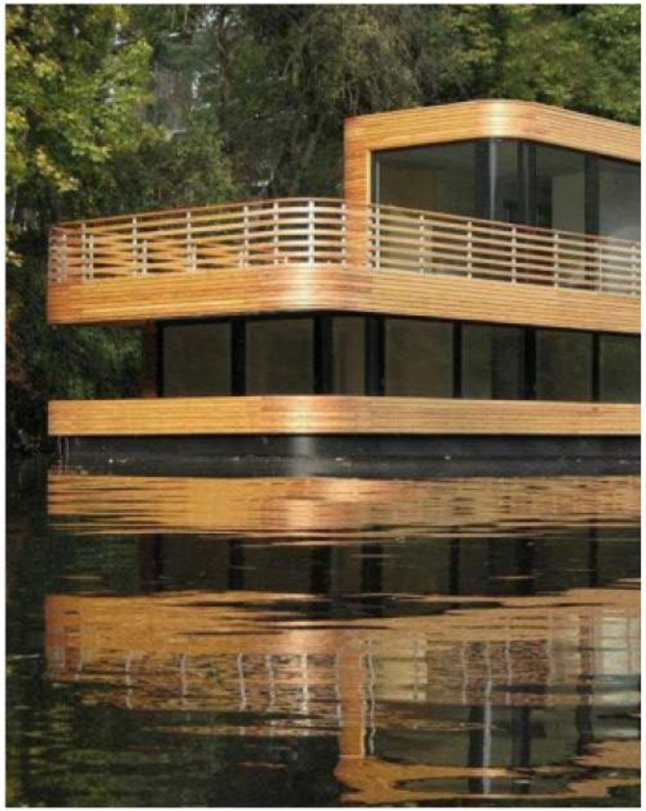


Figure 47 | Traumfänger — Hamburg, Germany

'Though more of a glorified barge due to its immobility, this gorgeous house comes from the brilliant minds at Hamburg's own Rost Niderehe architecture firm. Rost Niderehe put its signature modern touches in every corner of this houseboat, which touts gorgeous timber siding, an open back deck, and private bedrooms and bathrooms. Constructed in 2011, this home won the architecture firm a smattering of construction awards and recognition for its gorgeous style and sleek exterior finish. This beauty resides in the Eilbek Canal in Hamburg, Germany and likely won't acquire a new address any time soon, since it requires the help of a tugboat to get around.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift. [ONLINE] Available at: http://peppermunch.com. [Accessed 1 September 2016].

Figure 48 | Villa Näckros — Kalmar, Sweden

'Located in the town of Kalmar on Sweden's east coast, this contemporary houseboat offers incredible waterfront views, a spatial floorplan, and an incredible top-floor deck perfect for catching a sunset. With six bedrooms, just over 1,900 square feet of living space, and a technologically advanced kitchen, this home oozes luxury and affluence. The residence weighs in at a sturdy 165 tons, assuring no amount of wind, large waves, or floating ice have the ability to knock this marvel off its rocker. Owners also have access to roughly 1,000 square feet of rooftop-garden space, as well as an aluminum mooring bar fit for the fastening of any small boat.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift. [ONLINE] Available at: http://peppermunch.com. [Accessed 1 September 2016].

Figure 49 | Ar-che — Lusatian Lake District, Germany

'German architectural firm Steeltec 37 designed this charmer, which resides in a chain of artificially created lakes called the Lusatian Lake District. Steeltec 37 seemed to have a bit of fun with the production process, outfitting this vacation home with a curved roof, giving off the impression of an inflated sail on a sailboat. Because of the lack of shade and relative openness on the water, the home came standard with sliding, slatted screens on the exterior to help soften strong reflections coming off the lake. While capable of withstanding even the harshest of elements, its sturdy aluminum exterior also blends in perfectly with its surroundings. Moreover, because it's a vacation rental, any wandering soul has the opportunity to enjoy these digs next time they travel to the southern part of Brandenburg, Germany.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift.
[ONLINE] Available at: http://peppermunch.com.
[Accessed 1 September 2016].

Figure 50 | The Exbury Egg — Beaulieu River, UK

'The Exbury Egg may not look like houseboat ... but what this houseboat lacks in bells and whistles it makes up for in sweet, sweet solitude. The Exbury Egg is an efficient, self-sustaining collaboration between the SPUD group, PAD studio, and artist Stephen Turner, one that remains tethered on the River Beaulieu in southern England. Rising and falling with the tide, the Egg looks to be a unique place to zen-out and ponder life's more perplexing questions.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift.
[ONLINE] Available at: http://peppermunch.com.
[Accessed 1 September 2016].

Figure 51 | ParkArk — Utrecht, Netherlands

'ParkArk is the creation of the Rotterdam-based firm BYTR Architects. Unlike many of the exploratory, prototype houseboats out there, this model actually serves as a family residence. The owners of the ParkArk previously lived aboard a steel ship and requested that the the firm attempt to recreate the feel of their last home while incorporating an updated, modern aesthetic. The copper sheets that make up the lower exterior nearly graze the water, allowing the design to parallel that of the canal. A large skylight also floods the house with natural lighting, while a green roof further melds the structure with the surrounding shrubbery.'

Sunil John. 2016. Unreal houseboats that will set your imagination adrift.
[ONLINE] Available at: http://peppermunch.com.
[Accessed 1 September 2016].

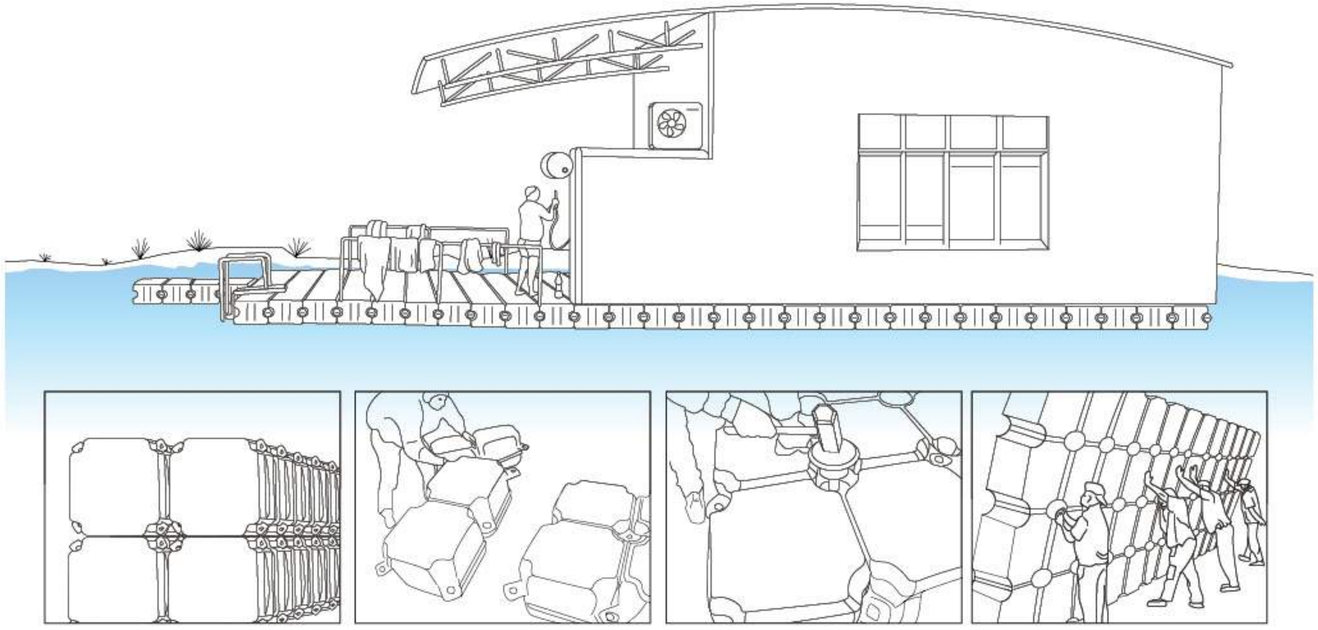


Figure 52 | | modular platform assembly; weekend cottage

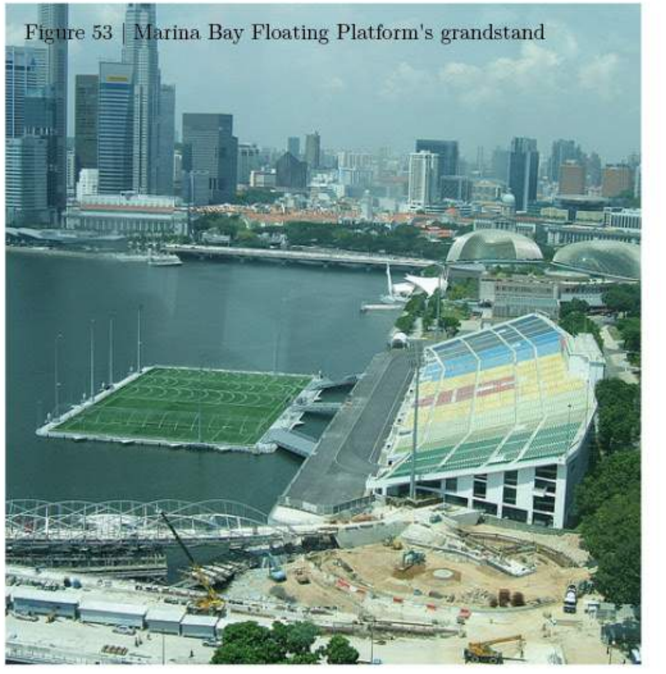


Figure 53 | Marina Bay Floating Platform's grandstand

Platforms; floating platforms

Even though the large bulk of modern construction is located on dry land, building on water has also been utilised. The basis of on-water construction are floating platforms that can serve purposes of various kinds.

At the present time, different kinds of platforms related to the water (such as modular, static or jack up) are in use. Some of them are used as an open space, a building base, a docking bay and a pedestrian walkway (additionally, there are also floating pump platforms, small pile drivers, drilling platforms, movie sets, painting work barges, feed barges, advertising sets, houseboat/houseboat floats, temporary accommodations systems, sewage pumping stations, floating restrooms, floating campsites). The floating dock, built from modular parts of floating cubes, is very popular in China according to Xinyi Floating Dock. (Xinyi Floating Dock. 2016.) The dock structure created form cube modules is very flexible, light and easy to assemble. They can be used as a temporary solution or even as a solution for longer periods (e.g. small weekend cottage).

Not all of the platforms are flexible and lying on the water. Similar to stilt houses, kelong is a fixed platform, offset from the water, built predominantly with wood. It can be found in the waters off the coast of Malaysia, the Philippines and Indonesia. Fishermen, commonly for fishing purposes, but also as dwellings, use kelongs if they are large enough. (Wikipedia. 2014. Kelong.)

Types of Floating Platforms:

- Spar Platforms – suitable for harsh environments with ice and cold temperatures

- Semi-Submersible Platforms – suitable for mid-range and deep water production and drilling

- Tensioned Leg Platforms – suitable for supporting dry trees and is cost effective

- Extendable Draft Platforms – suitable for ocean science measurements and hydraulic power

Floating platforms do not require ballasting or the use of excess materials in their construction, which makes them different from barges and large ships. Though they're cost-effective, their use is limited by the loads they can hold, as they have relatively low buoyancy. To achieve more buoyancy, air tanks can be added in the cavities and on their sides, so long as they do not impact the ability of the floating platforms to withstand high winds and waves in cases of strong storms.

Floating platforms have a place in residential real estate, as there are various benefits and perks to living near or on the water for the homeowners, and especially given that experienced construction companies are able to build foundations, housing structures ferry landings, gangway platforms and fuel stations on the water.

Concrete floats are popular as support structures in this type of architectural design because of concrete's strength and stability, so long as they are buoyant, level, with in-floor insulation and heating, and are varmint-free. Most such floating platforms are constructed

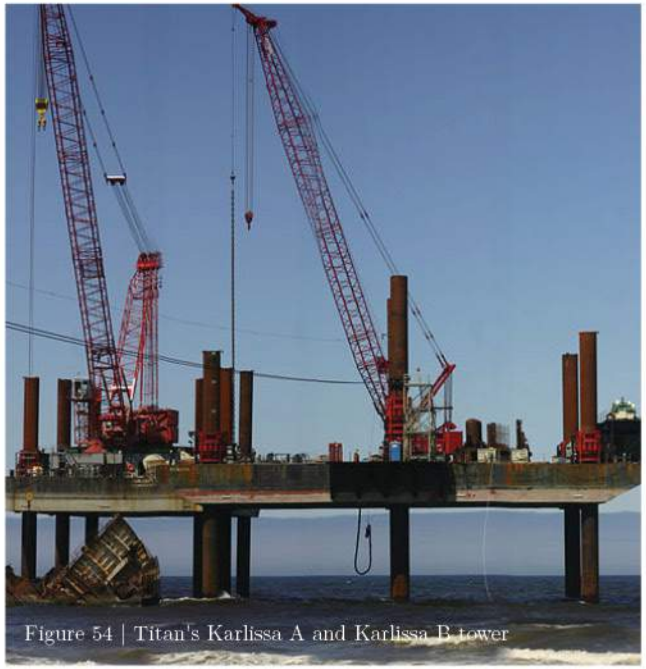


Figure 54 | Titan's Karlissa A and Karlissa B tower

at the depth of 1,5 m, though they most often require only about 1 m for floatation. They are so effective that they can be used for large venues, an example of which is The Float at Marina Bay in Singapore [see Figure 54], used for exhibitions and concert performances.

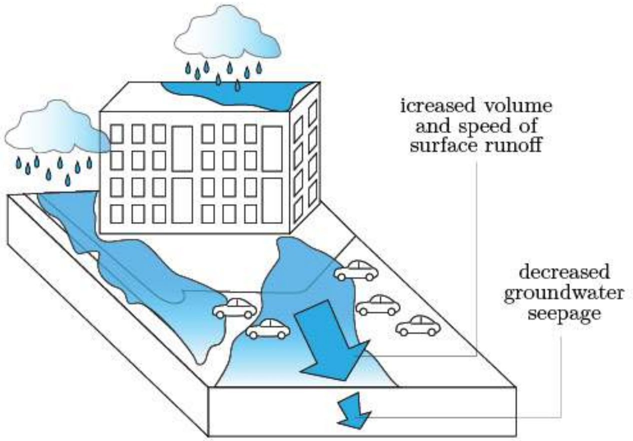
Another modern kind is a jack platform [see Figure 55], which is the type used mostly for offshore drilling and wind farm service platforms. They are one of the most popular types of mobile platforms. Notwithstanding the fact that jack platforms have many advantages – are strong and easily carry heavy weights – they have some serious disadvantages, such as the mechanism that requires extra energy for the platform to move vertically. Also like many other mechanical things, jack platforms require constant supervision and maintenance, raising the question of considering economic profitability.

LID; 'sponge cities'

Low-impact development (LID), as it is called in Canada and the United States, is a design approach to land planning and engineering specifically targeting the handling of and dealing with stormwater and other water runoffs as part of a city's infrastructure, with the main aim to work with the natural resources to conserve the landscape and protect water quality. [see Figure 56] This approach in China is defined as a 'sponge cities'. 'Sponge cities' are more and more popular every day given that all the world's countries, and especially China, are facing rapid development of big cities. [see Figure 57] This development's negative impact on the nature is in large part the cause of a rising number of floods in human-populated areas – the so-called new development floods.

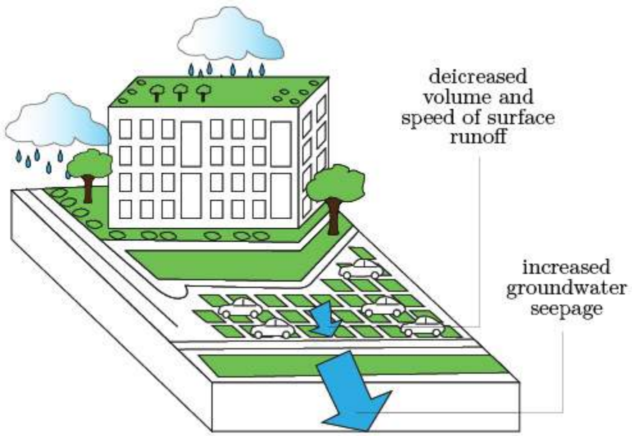
The main function of 'sponge cities' in China is to filter that water and enable the flow by providing necessary infrastructure. Consequently, different underground reservoirs and artificial canals are built to accommodate the water's movement. The whole system is called 'sponge cities', as it acts literally like a sponge – it collects the large amount of water when it appears, stores it in a suitable place and, when appropriate, channels that water further into different systems.

IMPERVIOUS SURFACE



Imperial 'hard' surfaces (roof, roads, large areas of pavement, and asphalt parking lots) increase the volume and speed of stormwater wunoff. This swift surge of water erodes streambeds, recuces groundwater infiltration, and delivers many pollutants and sediment to downstream water.

IMPERVIOUS SURFACE



Pervious 'soft' surface (green roof, rain gardens, grass paver parking lots, and infiltration trenches) decrease volume and speed of stormwater runoff. The slowed water seeps into the ground, recharges the water table, and filters out many pollutants and sediment before they arrive in downstream waters.

Figure 55 | Impervious and Pervious surfaces

'The diagram left, from the University of Maryland's Integration and Application Network, shows a conventional stormwater situation on the left, and a low-impact develop situation on the right.

Essentially, applying LID means thinking creatively about where to allow water to absorb in the city or town. In a natural area, such as a forest, there are so many places for water to go. If you've ever felt rain fall from the leaves of a tree long after the rain has stopped, you can begin to imagine how much water a forest can hold. In a city though, we have to recreate places where water can hang out, and slowly evaporate or seep into the ground to form our groundwater. And we need to recreate these places everywhere we can. The water quality of our lakes, rivers and harbours will improve and our groundwater quantity will increase only when LID is everywhere. Every property owner needs to think about recreating these pockets for water to go.' University of Maryland's Integration and Application Network, (2014), LID [ONLINE]. Available at: http://managingstormwater.blogspot.com [Last Accessed 9 June 2016]

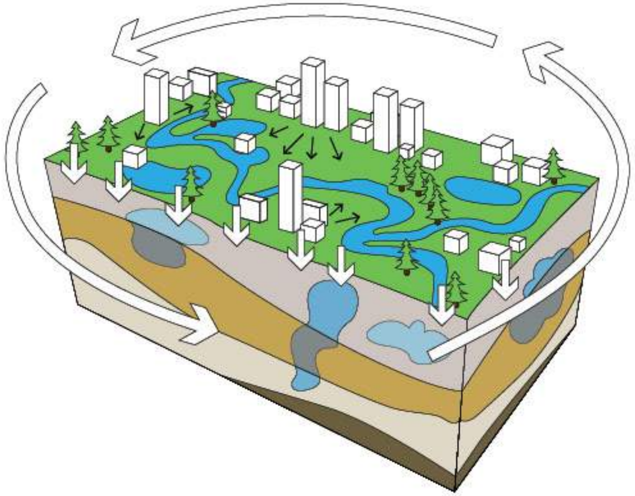


Figure 56 | sponge city

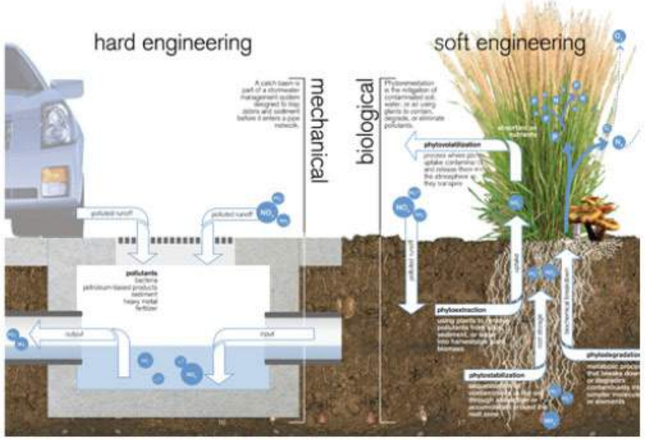


Figure 57 | LID; Street section

Figure 59 | LID; Street section II

'According to en.people.cn, 'China has set a timetable for its "sponge city" program, which seeks to help cities better absorb rain to improve the environment, an official said on Friday. By 2020, 20 percent of cities should have modern sewer systems and infrastructure that allows for efficient absorption of water, with the number rising to 80 percent by 2030. About 130 cities across the country have mapped plans to turn themselves into sponge cities so far, said Vice Minister of Housing and Urban-Rural Development Lu Kehua. The program will see the construction of high-level urban sewer systems, new roads, residences, industrial parks and public green areas, according to a statement released after a State Council executive meeting on Sept. 29. New sewer systems will drain rain water quickly and guide it to collection facilities for recycling. The government encourages private investors to participate in the construction of the new sewer systems and asks financial institutions to provide support. Heavy rain often results in floods in cities with outdated sewer systems. In one case, 79 people died in Beijing after a rainstorm on July 21, 2012.' (Xinhua. 2015.)

Figure 58 | LID; Green Infrastructure

Figure 60 | LID; Roof

When implementing LID, different functions are activated in the urban space. A good example is the chart that was made by NL Urban Solutions. Quality of space will be increased. New ways of integration will appear.

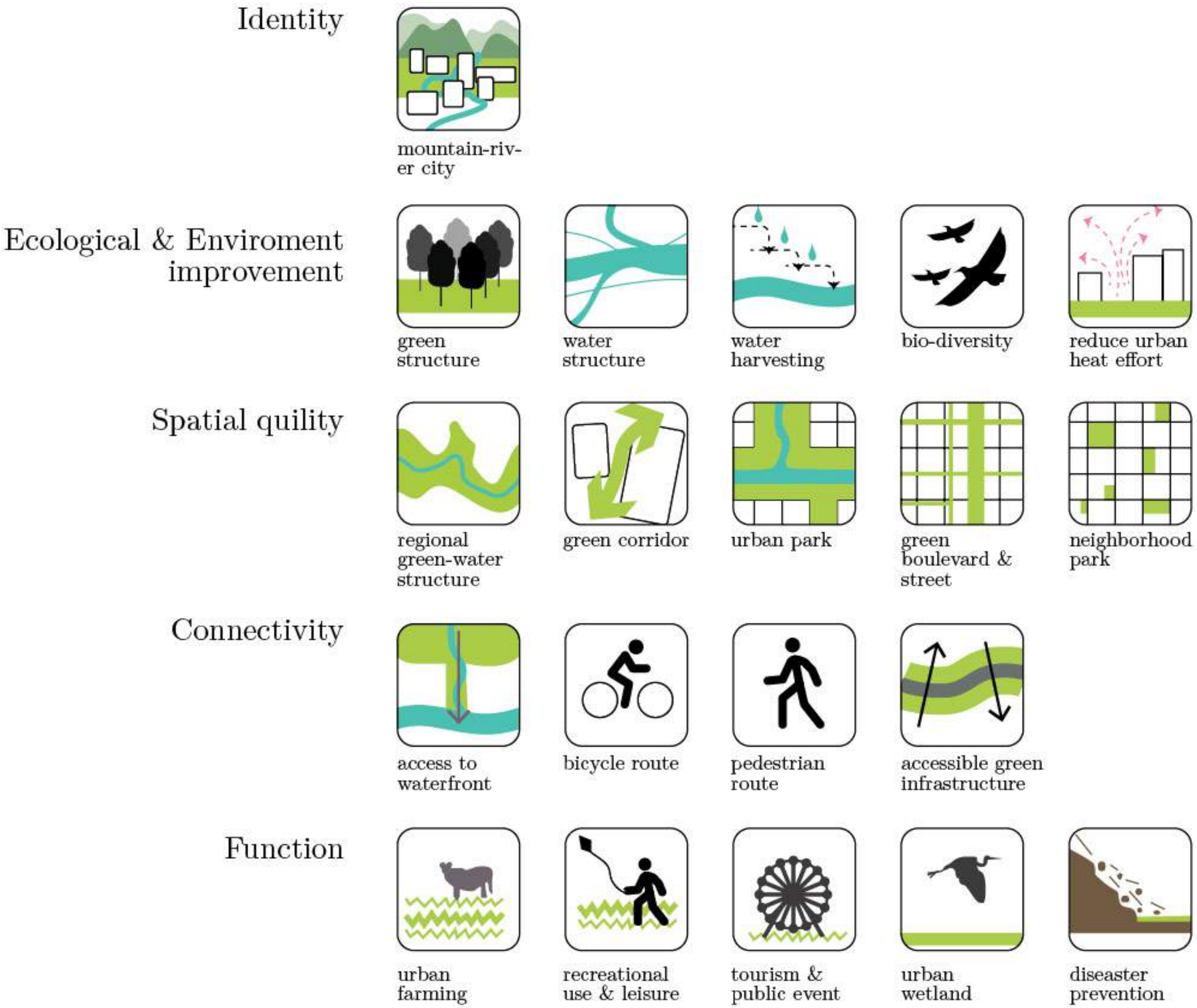


Figure 61 | Different functions in LID by NL Urban Solutions

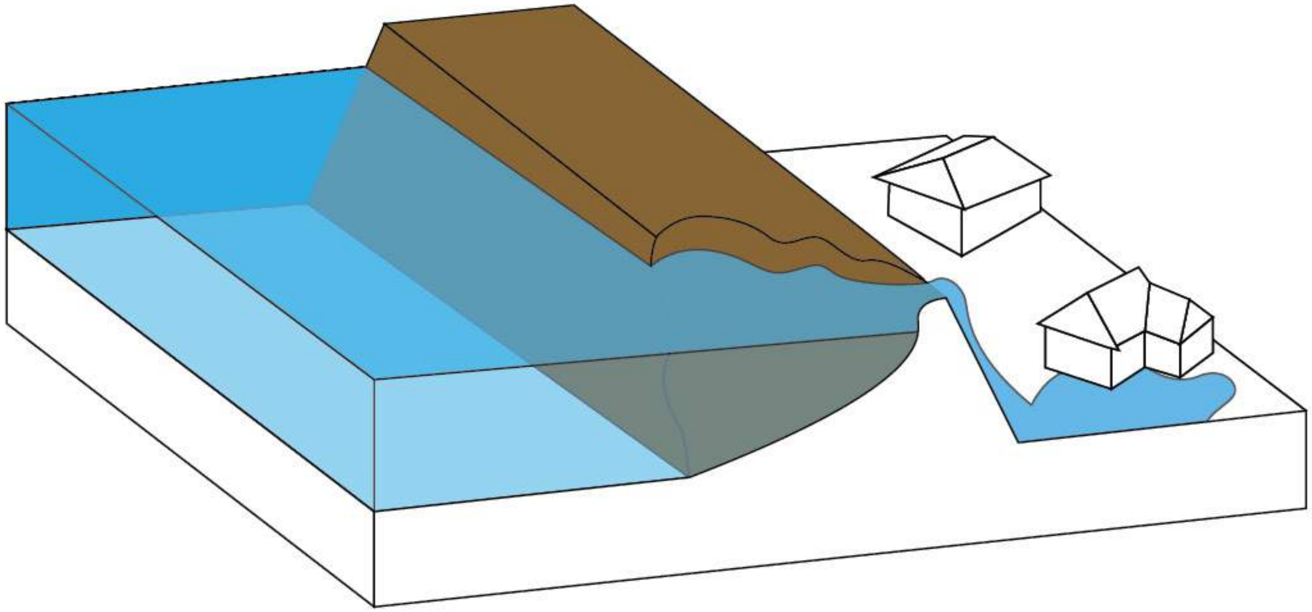


Figure 62 | Levees create a problem when they break.

Land protection techniques

At the very end of the Dwellings Systems Overview, it is important to mention land protection techniques as well. When it comes to land, it is hard to decide if the protection is the best solution or not. It is very often used as a solution for new development floods – cities and their inhabitants are protected from those floods by protective barriers or, if there is a river nearby, an artificial river canal. The problem is that these kinds of floods would demand building and rebuilding artificial levees from year to year, which is not a sustainable solution, as levees are only temporary solutions, because while they can protect a building or a city, they often have to be very large. Dams and levees create a problem when they break. [see Figure 70] They are barriers that provide a significant resistance to water. As they are acting in opposition to nature, when pressure reaches its critical level, they can be overloaded and break, letting the enormous amounts of water flood across the area – such as in the case of Hurricane Katrina that hit New Orleans in 2005, when the city was almost fully flooded because their levees broke, causing large amounts of damage and lost lives.

Although dams and levees are common on land during the flash floods, land can be protected also by wharfs (extending the land area on a water), floating piers (help to carry different platforms), seawalls (literally blocks the water), lagoons (a stretch of salt water separated from the sea by a low sandbank or coral reef), estuaries (the tidal mouth of a large river, where the tide meets the stream), and many others.

Water dwelling systems summary

Table 4 | Advantages & Disadvantages of Water Dwelling Systems

	Advantages	Disadvantages
Wurt Dwellings	Best option for large dwellings	Access to living area is difficult; height limitations mean flooding is still possible; residents are trapped within when flooding takes place
Floating Platforms	For situations where construction ground is limited or lacking; is mobile; no height limitations, as it rises with the water level; minimized carbon footprint	Suffers stronger external loadings from rain, ice and wind; corrosion increased as it's submerged in water; even levelling must be maintained by symmetrical house placement; pluming and sewage fixtures must be accommodated
Static Elevation	House elevated to a predetermined base flood level; original architecture preserved; allows for high density houses	House elevated to a predetermined base flood level; original architecture preserved; allows for high density houses
Pile	For situations where construction ground is limited or lacking; allows for high density houses; minimized carbon footprint	For situations where construction ground is limited or lacking; allows for high density houses; minimized carbon footprint

3. Amphibious buildings

Figure 63: Amphibious plane

Definition of Amphibious Building

In last two chapters, Dwellings systems in the past and chapter Dwellings systems in the present, most important dwellings systems were presented. Those can be observed as 'ancestors' of the amphibious building. They all have in common that they are meant to deal with water with respect to human dwellings in one way or another. All those systems serve to provide a safer place to live for their inhabitants. The main difference between all previous systems and the amphibious system is that the amphibious system does not try to resist the water rise. The amphibious system adapts and works with its surroundings.

Amphibious buildings are those related to, existing in, or suited for both land and water. They are mainly designed for floodplains and flooding-prone areas. Wherever flood is probable, instead of building a 'normal building', an amphibious building should be built instead, because amphibious buildings are designed to safely exist within the determined water levels when needed. There are several types of amphibious buildings and some of them can be designed as light weight timber buildings, which usually underneath themselves have a concrete 'dock' that fills gradually from the ground and slowly with the help of a buoyancy system raises the building with the water rise. One such building can be found in the UK and it is the first amphibious house in the UK, designed by Baca Architects, that was built on the flood banks of the Thames River in Marlow and completed in 2014.

Amphibious building designed by Baca Architects is 200 m² big house located 10 m from the Thames river. This house can float around 3 m high on its own, which is above the predicted and projected flood levels in the area. The building by itself cannot float away because the design does not allow for this to happen. The necessary structure is designed to keep the house from drifting away in the occasion of floods. Amphibious buildings are not moving around like houseboats. They are meant to stay at the site where they are built. It is extremely important for the building to be affixed to its location in many countries, and especially in China, where a house is defined as private property that does not move (不动产 immovable property – House cannot be moved!). The highest that Baca Architects' amphibious house can float is 4 m. The ability to move vertically with the flood makes this building a very secure model for the surroundings in which it is located. This amphibious model designed by Baca Architects is the very first of its kind, but there is no reason to believe that through time the whole system could not be further improved to allow for a higher floatation limit and more affordable production.

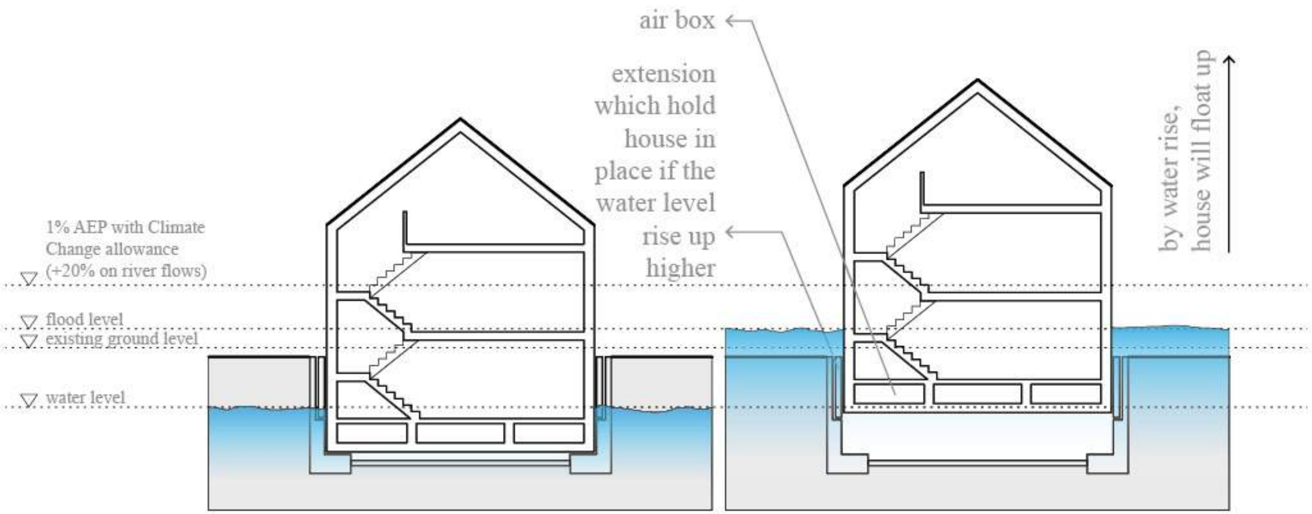


Figure 64 | Amphibious building by Baca Architects case study [not to scale]

This kind of amphibious building needs a boosting mechanism that would support the buoyancy system, which necessitates regular testing and maintenance irrespective of whether there are any floods or not, in order to ensure that the base and the lofting system are constantly functional. According to Baca Architects design, the dock of their kind of building must be pumped full of water to raise the house roughly 0,5 m for a floating test every five years. After the completion of the procedure, water can be released and the building can be slowly attached to the 'dock' again. (BUSINESS INSIDER. 2014.)

At the present time, it is hard to find a large number of publications about different amphibious buildings of this kind. They are still very new in architecture and many people mistake them for houseboats due to their similar appearance. Their differences, however, are considerable and need to be addressed: One, this kind of amphibious house has an open basement system, allowing or the water to enter during flooding, necessitating the designers to conceal the 'dock' of the building either in the ground or in standing water. Two, it needs to contend with two different set of forces that are begin exerted in its case, those that exist while it rests on the ground, and those that exist while it's floating on water during flooding; in contrast, houseboats only have to contend with forces involved in their floating on water. However, the biggest difference is that of their connection to land. Amphibious buildings are designed for places where water levels are controlled but sometimes prone to extreme flooding (such as in flash floods); therefore all utility services can be connected to the municipal pipes. Houseboats, on the other hand, must contain all utilities within the structure, as they move both vertically and horizontally, while some amphibious buildings at the present time are capable of moving vertically. Many examples of houseboats can be found in Netherlands, the United States, and they are getting more and more popular in China as a luxury cottage.

The word 'amphibious' has existed from mid-17th century (meaning 'having two modes of existence or of doubtful nature'): from modern Latin amphibium 'an amphibian', from Greek amphibion (noun use of amphibios 'living both in water and on land', from amphi 'both' + bios 'life').

Having all that in mind and after familiarization with previous chapters, one must understand the existence of three main amphibious models:

> *1. amphibious system one – static elevation system*
>
> *2. amphibious system two – mechanical amphibious system*
>
> *3. amphibious system three – buoyant amphibious system*

The system mention previously (Baca Architects amphibious house system) is a buoyant amphibious system designed by UK Baca Architects. The buoyant amphibious system is affordable, sustainable and does not consume external energy, only energy produced by the flood itself. In the case of this system, the structure's weight is distributed between land and water simultaneously – on the water through the structure's buoyancy, and also on the solid ground under the water through the structural elements holding it in place. The mechanical amphibious system, on the other hand, requires an external energy source to move with the flood. They are able to avoid flooding only by combining such systems as jack platforms or hydraulic pumps to temporarily elevate the structure with the building on it, and are thus called 'hybrid building' conditions. The mechanical amphibious system is expensive and requires specific technology for proper functioning. The static elevation system , also called wet-proofing strategy, relies on the building's residents occupying the lower floor during dry season and moving to higher floors during flood appearance or the building itself is a wet-proofed building and in case of flooding, the water will not enter inside. In such cases, it is implied that the ground floor access to the building would be blocked and an alternative access to the house would be used.

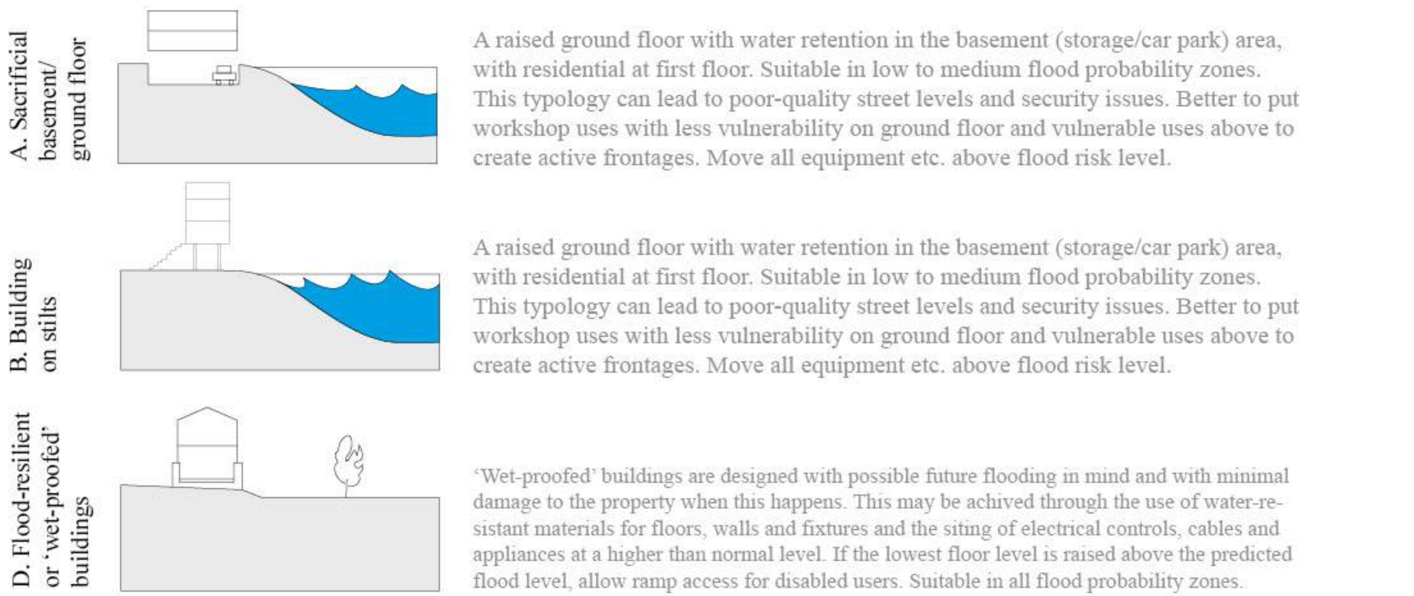


Figure 65 | Flood mitigation: building typologies that work with water (Bell S., Paskins J. 2013.)

As resources are often not unlimited, when talking about amphibious buildings, the focus is mainly on the buoyant amphibious and static elevation systems, with the latter being the old-fashioned model most commonly appearing in the past and still used in the design of large buildings today, and the former being the new model that is slowly gaining popularity with the smaller buildings. Even so, it should be noted that most often, when speaking of amphibious buildings, people are mostly thinking only of the buoyant amphibious system, rather than all three.

Static elevation system (type I)

The static elevation system63 is the cheapest of all three and the simplest amphibious model. This model is usually used for large buildings that are very heavy and too demanding for the buoyancy system. This system includes all buildings that are static and wet-proofed [see Figure 68]. The more likely type meant when talking about the static elevation system are buildings on stilts, but that it is not the rule that only buildings on stilts are the ones that fall into the group of the static elevation system. The static elevation system consists of three main subgroups typologies: a) buildings on stilts, b) buildings with sacrificial basement/ ground floor and c) wet-proofed buildings.

Stilt-buildings are a very simple option. The building is built on a specific high offset from the ground. Before building such a building, it is crucial to know the water rise level. This system can be used not only for protection against flooding, but also cold weather, as it allows for good ventilation under the building. The disadvantages of this building typologies can be the building height. In some locations, regulations disallow the construction of buildings higher than 2 floors, and by choosing this typology of the amphibious static elevation system, the owner of a specific building can lose one whole floor (such is the example with Amphibious House by Baca Architects, where they were forced to use the buoyant amphibious system because of high regulations). The great advantage of this typology is that, when having a large building, the architect can offer dozens of different public functions underneath


Figure 66 | House Lifting

Figure 67 | House Lifting II

the building. With a large building, the loss is much lower than the gain given the building's size.

The buildings with sacrificial basement/ground floor are buildings in which the basement or the ground floor is allowed to flood during periods of flooding, necessitating that the occupants move to the higher floors during these times. In this typology, the architect should consider the functions located on the level meant to be scarified. It is not recommended to design complex functions on these lowest floors. Usually these floors is the ones that can be easily evacuated, and when and if the water level drops, the loss incurred is purposefully minimal.

The wet-proofed buildings are the ones in which water-proof materials are used in the initial construction. The goal of this static elevation typology is to provide minimal damage to the property when the flood happens. This typology is characteristic with its materials – special water-proof materials are used in construction so that the rising water cannot penetrate the walls of the building. In such cases, ground floor access to the building would be blocked and alternative access to the house would be used.

One key aspect of the static elevation system is knowing the maximum water level, as this system is incapable of adjusting the building's height the way that the mechanical and buoyant amphibious systems allow for. It should be noted that though these constructs are constructed to be fixed in their position, it is possible to lift the building itself using mechanisms alike to those used in the mechanical amphibious system and replace the basal part of the building (often stilts) with another that would lift it higher than before, thereby extending the elevated structure, building a whole floor underneath it, or even moving the whole building away if necessary.

The static elevation system is very practical for commercial buildings in urban areas where the ground floor can be used as a pedestrian open free zone. This space can be used for different kinds of temporary small structures and activities, e.g. Chinese street food, small street shops, children playgrounds, recreational parks and so on. Therefore, even the relatively minor cost of losing the ground floor can be mitigated in the implementation of this system in urban areas.

Mechanical amphibious system (type II)

The mechanical amphibious system is a mechanical building with an external energy source that is able to avoid floods by combining different systems together such as a jack platform or hydraulic pumps to temporarily elevate the structure with a building on it. [see Figure 69 & 70] This model can be called 'hi-tech' due to the many intelligent sensors and an almost necessary 'Building OS' that is responsible for proper function of a building.

When water appears, building sensors should detect the change, measure the significance of the water's appearance, and calculate the proper action to be undertaken, including closing the windows and doors on the lower level and after that lifting the building up.

Hydraulic pumps systems push the building up in accordance with the movement of water, and this is also controlled by the 'Building's OS'. The whole process can be observed by a mobile device through iOS or similar.

House raising, the process of separating a building from its foundation and temporarily raising it with hydraulic or screw jacks, has been present for long a period of time, but was not used in the interactive protection against floods. Its main function was instead structure relocation. According to the International Association of Certified Home Inspectors, a homeowner can expect to pay up to around 9.000 EUR to raise their 100 m² house by 1-2 m, and older homes may be more difficult to lift, as they typically weigh more because of their plaster construction and sturdier wood, though naturally this is meant mainly for buildings never meant to be moved away, rather than amphibious buildings. Well prepared buildings with their own lifting systems can have lower lifting costs, with the main one being the power needed for the mechanism to lift the building up. There are many different systems at this time, with one popular among them being Atlas House Lifting System 5.0 (short Atlas HLS 5.0). This lifting system is used primarily to lift houses in order to replace failing foundations or renovate basements, to add a floor beneath a bungalow, as a part of a structural move, in response to issues arising from flooding, extreme weather or seismic activity, etc. These and others can be implemented as part of the mechanical amphibious system lifting mechanism.

Buoyant amphibious system (type III)

This amphibious building mechanism is not as complicated as people would like to assume. The buoyant amphibious system consists of two mayor parts controlled by two systems, these being a basement or 'dock' and the building itself. The dock is equipped with a vertical guidance system, while the building is equipped with a buoyancy system. The vertical guidance system is the link between the dock and the building. The buoyancy system beneath the house displaces the water to provide flotation as needed, while the vertical guidance

<table>
<tr><th colspan="6">Table 5 | Technical Feasibility Comparison Chart (Fenuta E. V. 2010.)</th></tr>
<tr><th colspan="2">amphibious project name + location</th><th>completion</th><th colspan="2">architect/builder</th><th>challenges</th></tr>
<tr><td colspan="2" rowspan="2"></td><td>mid 1970's to present</td><td colspan="2">individual homeowners</td><td>annual spring flooding of Mississippi river lakefront in rural Louisiana</td></tr>
<tr><th>max height during flooded conditions + total living area</th><th>buoyancy + vertical guidance systems</th><th>major building materials</th><th>technical feasibility application to the BFE</th></tr>
<tr><td colspan="2">fishing campus raccourci old river, Louisiana</td><td rowspan="2">4,5 - 8,0 m; size varies – 50 - 90 m2 (typical size of a single-wide)</td><td rowspan="2">expanded polystyrene (EPS) blocks fastened under the frame with sleeves that slide up on fixed vertical guidance post</td><td rowspan="2">steel / timber, EPS foam for buoyancy</td><td rowspan="2">amphibious fishing camps in pointe coupee parish provide the basic system configuration that needs to be engineered, made code compliant and aesthetically appropriate for urban applications</td></tr>
<tr><th>cost</th><td>4500EUR (or less)</td></tr>
<tr><th colspan="2">amphibious project name + location</th><th>completion</th><th colspan="2">architect/builder</th><th>challenges</th></tr>
<tr><td colspan="2" rowspan="2"></td><td>2006</td><td colspan="2">Ger Kengen
Factor Architecten
Chris Zevenbergen
Durea Vermeer
Construction</td><td>60% of Netherlands below sea level creates a vulnerable topographic condition

supplement to intrastructural flood mitigation strategies, constructed on a recreational site outside the dike system</td></tr>
<tr><th>max height during flooded conditions + total living area</th><th>buoyancy + vertical guidance systems</th><th>major building materials</th><th>technical feasibility application to the BFE</th></tr>
<tr><td colspan="2">Amphibious housing in Maasbommel, Netherlands</td><td rowspan="2">5,5 m
150 m2

(approx.) for each 2-stprey housing unit</td><td rowspan="2">70-tonne concrete box provides buoyancy and forms the basement on which the wooden superstructure is built

boxes come in semi-detached pairs, connected by deck - each pair is set into aniche in the river bank and held there by 2 large steel posts</td><td rowspan="2">timber, concrete, steel</td><td rowspan="2">Maasbommel was the first modern built amphibious architecture project, classifying it as a type, demonstrating its feasibility and functionality for flood mitigation in below sea-level applications</td></tr>
<tr><th>cost</th><td>5900 EUR (including temporary flood tank)</td></tr>
</table>

system gives the building the ability to move swimmingly up or down together with the flood. This type of amphibious building is capable of swimming movement for the whole duration of the flooding period.

It is important that the building is in some way connected to the ground water that would flow under the buoyancy system in order to allow for lifting as the dock is filled gradually from the ground up to coincide with the rise in the flood water level. This ground water can be river water, lake water, or any other source. According to the Baca Architects, the house can rise up to 3 m to cope with a 1 in 100 flood event and the vertical guidance system can extend almost 4 m above the ground level such that in the event of an even bigger flood, the building would still remain connected to it. Therefore, this type of amphibious building must be specifically designed for a certain place, and that both the geography of the site and the water level fluctuations on it throughout the year are incorporated into the design. Detailed climate analysis should be conducted before any design is made. Important questions that need to be answered are: how often does flood appears; what is the maximum level of water rise and what type of flood is being faced.

Infrastructure of the buoyant amphibious system is flexible. Electricity and telecommunications are easy to implement, while hydro infrastructure (the water supply and faeces drainage) represent a challenge. Although it is not the simplest task, the pipes are designed to extend up to 3 m. This flexibility allows for all services to remain clean and operational during any flood event. The buoyant amphibious system is designed to achieve low-cost, which is the reason why most of structure stays in place and only the necessary parts are mobile. The goal of the buoyant amphibious system is to offer a building that requires minimum maintenance and maximum cost effectiveness. Nevertheless, this kind of building still has to be tested and maintained from time to time in order to ensure that if unexpected flooding occurs, the system will still function. Every five years the dock should be pumped full of water to test the condition of whole mechanism. It is enough to lift the building around 50 cm.

The buoyant amphibious system building combines

Table 5 | Technical Feasibility Comparison Chart (Fenuta E. V. 2010.)

amphibious project name + location		completion	architect/builder		challenges
		2007	dr. Elizabeth English working with LSU mechanical engineering and Hurricane centre students		full scale prototype conducted on LSU campus demonstrating the efficacy of the buoyant foundation system
		max height during flooded conditions + total living area	**buoyancy + vertical guidance systems**	**major building materials**	**technical feasibility application to the BFE**
LSU hurricane center prototype baton rouge, Louisiana		1,5 m 30 m2 (4 x 7,5 m)	expanded polystyrene (EPS) blocks fastend to steel substructure with sleeves sliding on four fixed vertical guidance post	steel / timber, EPS foam for buoyancy	a simple demonstration that the proposed BFP system works in an observed, measured calibrated flood test in a controlled test facility demonstrating the technical feasibility
cost	5900 EUR (including temporary flood tank)				
amphibious project name + location		**completion**	**architect/builder**		**challenges**
		2007	Spatz Develpments and Noah's Ark Project		situated in a low-lying, flood-prone neighbourhood - lake view, New Orleans Noah's ark project provides flood protection for a 2-storey, new construction house, allegtafes the inconvenience of a permanently elevated house by allowing the house the remain close to street level
		max height during flooded conditions + total living area	**buoyancy + vertical guidance systems**	**major building materials**	**technical feasibility application to the BFE**
Noah's ark project, New Orleans, Louisiana		3,66 m 250 m2 (approx.)	a hollow 0,9 m height barge welded together from plate steel and iron trusses that carry the weight of this steel-framed home wooden vertical guidance posts and four corners of the house	steel for frame timber for vertical guidance post prefabricated construction	demonstrates the technical feasibility and appropriateness for New Orleans using pre-fabricated new construction
cost	477,435 EUR				

components from different disciplines into one. According to UK Baca Architects, the buoyant amphibious system is slightly more expensive than other present solutions because of the two foundation systems (dock and hull), though they are ideal for floodplains and flooding-prone areas.

As the buoyant system is interesting and not well known, the following table introduces technical feasibility comparison chart of currently built buildings belonging to it. [see Table 5]

Case Studies

A case study is a study conducted in a certain period of time about a person, group, or situation. Such studies are likely to appear in formal research thesis, journals and professional conferences. In doing case study research, the "case" being studied may be an individual, organization, event, or an action, existing in a specific time and place.

Choosing case studies should not be based on the amount of information available in each of the cases, but rather on the quality of that information, commonly considered interesting, unusual or particularly revealing set of circumstances. Having that in mind, one must be aware of the logical structure while doing case studies for a topic (such as the amphibious buildings). As the previous chapter (Definition of Amphibious Buildings) describes and defines three different amphibious building types, it is logical to conclude that for the proper case studies at least one case per system should be analysed.

ICAADE 2015 offered an overview of eight important examples of amphibious buildings on their official web site: Amphibious House on the River Thames in Marlow, Buckinghamshire, England by Baca Architects; Amphibious House Prototype in Bangkok, Thailand by Site-Specific; Ohé & Laak Maasvillas in Maasplassen Lakes, The Netherlands by Dura Vermeer; Watervilla in Kortenhoef, The Netherlands by WaterStudio; LIFT House in Dhaka, Bangladesh by Prithula Prosun; FLOAT House in New Orleans, Louisiana by Morphosis Architects; Amphibious Housing in Maasbommel, The Netherlands by Dura Vermeer and Am-

Table 5 | Technical Feasibility Comparison Chart (Fenuta E. V. 2010.)

amphibious project name + location		**completion**	**architect/builder**		**challenges**
		2009	Tom Mayne Morphosis Architects Brad Pitt Make it right foundation		amphibious housing solution subsidised by MiR innovative sustainable structure to protect a single-storey new construction house from flooding, alleviates the inconvenience of a permanently elevated home, facilitates the local porch culture by allowing the house to remain close to street level
		max height during flooded conditions + total living area	**buoyancy + vertical guidance systems**	**major building materials**	**technical feasibility application to the BFE**
FLOAT house, New Orleans, Louisiana		3,66 m 100 m2 (approx.)	the base of the house is preconceived as a chassis - acts as a raft, allowing the house to rise vertically on two steel guidance post, floating up to twelve feet as water levels rise - the 'chassis' made from polystyrene foam coated in glass fiber reinforced concrete	steel, concrete, EPS foam coated in glass-fiber reinforced concrete, house in wood-frame construction	demonstrates the technical feasibility and appropriateness for the local culture of New Orleans, particularly the lower ninth ward
cost	136,410 EUR (list price subsidised by MiR - actual cost of construction is undisclosed)				
amphibious project name + location		**completion**	**architect/builder**		**challenges**
		2010	Prithula Prosun uwm.arch candidate		rapid urbanisation - large portion of the city's population in slum and squatter settlements low-lying portions of the city experience annual flooding due to the overflow of surrounding rivers and heavy monsoon precipitation
		max height during flooded conditions + total living area	**buoyancy + vertical guidance systems**	**major building materials**	**technical feasibility application to the BFE**
LIFT house, Dhaka, Bangladesh		1,5 m 40 m2 for each 2-storey housing unit	buoyancy is achieved from two different systems: one of the dwellings has a hollow ferrocement foundation, the other is a bamboo frame foundation filled with recapped empty water bottles - the steel vertical guidance system attaches the bamboo dwellings to the brick and concrete service spine - dwellings slide up and sown vertically	bamboo, masonry, ferrocement, plastic water bottles for buoyancy. slotted steel tubes cast into masonry base for vertical guidance	demonstrates the technical and economic feasibility and appropriateness for a low-income population and use of sustainable materials
cost	3600 EUR per unit				

phibious Fishing Camp in Old River Landing, Louisiana by bouyantfoundation. It is important to note that all those examples belong to the buoyant amphibious system and that none of them are part of the static elevation or mechanical amphibious systems. The main reason for this lack of examples is that they are either not interesting enough for the current architectural public or are very expensive (respectively).

Amphibious House on the River Thames in Marlow, Buckinghamshire, England by Baca Architects and Amphibious House Prototype in Bangkok, Thailand by Site-Specific are the two most appropriate examples for the buoyant amphibious system. Both of them are relatively new, however they are quite different to each other. The Thailand building (Site-Specifics) is based on a historical system used by people from Thailand in the past, while the England building (Baca Architects) is a new approach by young. The Baca Architects project uses the whole basement as the house's buoyant system, while the Site-Specific project has an attached buoyant system under the house ground floor. Although both systems belong to the same type, they are different in their core structure and approach to this specific system, making them two cases perfect for proper case study of the buoyant amphibious building.

By analysing and observing these two projects, one can learn how simple systems find very efficient usage in architectural world and design. Both of them are good systems and easily applicable to a specific place after a proper analysis. Since the amphibious way of living is new or fully unknown to many people situated at the floodplains and flooding-prone areas and because of the appeal of the 'old way' of living, the Site-Specific system is presumably more enticing compared to Baca Architects design, which leads to inhabitants of such areas remaining unpersuaded by newer and possibly better system in spite of the danger they may find themselves in. All this makes one more reason for architects to point out and promote amphibious solutions more and more.

One case study per system will be conducted for the remaining two systems (the static elevation system and the mechanical amphibious system). There are many projects suitable for analysis as the example for the

Table 5 | Technical Feasibility Comparison Chart (Fenuta E. V. 2010.)

amphibious project name + location	completion	architect/builder		challenges
	projected 2011/2012	dr. Elizabeth English The Bouyant Foundation Project		the BFP provides an alternative form of flood protection to alleviate the inconvenience of permanently elevated homes - allowing homes to sit close to street level under normal conditions and float when it floods - greater degree of protection from extreme flooding than permanently elevated homes
	max height during flooded conditions + total living area	**buoyancy + vertical guidance systems**	**major building materials**	**technical feasibility application to the BFE**
BFP project for New Orleans, Lousiana	7,6 m 65 - 100 m2	coated EPS foam for buoyancy fastened to the steel substructure - telescoping vertical guidance posts that pull out of the ground as the house rises are being developed	steel, coated EPS foam for buoyancy (possible use of thermo-plastic timber in place of steel)	combines all design parameters listed above as well as potentially implementing thermoplastic timber
cost: 18,000 EUR + (cost to restore upper portion of the house if necessary				

static elevation system, with one having already been mentioned in Dwellings Systems In The Present – the Teahouse, located at the East lake scenic area in China and designed by the Chinese architect 王澍 (Wang Shu). However, there were several reasons why this project was not chosen for this purpose:

The Teahouse is located outside of the urban area and this thesis focuses on how to implement amphibious architecture inside an urban area. Urban areas of cities such as Chongqing are mainly populated by large buildings. Regardless of the density of large buildings in it, a proper urban area can not exist without small buildings (in case of amphibious architecture, low-rise flooding-adaptable buildings). Therefore, understanding the relationship between big and small buildings, their positions and forms as relating to one another, is extremely important when it comes to amphibious architecture and should be consider in the choice of case studies.

Since amphibious buildings exist in three main forms that are defined and explained in Chapter Definition of Amphibious Buildings, it is important to note which systems can be implemented for which types of buildings. Large buildings are often too heavy for the buoyant amphibious system, though this is a limitation that will in the future no doubt be continuously improved upon. The static elevation system is far better suited for large buildings as well as small, yet it cannot be the only system used in amphibious urbanism, either. Therefore, a combination of systems is preferable when considering the interplay between large and small buildings within an urban area, with the rule being 'what is small can float and what is large can offset', which is the reason why the case study for the static elevation system is that of a large building rather than small.

The study of all available systems in this thesis is important even though the main focus of the thesis is on amphibious low-rise flooding-adaptable buildings

Figure 68 | Amphibious housing in Maasbommel, Netherlands

because this topic is covered within the scope of amphibious architecture significance in the Chongqing flooding-prone and floodplain urban area, meaning that amphibious architecture and amphibious urbanism are investigated, analysed and defined, and that in urbanism, the relationship between all components is important and crucial. Without understanding the relationships in amphibious urbanism between small and large buildings, one cannot properly analyse the given topic either.

Sharp Centre for Design, an extension of the main building of the OCAD University (Ontario College of Art and Design) located in Toronto, Ontario, Canada designed by William Alsop of Alsop Architects in 2000 and completed in 2004 is an example of the static elevation system where a large building is perched 26 metres above ground on 12 slanting stilts. While the building itself is not meant to be an amphibious building, its design falls squarely under that covered by the static elevation system, and therefore it serves as an excellent case study for a large urban-area building. Its very existence proves that elevating large buildings can be effectively done, and that the space under them can be used for many different functions, whose economic loss would not be great in case of flooding.

Buildings like the Sharp Centre for Design by William Alsop can at the first look appear very expensive and hard to build; however, compared to the loss that can occur in flooding prone coastal areas, it is acceptable and reasonable.

For the mechanical amphibious system, the author's own conceptual design is used, as these projects are comparatively few. It is important to say that the mechanical amphibious system conceptually is very similar to the Amphibious House Prototype in Bangkok by Site-Specific, as, similarly to it, the mechanical amphibious system also consists of two mayor parts – the building and the system underneath the building used for its elevation and lowering. While it is expensive, the mechanical amphibious system can carry heavy buildings much more easily than the buoyant amphibious system can. While the static elevation system may at first glance appear superior to the other two, the mechanical amphibious system and the buoyant amphibious system allow for the inhabitants of the buildings to live on the ground level, rather than having to constantly climb up and down in order to exist in the building in question.

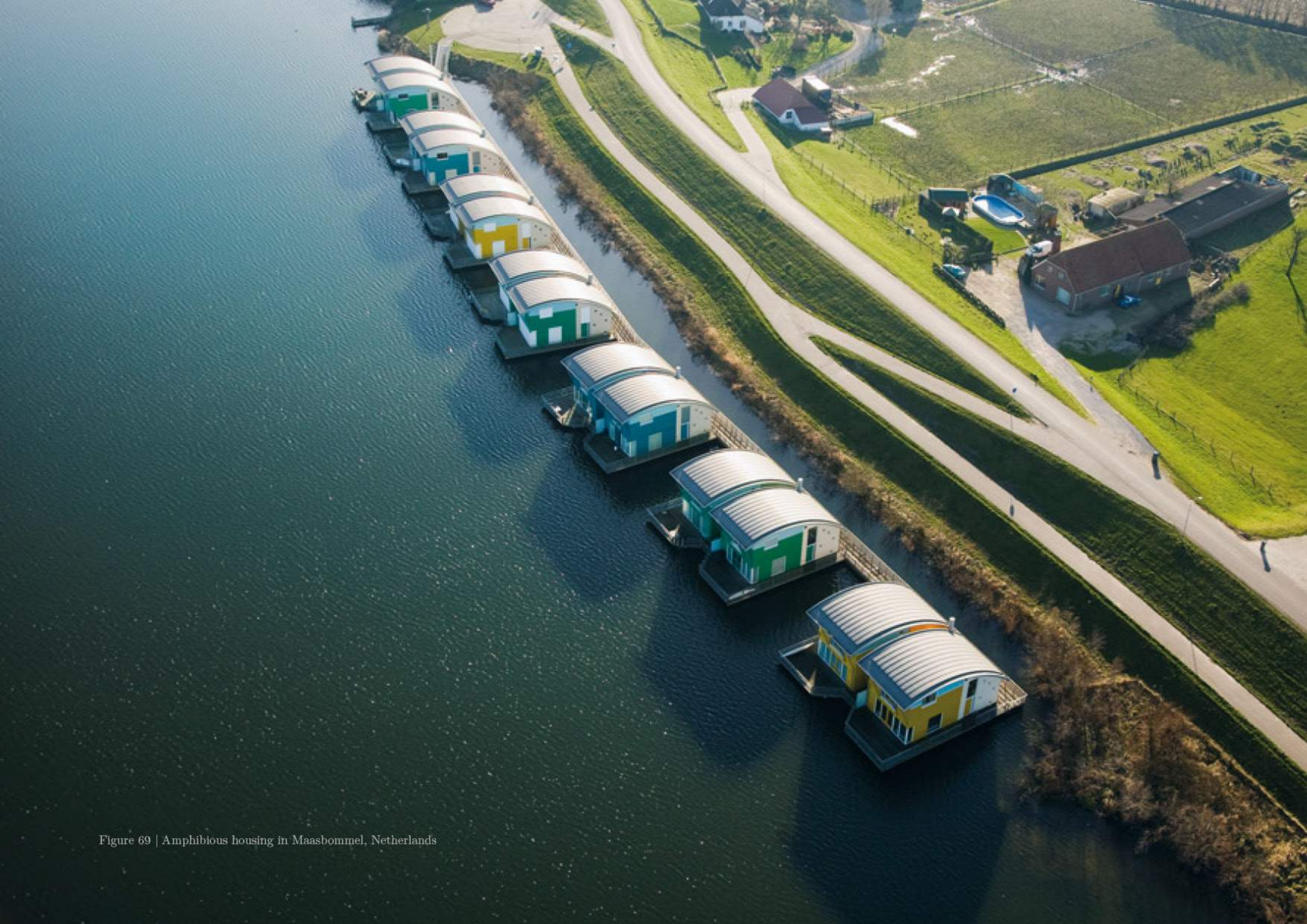


Figure 69 | Amphibious housing in Maasbommel, Netherlands

Amphibious House on the River Thames

Figure 70 | Amphibious housing by Baca Architects

Figure 71 | Amphibious housing by Baca Architects II

Table 6 | Simentic Differential of Amphibious House on the Ribert Thames

Name	**Amphibious House on the River Thames**
Architects	**Baca Architects** (www.bacahomes.co.uk)
Location	Marlow, Buckinghamshire, England
Construction year	2014
Cost (EUR)	900 000[1]
Allowed planning high (storeys)	2
Total storeys	3
Area (m^2)	200
Amphibious type	buoyant amphibious system
Construction purpose	legal issue
Distance from water sources (m)	10
Max. flotation level (m)	2,7
Maintenance (every _ years)	5
Building OS (YES/NO)	NO
Inaccessible/Accessible during the flood	●●●●●○○○○○
Conservative/Innovative design	●●●●●●●○○○
Sophisticated/Simple design	●●●●●●●●●●
Big/Small low-rise building	●●●●●○○○○○
Expensive/Affordable	●●●●●●●○○○
Urban/Suburban/Rural area	●●●●●●●○○○
Rare/Frequent floods	●●●●●○○○○○
Gradual/Flash flood area	●●●●●●●●○○

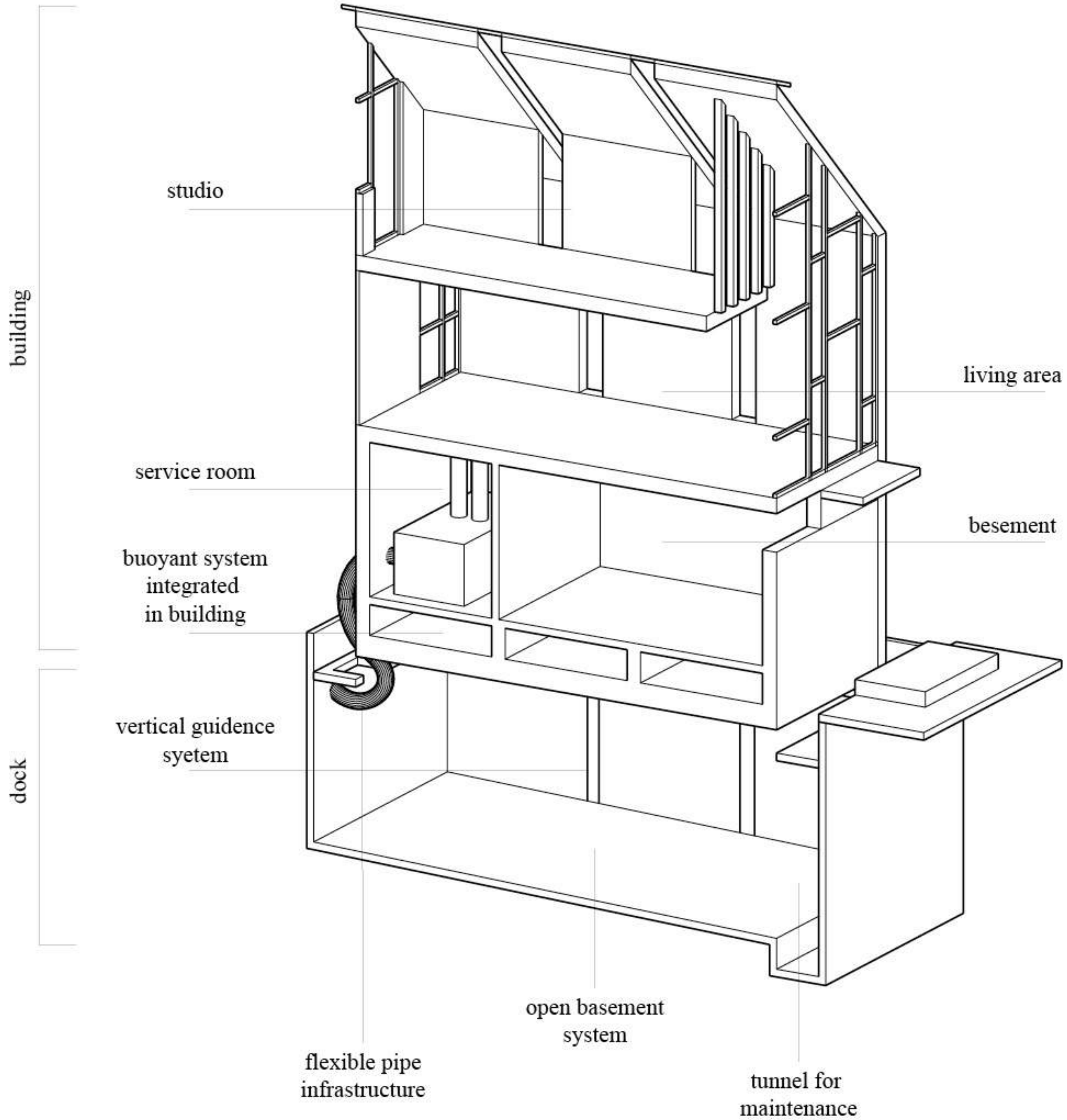


Figure 72 | Amphibious House on the River Thames isometric

The Amphibious House on the River Thames is the first amphibious house in the UK, designed by Baca Architects. It was built on the flood banks 10 m from the Thames River in Marlow. Construction was completed in 2014. Indoor space of this building is around 200 m². This building can float around 3 m high on its own, which is above the predicted flood levels and projected flood levels in the area. The building by itself cannot float away, as the design itself prevents this from happening in case of flooding.

Baca Architects have found that the flooding level in Marlow tends to change from year to year and that existing traditional amphibious systems such as static elevation were not suitable. They could not build high enough to satisfy the needs of the static elevation, and a houseboat was not a solution due to the legal issue they were facing in UK. Therefore, their conclusion was that the buoyant amphibious system is more appropriate for the existing condition of their building site.

The ground water of the island is linked to the river Thames, so that in case of the rise of water level, the ground water level of the island rises as well, gradually filling the dock of the building and thereby lifting it in tandem with the water level rise. When the building reaches ground level, the buoyancy system takes over, keeping the building floating on the water's surface. As previously noted, the maximum rise of the building is 2.7 m, while the guide posts extend for 4 m above ground for added protection in case of water rising above maximum predicted levels.

What makes this amphibious house interesting and special is its buoyant system that is literally a basement of this specific house. Unlike the others, Baca Architects chose a creative approach to the buoyant system and succeeded in making the most of it.

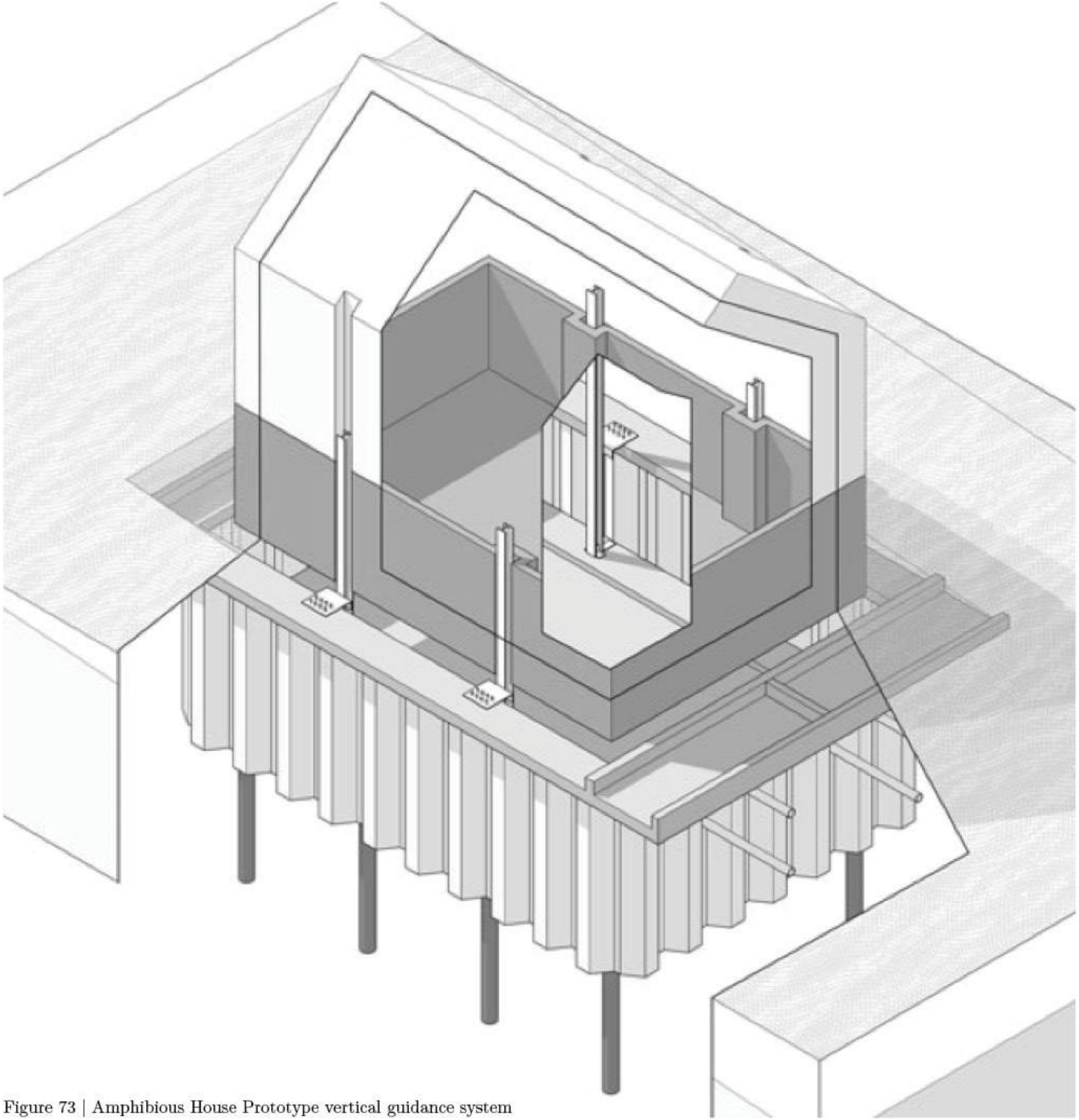


Figure 73 | Amphibious House Prototype vertical guidance system

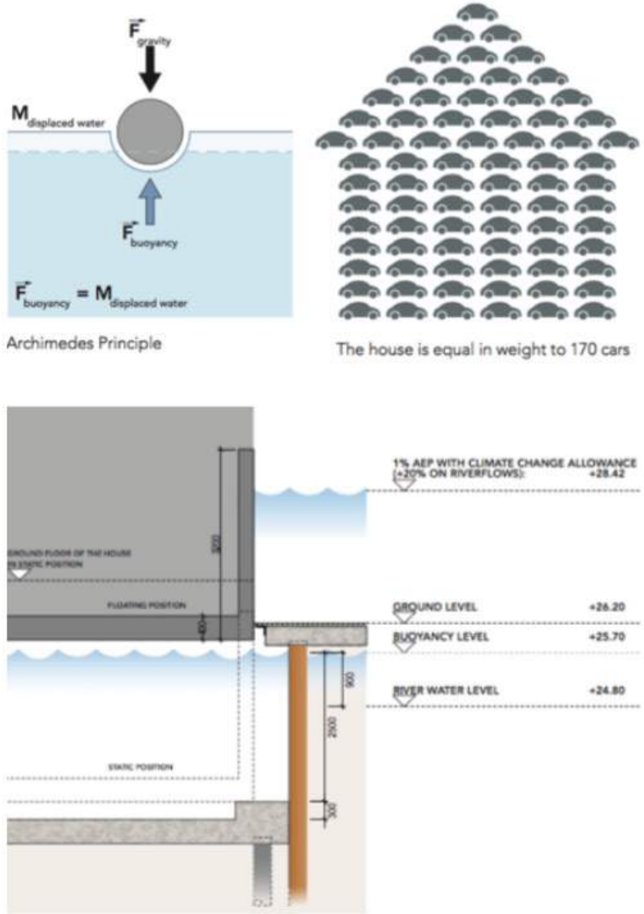


Figure 74 | How amphibious house works?

This amphibious house is covered by unusual zinc shingles that are diamond-shaped on the roof and two sides of it; otherwise it is relatively conventional.

These shingles are made of a titanium zinc product with a grey finish that has been pre-weathered. The zinc is UK-made.

The benefits of titanium zinc are:

- *Pleasing aesthetics that improve over time*

- *Resistant to corrosion naturally*

- *Long-life durability is excellent*

- *Maintenance is minimal*

- *Flexible and malleable – can be easily produced in different shapes such as roll cap or standing seam roofing sheets*

- *Very recyclable (at least 95%); re-use of the original metal possible without loss of properties*

- *Integrates easily with PV panels*

- *Allows for versatile design for roofing, whether for private residences or commercial and public buildings*

Fixing clips are used to fix the shingles to softwood boarding or plywood, but the installation requires skill.

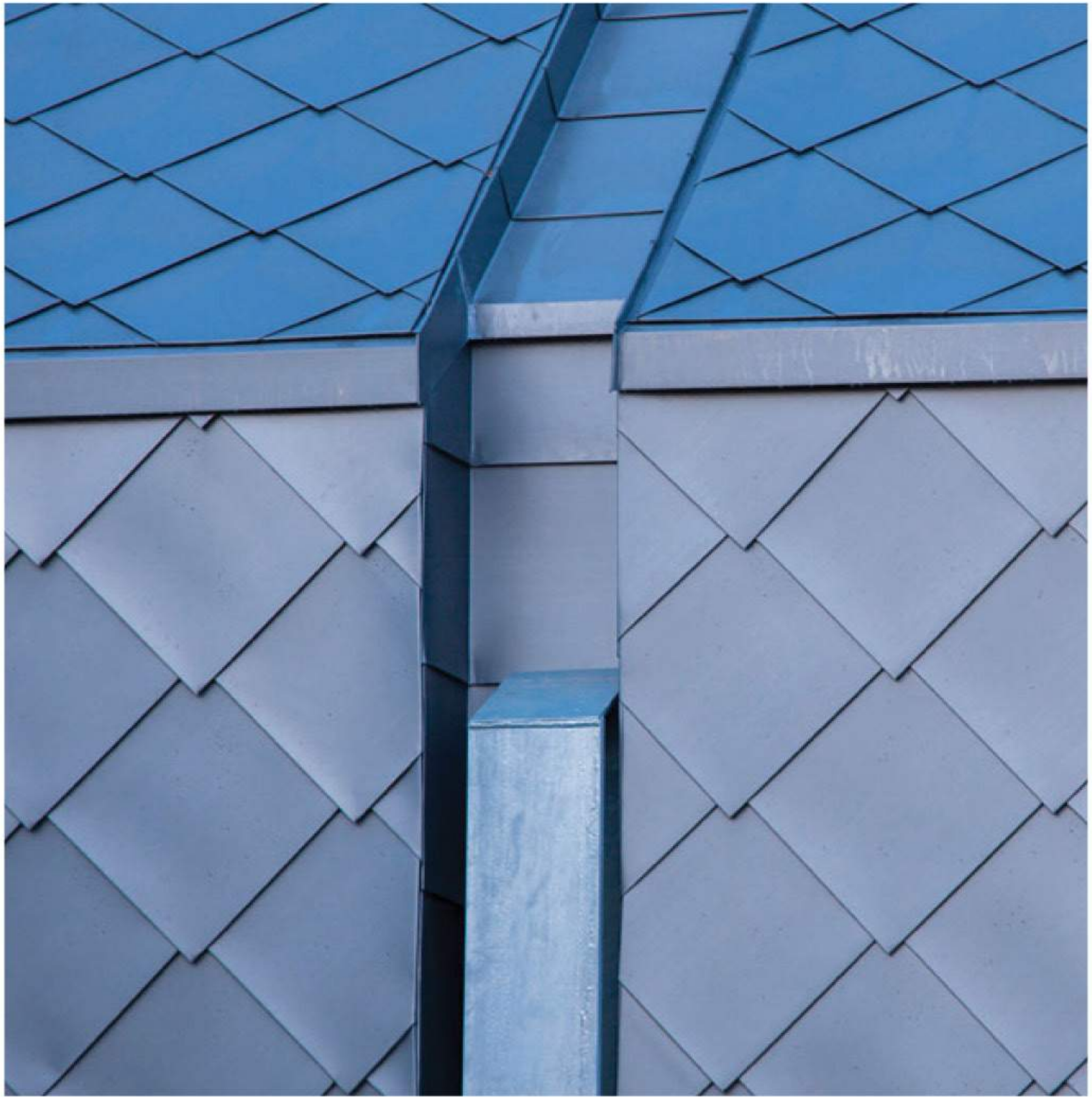


Figure 75 | Vertical guidance system detail

Amphibious House Prototype

Figure 76 | Amphibious House Prototype

Table 7 | Simentic Differential of Amphibious House Prototype

Name	**Amphibious House Prototype**
Architects	**Site-Specific Co. Ltd** (asitespecificexperiment.wordpress.com)
Location	Ayutthaya , Thailand
Construction year	2013
Cost (EUR)	77 000
Allowed planning high (storeys)	unknown
Total storeys	2
Area (m^2)	100
Amphibious type	buoyant amphibious system
Construction purpose	frequent flood
Distance from water sources (m)	unknown
Max. flotation level (m)	3
Maintenance (every _ years)	unknown
Building OS (YES/NO)	NO
Inaccessible/Accessible during the flood	●●●●●○○○○○
Conservative/Innovative design	●●●●●●●●●○
Sophisticated/Simple design	●●●●●●●●●○
Big/Small low-rise building	●●●●●○○○○○
Expensive/Affordable	●●●●●●●●○○
Urban/Suburban/Rural area	●●●●●●●○○○
Rare/Frequent floods	●●●●●●●○○○
Gradual/Flash flood area	●●●●●●●●○○

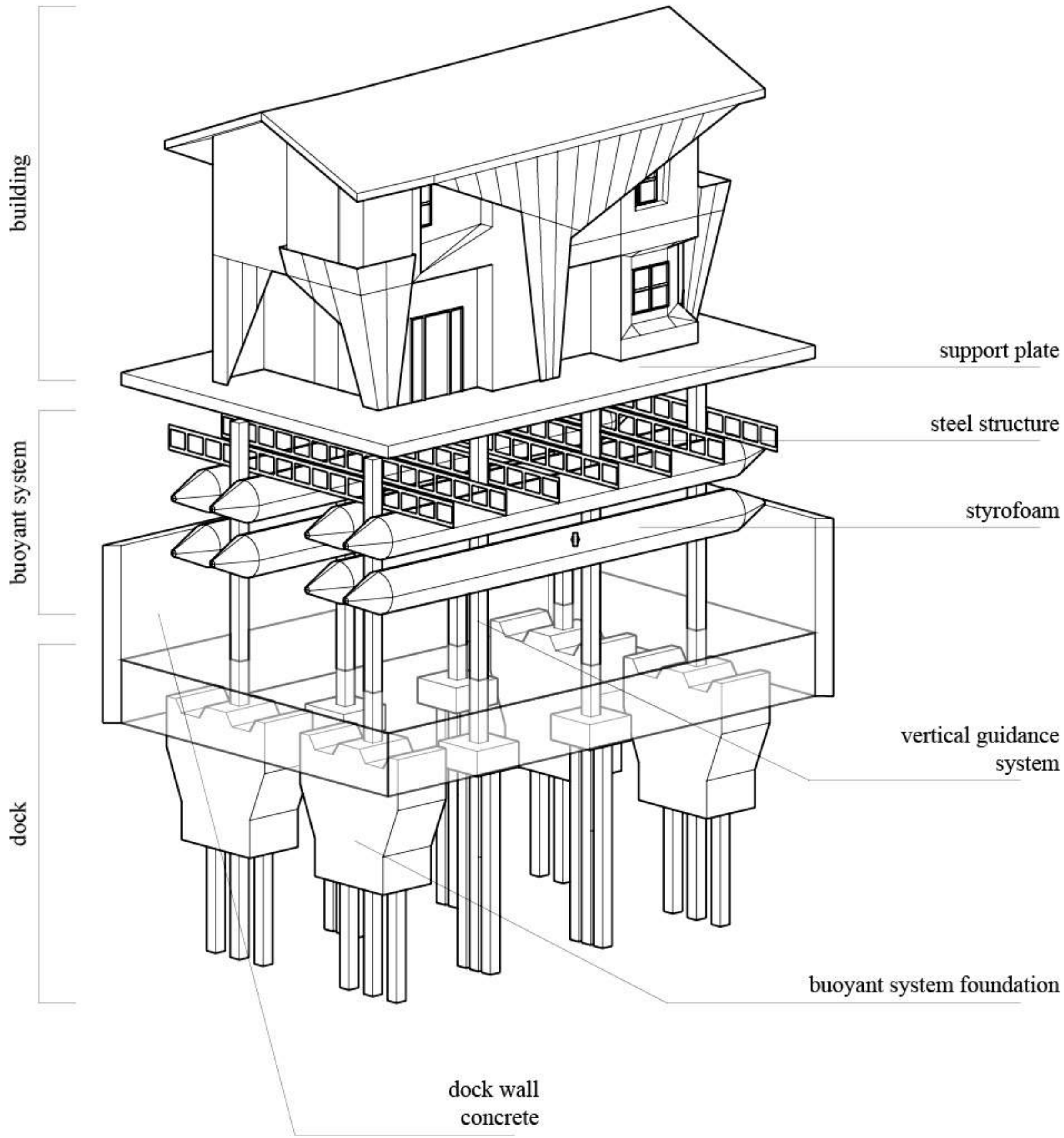


Figure 77 | Amphibious House Prototype isometric [own illustration and study]

Amphibious buildings have become an indispensable solution for Thailand since Thailand encountered the worst flooding in five decades from July 2011 to January 2012. These floods killed 800 people and brought the loss of 40 billion EUR. Most of Thailand's population initially lived on riverbanks and their houses were equipped to deal with the rise and fall of water; however, after moving inlands, the houses gradually lost these capabilities even though flooding was quite common. Site-Specific, together with the Prefab Laboratory, were tasked with solving this issue

Traditional Thai houses from Southern Thailand that are built on rafts were the inspiration for the design of the Amphibious House Prototype by Site-Specific. The building materials of the Amphibious House Prototype in Ayutthaya are prefabricated panels with steel frame allow for a lightweight, yet sturdy design. Styrofoam-filled steel pontoons are set within the foundations of the house, and a cubical floatation device is installed as well that can lift the building up to 3 m above ground if necessary.

The amphibious House Prototype is 100 m^2 two-story family house that can accommodate up to 5 residents with a construction costs of 77000 EUR (2.8 million baht). The amphibious House Prototype by Site-Specific Co. Ltd lead by architect Chuta Sinthuphan is an excellent solution for the highly-populated, often poor areas of Asia that are commonly affected by monsoons, hurricanes and other storm types causing large rises of water, especially effective in low-lying coastal cities.

Unlike the Amphibious House on the River Thames by Baca Architects, the Amphibious House Prototype in Thailand by Site-Specific Co. Ltd has no basement that can be inhabited. Here, the buoyant system is located under the ground floor and is more alike to a separate part of the house. It is inspired by the traditional way of making amphibious buildings in Thailand, where more and more construction projects are returning to using traditional structures to deal with floods, such as stilts and buildings on barges or rafts.

Amphibious House Prototype also has a dock like the Amphibious House on the River Thames to which house is connected and fixed horizontally so that it can only move vertically.

The Sharp Centre

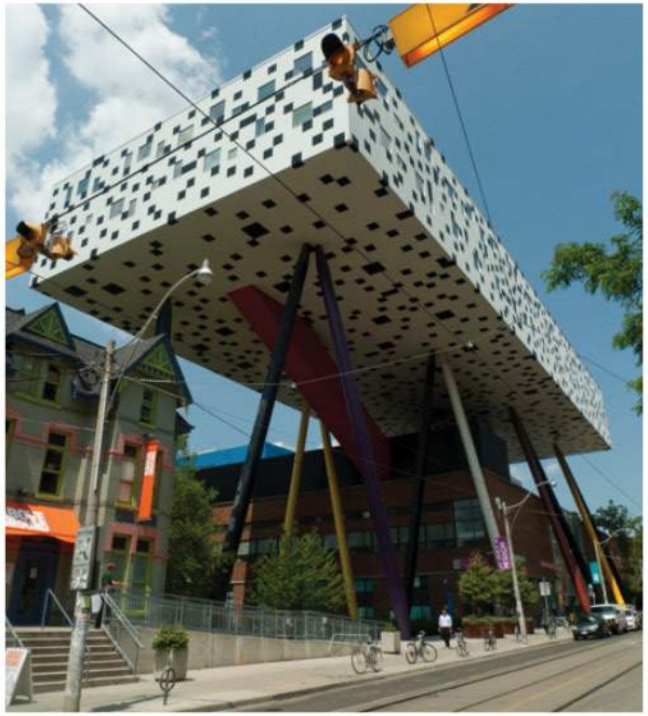


Figure 78 | The Sharp Centre – Human Perspective

The Sharp Centre for Design – an extension of Ontario College of Art and Design, Toronto Canada – stands 26 m above the mixed Victorian and modern streetscape. Architect William Alsop improved the pedestrian circulation in the area as well as created a new outdoor public space by raising this building above the ground. According to Alsop Architects, it is 'An element in the urban scene that holds its own with tough urbanity, while allowing new public space to open up beneath it.'

The structure contains two stories of studio, classrooms and offices that connect to the existing facility by a core of elevators and stairs. It was designed in 2000 by William Alsop at Alsop Architects and completed in 2004. The box shape building is 82.3 m long, 30.5 m wide. It has 12 slanting stilts holding its weight.

The building was awarded the "Award of Excellence"

Table 8 | The Sharp Centre

Name	**The Sharp Centre**
Architects	**William Alsop** (www.all-worldwide.com)
Location	Toronto, Ontario, Canada
Construction year	2004
Cost (EUR)	38 000 000
Allowed planning high (storeys)	unknown
Total storeys	2
Area (m^2)	7800
Amphibious type	suggested to be fixed elevation system
Construction purpose	campus redevelopment
Distance from water sources (m)	2000
Max. flotation level (m)	26
Maintenance (every _ years)	not necessary as in other amphibious systems
Building OS (YES/NO)	NO
Inaccessible/Accessible during the flood	●●●●●○○○○○
Conservative/Innovative design	●●●●●●●●●●●
Sophisticated/Simple design	●●●●●●●●●●●
Big/Small low-rise building	●●○○○○○○○○○
Expensive/Affordable	●●●●●●●●●○○
Urban/Suburban/Rural area	○○○○○○○○○○○
Rare/Frequent floods	not deigned for flooding
Gradual/Flash flood area	not deigned for flooding

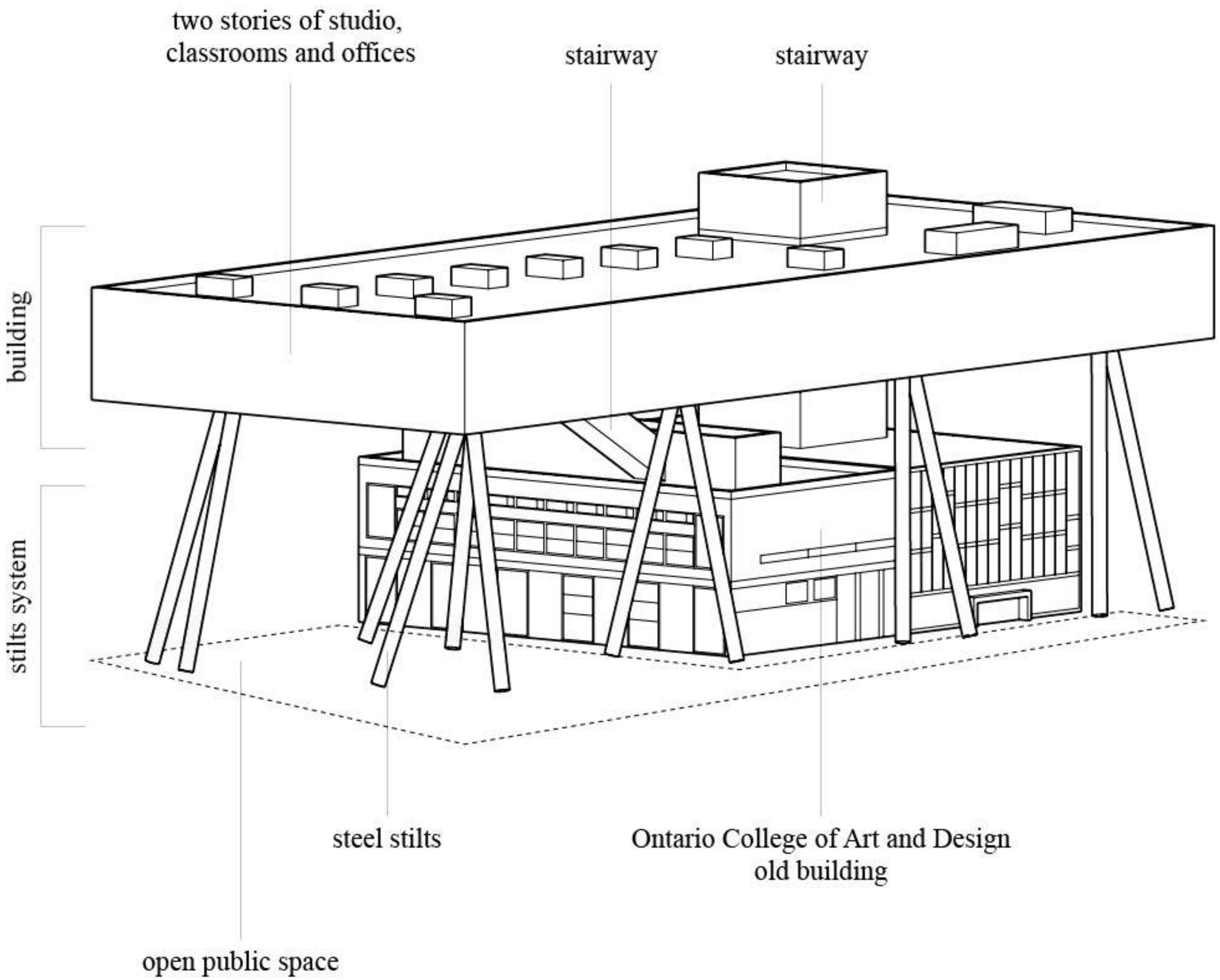


Figure 79 | The Sharp Centre isometric

from the Toronto Architecture and Urban Design Awards, the City's highest design award handed out every two years. According to the competition jury, 'Will Alsop's academic building is an altogether original and welcome enrichment of Toronto's urban fabric; artistically bold and imaginative, and respectful of residents and users in its culturally intense neighbourhood.' The Sharp Centre is considered to be a Toronto architectural landmark. It has also received the first-ever Royal Institute of British Architects Worldwide Award, the award of excellence in the "Building in Context" category at the Toronto Architecture and Urban Design Awards, and was considered the most outstanding technical project overall in the 2005 Canadian Consulting Engineering Awards.

The original plan for the building was at a currently-nearby parking lot, and had to be lifted off the ground due to the complaints of the neighbourhood it is part of, so that as of its completion, it partly hovers over the said parking lot, as well as the existing building of OCAD.

This building is not meant to be an amphibious building or anything what has to do with water, but it is clearly building with a static elevation that can fit the standards of the static elevation system, the first type of an amphibious building.

The Sharp Centre is proof that large buildings can be amphibious as well. Unlike the previous case studies, this system would require no maintenance, though unexpectedly high water levels may pose some problems. The space under the building is used as an open public space that can have various types of functions, and in case of flooding, open space under the building can be easily rehabilitated with minimal costs.

Another good function of the open space under the building is that it provides a good pedestrian infrastructure and opens new possibilities for urbanism. This kind of amphibious building would be able to sit next to the water and the only thing that should be considered is how to deal with an access to the building during the flood, which is where amphibious urbanism starts to be of a big importance.

Mechanical Amphibious Building Concept

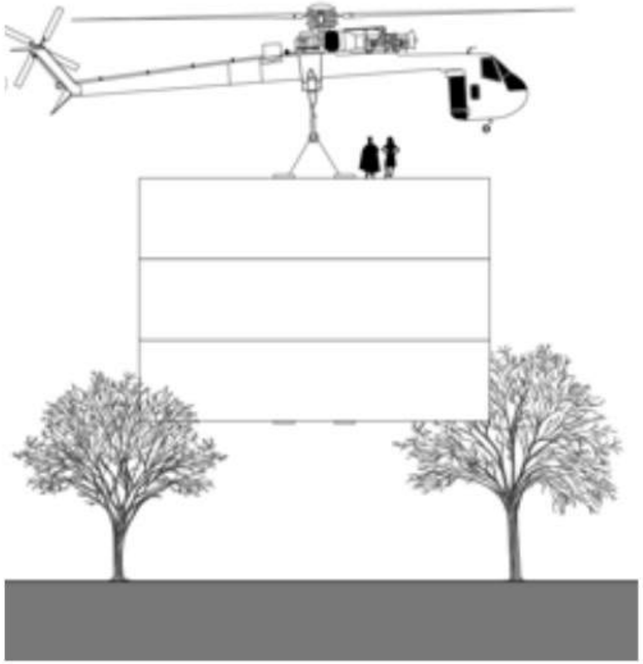


Figure 80 | Mechanical Amphibious Building

The Mechanical Amphibious Building Concept is an amphibious building belonging to the mechanical amphibious system that is designed to resist the flood. This building consists of two main parts – the mechanical system that raises the building, and the building that is designed to hang. The building is a big box of metal constructions that is easily assembled from prefabricated parts. The entire building rests on the central part of the building and the forces inside the building secure the building on the mechanical raising system.

The amphibious dock is a machine that uses the technique of the 'screws'. The so-called 'screws' are rotating and the external thread is pushing the internal tread up. The whole building acts like a socket and the dock acts like a plug.

Table 9 | Simentic Differential of Mechanical Amphibious Building Concept

Name	**Mechanical Amphibious Building Concept**
Architectural student	**XXX**
Location	unknown
Construction year	unknown
Cost (EUR)	unknown
Allowed planning high (storeys)	unknown
Total storeys	3
Area (m^2)	800
Amphibious type	mechanical amphibious system
Construction purpose	unknown
Distance from water sources (m)	unknown
Max. flotation level (m)	5
Maintenance (every _ years)	1
Building OS (YES/NO)	YES
Inaccessible/Accessible during the flood	●●●●●●●●●○○
Conservative/Innovative design	●●●●●●●●●●○
Sophisticated/Simple design	●●●●●●●●●○○
Big/Small low-rise building	●●●●●●●●●●○
Expensive/Affordable	●●●●●●●●●○○
Urban/Suburban/Rural area	unknown
Rare/Frequent floods	unknown
Gradual/Flash flood area	unknown

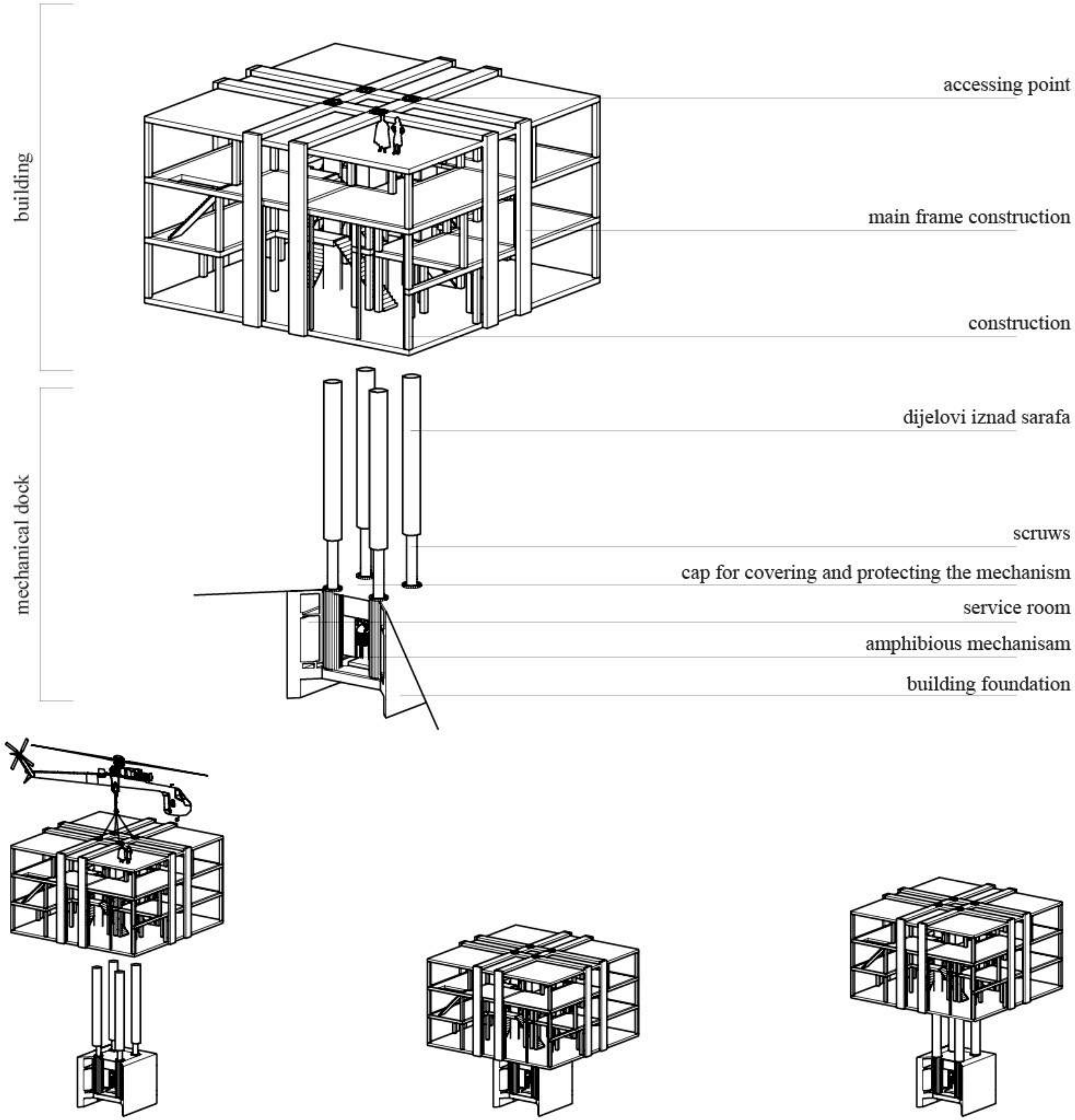


Figure 81 | Mechanical Amphibious Building Concept [own project concept and illustration]

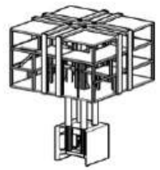
The idea of this building concept is that the building is assembled elsewhere and then brought to the site. To stimulate and support this amphibious system, a good idea would be for the government to help install the mechanical part (dock), while the homeowners would buy the cube. This strategy can help safely populate floodplains and flooding-prone areas quickly and efficiently with a new way of living. The idea of a 'metal cube' is that such a module can be used to combine and build more complex structures, in opposition to concrete construction that is always fixed to a specific place. The biggest problem here is the mechanism and the power needed to lift such a 'cube', however if the power can be provided by public sources and the mechanical part were owned by a country rather than the individuals, such a model can be easily affordable. An administrative system such as the one proposed above has been used in Vienna, where the city provided the support for new buildings to possible inhabitants, covering the raw structure of the buildings, while the inhabitants covered the remaining costs during the purchase of the apartments.

The metal construction here should be observed more as a grid inside which something is happening. The architectural creativity would not be prevented, but rather enriched by this specific structure that makes this building possible.

Possible mechanical amphibious community would in any case an experimental community. The mechanical systems must be perfected and improved in order to meet possible profitability. It is important to note that such a building would be acceptable in specific conditions and in most cases, the static elevation system and buoyant amphibious systems would be more cost-effective.

Case Studies summary

Table 10 | Case Studies summary

	1	2	3	4
amphibious project name + location	 **Amphibious House on the River Thames, UK**	 **Amphibious House Prototype, Thailand**	 **The Sharp Centre, Canada**	 **Mechanical Amphibious Building Concept**
architect/builder/ designer	Baca Architects	Site-Specific Co. Ltd	William Alsop by Alsop Architects	XXX, student
Construction year	2014	2013	2004	unknown
Cost (EUR)	900 000	77 000	38 000 000	unknown
Total storeys	3	2	2	3
Area (m^2)	200	100	7800	800
Amphibious type	III	III	I	II
Construction purpose	legal issue	frequent flood	/	/
Distance from water sources (m)	10	unknown	2000	/
Max. flotation level (m)	2,7	3	26	5
Maintenance (every _ years)	5	unknown	/	1

Inaccessible/Accessible during the flood	●●●●●○○○○○	●●●●●○○○○○	●●●●●○○○○○	●●●●●●●●○○
Conservative/Innovative design	●●●●●●●○○○	●●●●●●●●●○	●●●●●●●●●●	●●●●●●●●●○
Sophisticated/Simple design	●●●●●●●●●●	●●●●●●●●●○	●●●●●●●●●●	●●●●●●●●○○
Big/Small low-rise building	●●●●●○○○○○	●●●●●○○○○○	●●○○○○○○○○	●●●●●●●●●○
Expensive/Affordable	●●●●●●●○○○	●●●●●●●●○○	●●●●●●●●○○	●●●●●●●●○○
Urban/Suburban/Rural area	●●●●●●●○○○	●●●●●●●○○○	○○○○○○○○○○	/
Rare/Frequent floods	●●●●●○○○○○	●●●●●●●○○○	/	/
Gradual/Flash flood area	●●●●●●●●○○	●●●●●●●●○○	/	/

3. Amphibious buildings

Figure 82 | Amphibious Architecture

Definition of Amphibious Architecture

Amphibious architecture is a branch of architecture encompassing design specifically adjusted to deal with flooding, which would allow for otherwise ordinary structures to float on the water surface rather than be damaged by the flood or to be able to withstand the flood.

An amphibious foundation is constructed in such a way as to allow the amphibious building to lie on the ground until the flood appears. As a rule, buildings have been considered as structures strongly connected to the ground and not prepared for flooding; however, those located on floodplains and flooding-prone areas would far benefit from being amphibious buildings with amphibious systems appropriate for certain sites and situations. In the buoyant amphibious system, amphibious buildings contain an extra part in comparison to normal buildings – a dock, which is necessary in order for them to be able to rise off the ground in case of flooding.

Amphibious architecture strives to find ways of working in tandem with the natural cycles of flooding instead of attempting to withstand it forcibly. That principle brings a different and better approach to architecture in floodplains and flooding-prone areas. Amphibious architecture is a place where urban desegregation is inevitable. It is hard to separate amphibious architecture from urbanism because amphibious architecture is very depended on urban structure and detailed site analysis. Amphibious architecture and urbanism together create a 'hybrid' that is capable of preserving the human connection with nature.

Therefore, we can say that amphibious design takes into account site selection, planning the use of the site land, incorporating the amphibious buildings into the various other flood defence and management systems, and also taking local legal policies into consideration. Amphibious engineering deals with things like infrastructure, mechanical systems and utilities, system components and selection criteria, and codification and certification concerns.

Amphibious architecture is architecture whose main focus are designs adjusted for both dry and wet conditions equally effectively, so that flood-related damage may be prevented. ICAADE 2015 brought together diverse definitions of amphibious architecture developed around the world. According to the Bouyant Foundation, it is 'an alternative flood mitigation strategy that allows an otherwise-ordinary structure to float on the surface of rising floodwater rather than succumb to inundation.'

Various architectural and engineering offices such as James Davidson Architect , Buoyant Foundation project , Clean Tech Delta , Dura Vermeer , Waterstudio. NL , Dutch Docklands , Baca Architects , Site-Specific , as well as various organizations and various universities such as Waterloo Architecture , University of Waterloo , TU Delft Netherlands , UNESCO-IHE Institute for Water Education and others were partners and support of the ICAADE 2015 program. They all had shared interests in amphibious architecture and continue to contribute to the research and further development of amphibious architecture.

The importance of the amphibious architecture has been well recognised in London, UK. Many architects, as well as architectural offices and organisations, are analysing the current situation and looking for a proper solution for the near future. They all are considering expansion around and on top of the Thames River, which calls for the use and development of amphibious urbanism.

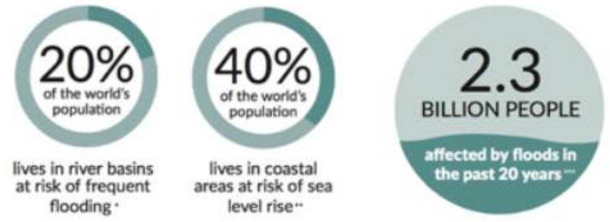
'The biggest trap that architects and developers are falling to in designing the buildings along the river is actually an overdevelopment. Overdevelopment causes roadblock buildings between the river and the streets behind.' – Jon Robertson, Founder of John Robertson Architects

Standards must be set – standards such as how much space around the river or other body of water should be left free and how much green ground must stay untouched in an urban area to satisfy the need for proper amphibious urban area. Sofie Pelsmakers, architect and environmental designer, gives very good guidance on how to deal with amphibious urbanism in her book 'The Environmental Design Pocketbook' that has received commendation for the 2012 RIBA President's Award for outstanding practice-located research (31.10.12). Pelsmakers has noted that improving water storage on a macro-scale and managing water runoff is important and that allowance of a minimum of 5% space on urban land for water storage and the provision of efficient water flow channels is necessary. She further mentions other important steps for a successful water-resilient urban picture such as increasing of the green spaces, permeable surfaces and urban reservoirs to collect rainwater, designing of flood resilient buildings.

It is very hard to talk about amphibious architecture and not combine it with amphibious urbanism. Architecture and urbanism have always intersected, but in the case of amphibious architecture and amphibious urbanism, they are dependent on one another, which is why this chapter firstly covers the basic introduction to amphibious architecture and then fully focuses on the site and specific place where such an architecture can be found and applied.

Urban Context

Severe flooding has in recent times become and will continue in the future to be an extreme problem due to the impact that global climate change has had on the weather events and the rise of sea levels. The most in danger are populations living in the proximity to riverbeds and deltas, as these floodplain regions are in high danger of more frequent and violent flooding. It is estimated that 40% of all natural hazardous events in the world are floods of one type or another; unfortunately,



* Kundzewicz (2007);
** United Na ons Commission on Sustainable Development (2005);
*** Center for Research on the Epidemiology of Disasters (2015);

Figure 83 | Flood risk and consequences

only 1% of development aid is directed towards combating this natural disaster and mitigating the risks that accompany it.

In contrast to the existing situation that has the classical architecture not dealing with the various issues and events accompanying water rise, amphibious architecture by its very nature must take into account the communication between buildings and their surroundings. This brings it into direct interaction with amphibious urbanism.

In this case, then, amphibious urbanism takes care of the general communication of groups of buildings on a larger scale that includes streets and public spaces, whole neighborhoods and districts, while amphibious architecture deals not only with the buildings themselves, but also with the amphibious infrastructure of the city. It is important to note that connecting amphibious buildings is slightly more complicated than connecting classical buildings, as everything is vertically mobile in the amphibious world of architecture.

This is the situation where amphibious architecture and amphibious urbanism directly depend on each other and it is very hard to consider them separately. Whereas in classical architecture (where no floods are predicted or considered) the pedestrians are able to travel in all infrastructurally defined ways irrespective of building architecture, in case of flooding, the this extent of communication is lost or must be accomplished by way of small barges/boats, helicopters etc. This is where the necessity of connectedness between amphibious architecture and amphibious urbanism lies, as all natural pathways between buildings in the middle of a flood would be inaccessible, necessitating the consideration for flood-specific connections that must be incorporated into the architecture of the buildings in these areas.

Three Separate Stages of an Amphibious Building

It is important to emphasise the fact that amphibious buildings have three separate stages, of which the whole amphibious architecture is dependent. An amphibious building can rest on the ground, can float on

Figure 84 | Human behaviour in flood and non flood situation the water, or it can move. From this, it can be concluded that there are there main stages of an amphibious building:

1. *Stationary dry;*
2. *Moveable wet;*
3. *Stationary wet;*

Considering that the main concept of amphibious architecture, aside from protecting the building from destruction, is to offer humans the personal safety and the monetary security that comes with the flood not destroying their property, it is important also to consider the position of the building occupants with respect to these three stages of amphibious buildings. It is obvious that when it comes to the first stage (stationary dry), there is little to no problems when it comes to the communication between various locational points. However, this unlimited freedom that is offered the pedestrians in the case of this first stage does not exist when the amphibious building is in one of the two other stages, i.e. during a flooding event.

The most difficult transitional period for pedestrians is that in which the water is between 0 and 1 m in height, as in this case the pedestrians are not yet likely to accept the fact that they are in the 'wet' state, meaning that their normal pathways have become unusable, even though this height of water is more than enough to made all types of communication difficult. This thesis suggests the boatbridge system for connecting amphibious buildings and public floating spaces. Aside from the boatbridge system, it is also practical to use barges as connective elements between amphibious buildings, though it needs to be taken into account that the barges have some drawbacks, such as for instance that they are not considered usable if the water level is below 1 m (as is further extrapolated in Pedestrian Communication During the Flood).

Each stage corresponds to a different type of amphibious building. It must be remembered that type I amphibious building as defined in this thesis (Static elevation system (type I)) does not move vertically, therefore as static it cannot have the same type of communication with other buildings during the flood that the other two types of amphibious buildings have.

Type II (Mechanical amphibious system (type II)) and type III (Buoyant amphibious system (type III)) are mobile on the vertical axis, and as such demand pedestrian walkways capable of vertical movement. The advantages and drawbacks, as well as the differences in these two systems, are listed in the prior section of this thesis. Type III is more economical and sustainable from type II, as the main force that allows for the building's movement is the power of the water itself in comparison to type II where this force is mechanical. In the case of type II, the building can be raised above the flood level, in which case the connections must also be at this level, thereby raising the issue of whether the pathways would also need to be on a mechanical system, and this adding to the cost.

Pedestrian Communication During the Flood

One of the most important factors in amphibious urbanism, next to the question of where each type of amphibious building is located, the connectedness of various amphibious buildings during a flooding. Even though this topic falls more firmly in the sphere of amphibious urbanism rather than amphibious architecture, it must nonetheless be studied within the scope of the latter as well as the former.

In this thesis, the author continues to emphasize the importance of connectedness and interaction of people during flooding. Normal daily activities should not be forced to stop, especially in such cases when the flooding is a by-product of continual bad weather, such as in areas of monsoon climate. Depending on what is considered to be 'normal' weather, people living in different parts of the world respond differently to rainstorms, with e.g. Europeans often unwilling to venture outside of shelter during unfavourable weather, while Asians, especially those in wet regions with monsoon climate, appear to have a much higher tolerance for precipitation that can border on complete unaffectedness with respect to daily activity. Despite such behavioural differences, however, human activity cannot be brought to a halt by unfavourable weather conditions, and therefore the means by which individuals can accomplish their tasks must exist – in other words, it is crucial that everyone can move from one location to another (the store, school, workspace, home) as their tasks demand even in cases of flooding (cases which are long-lasting and seasonal in certain parts of the world, and thus absolutely unavoidable).

Floods have always been considered as natural disasters. Amphibious architecture offers to remove the fear associated with flooding by constructing dwellings and other vital city sections that are capable of working with the flooding instead of fighting against it, thereby removing the cause of such fear.

However, such buildings are not enough – establishing safe connections between them is just as imperative. The most common is the use of barges during flooding, which can be a very effective solution, though it must be noted that barges are not a viable option with any flooding where the water level is below 1 m.

As each type of amphibious building is unique, there must also exist specific communication network segments that allow for the connection between these three types (static elevation, mechanical and buoyant amphibious).

When it comes to type I (Static elevation system), the maximum distance of the building from the ground is pre-set and cannot be easily changed. The building is most often placed on stilts that define the building's elevation and are designed by taking the expected maximum flood level into account, so that the building itself remains above this point during a flooding event. In this case, elevated walkways make the most sense for connection, as they offer firm and stable pathways by which the pedestrians can commute between buildings. Elevated walkways are already widely in use, and there are plenty to be found in China as examples. [see Figure 87]

While this scenario is possible, it is important that it be well planned out. This type of building most commonly will have a stairwell along with an elevator that connects the building with the ground, and part of these will end up underwater in case of flooding. The dry section of the stairwell can serve as a dock for barges in cases of flooding (resembling the swimming pool stairs or paved steps into the sea) – the number of steps that are above water level may change, but this in no way impacts the difficulty of transfer onto a barge. [see Figure 86] This system would be applied only in cases of large commercial and residential buildings, and it would be accompanied by two levels of connections – the elevated walkways and the area below them intended for parks and other public areas that can be flooded without much damage. Small type III amphibious buildings can be positioned underneath these large type I buildings to serve as small bungalows or such commercial properties as small businesses, or some variation of urban area village.

Static elevation is not practical in the context of type II (Mechanical amphibious system) amphibious buildings as a connection to the walkways because these buildings are flexible and are not fixed. The building's height from the ground and water in the case of these amphibious buildings is dependent on the individual flood conditions, necessitating the use of boats for connection in these cases. Given the expense tied to this type of amphibious building, it is hard to predict that any sort of large neighbourhoods would be constructed primarily with this type of buildings, making it far more likely that it will be found as a rare lone example among types I and III amphibious buildings. It should be kept in mind that type II amphibious buildings are monumental and fully independent of its surroundings.

Type III amphibious buildings (Buoyant amphibious system) is the dynamic type whose movement is directly dependent on the floodwater. It is easy to implement in large neighbourhoods due to its low cost and economical design, and the assumption is that it will be used in primarily residential (suburban) areas populated by families with young children, elderly couples etc, making the needs for connections and communication between residents very high. The best solution for the neighbourhoods consisting of these types of amphibious buildings is the boatbridge system in the opinion of this thesis' author.

Boatbridge system – 'Amphibious Sidewalk'

Boatbridge system is inspired by the system that tourist boats in Chongqing use in order to connect the

Figure 85 | Static elevated walkways in combination with building

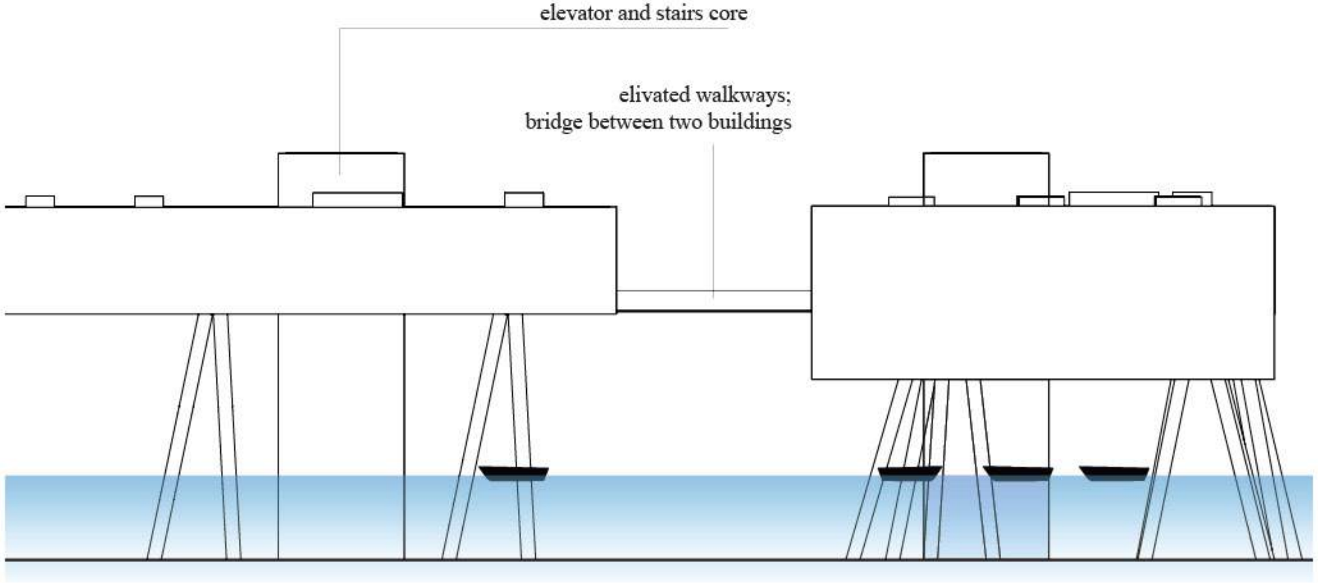


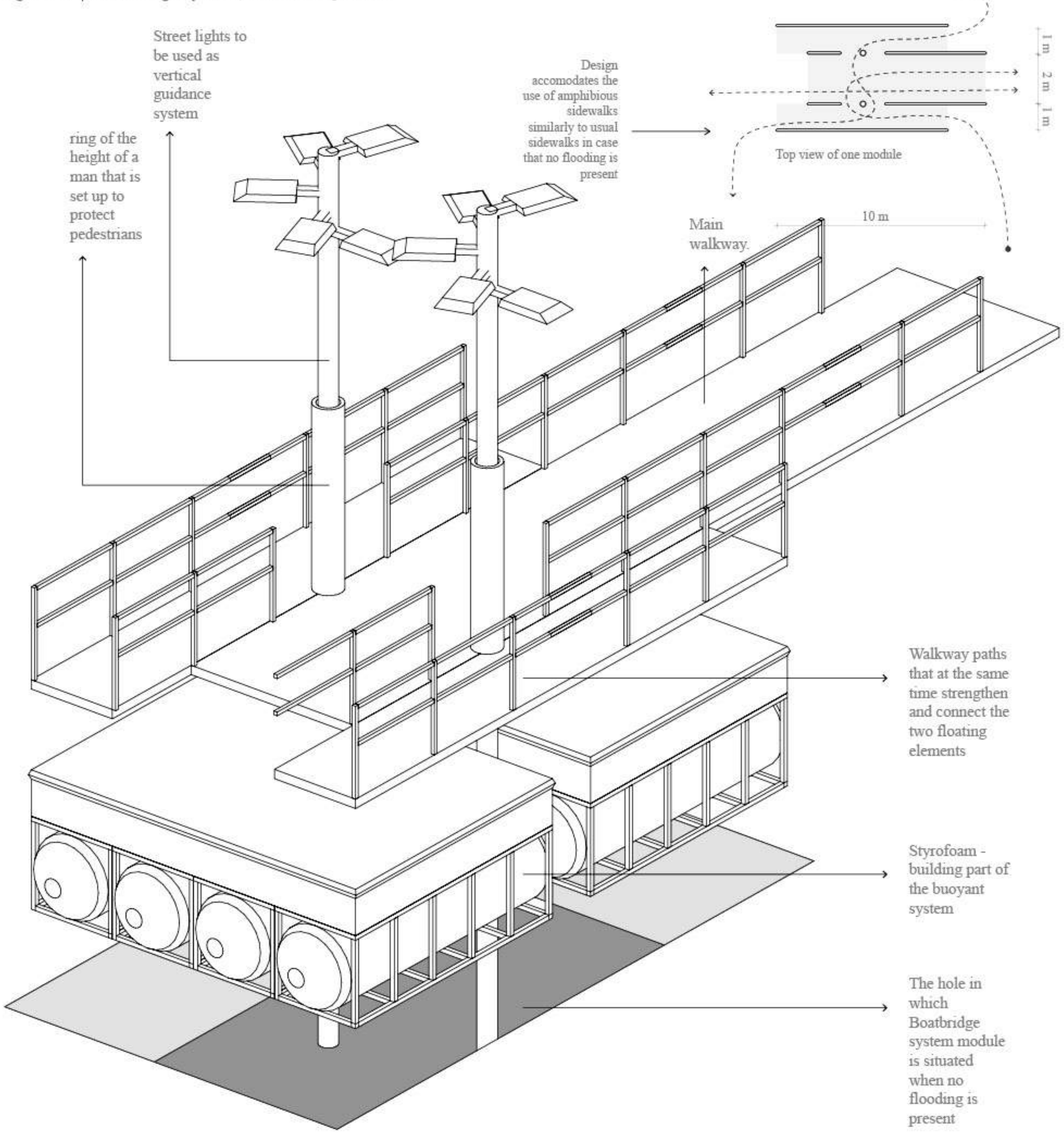
Figure 86 | Static elevated walkways

Figure 87 | Chongqing tourist boats lunching point

boats to the river shore. [see Figure 88] The shore itself is paved in a stepwise manner, allowing for the connection between boats and the shore to be adjusted to the river levels at any given point in time. The author has had a chance to study this system in Chongqing and to determine for himself the quality of such a connection. It does not appear in any way unstable, and there is no sense of insecurity when one is traversing the walkways, making it an excellent option for flooding-prone areas – and the idea for a boatbridge system was born (naturally, the initial shore–boat connection system would be adjusted to the needs of the flooding-prone areas, including residing on the ground during the periods of the year when there is no flooding present).

The Boatbridge system consists of modules that can be connected to one another, and it is in essence nothing more than an 'amphibious sidewalk': during flooding, its main purpose would be to rise with the flood and the buoyant amphibious system buildings to serve as bridges between buildings and behave in a similar manner to elevated walkways, while during the dry periods, it would behave exactly as a normal sidewalk.

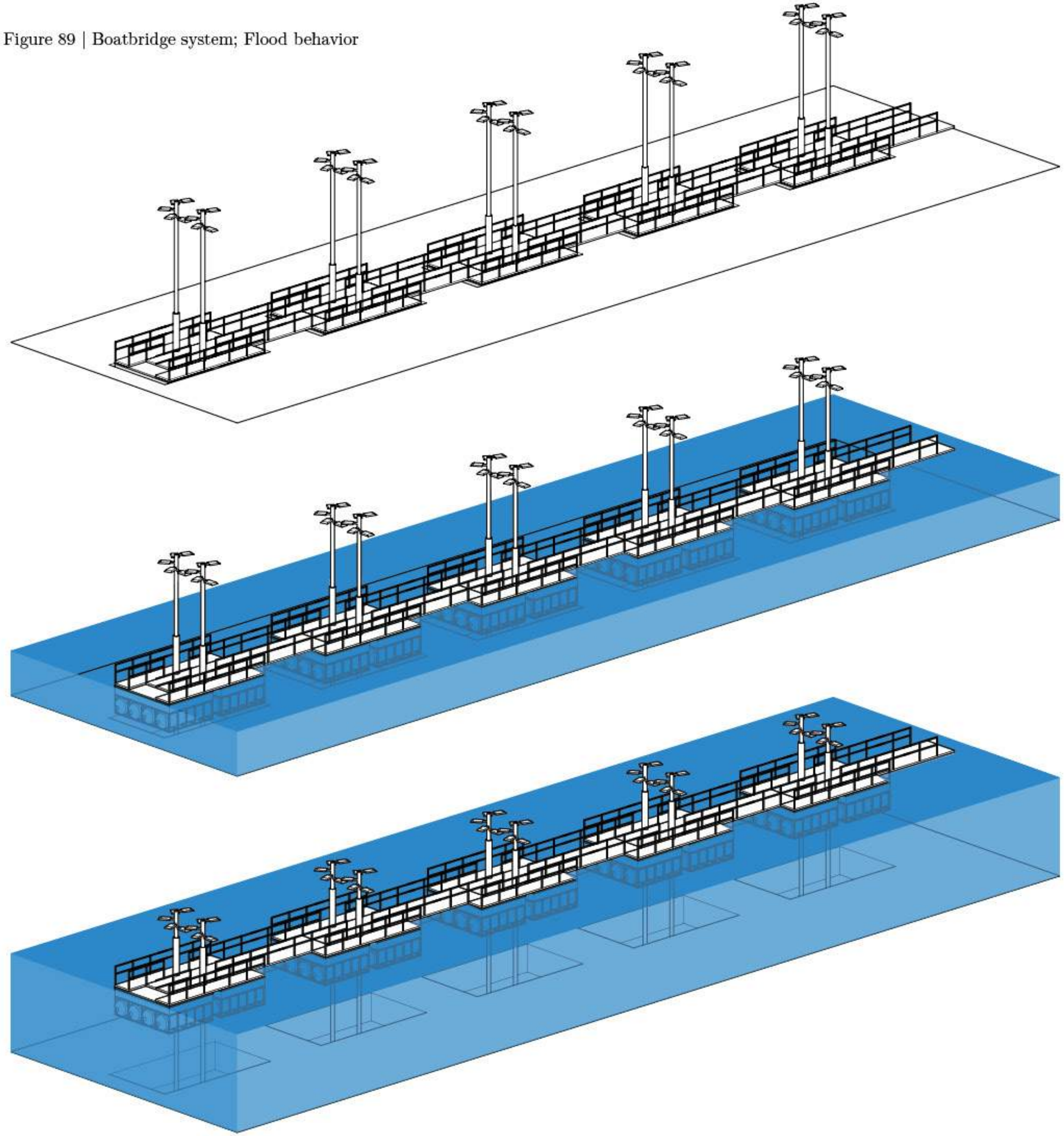
Figure 88 | Boatbridge system; Module explosion



Just as the type III amphibious buildings need a vertical guidance system, so too would the 'amphibious sidewalk' also need such a system. In this case, the vertical guidance system would be the streetlight poles, which would assist the boatbridge walkways to move vertically during flooding without any upset or damage. [see Figure 90]

asd

Figure 89 | Boatbridge system; Flood behavior



* illustration 1 of 3 shows the system during dry periods, when the boatbridge system is on the ground and integrated with the area infrastructure

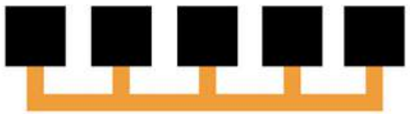
* illustration 2 of 3 shows the system in case of 1 m flood level

* illustration 3 of 3 shows the system in case of flood level over 1 m

Just as the type III amphibious buildings need a ver-
This system can offer various types of connectivity depending on the urbanistic needs, such as a direct connection between two amphibious buildings, a serial connection of several buildings in a row to a main corridor, or the connection of various buildings to a central floating platform that would act as a central hub. [see Figure 91]

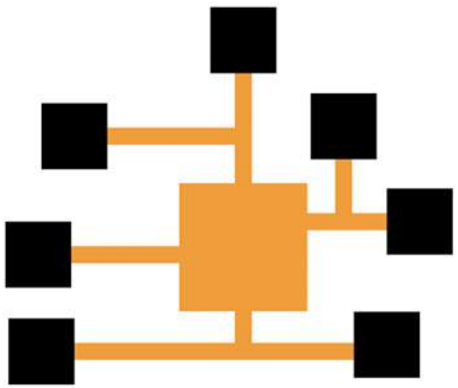
Boatbridge system
DIRECT CONNECTION

Amphibious house to amphibious house



Boatbridge system
LINEAR CONNECTIVITY

More Amphibious buildings connected to one another



Boatbridge system
PLATFORM HUB CONNECTION

More Amphibious buildings connected to one another through floating platform

Amphibious urban situation

Dotted red line represents pedestrian movement.
Hub communication established.
— boatbridge system; — static elevated walkways;

Figure 90 | Boatbridge system typologies

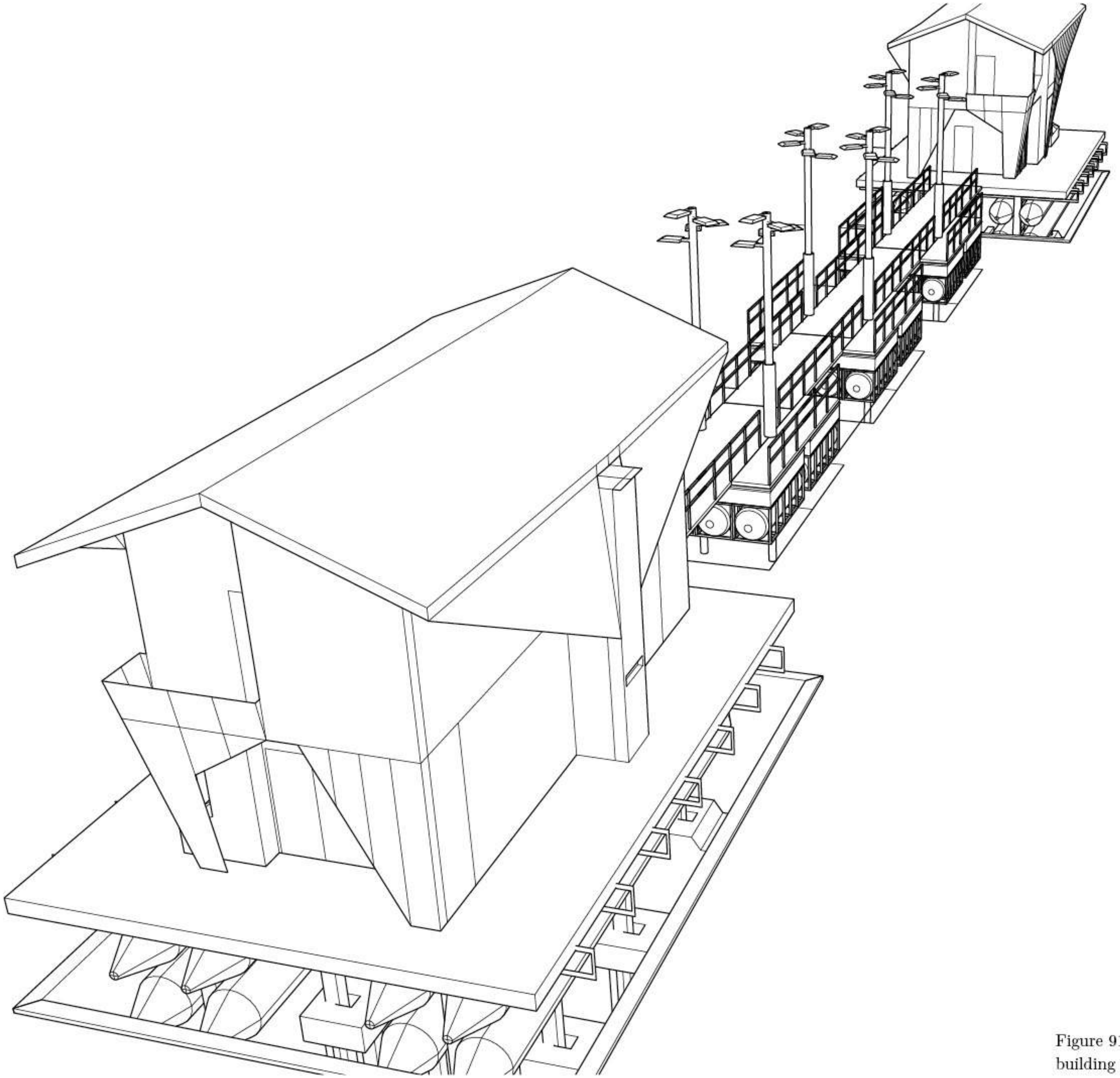


Figure 91 | Boatbridge system; direct connection: amphibious building to amphibious building

Amphibious Platform as a Central Element

Any given community (such as a residential neighbourhood) requires certain things in order to function properly. Helicopters are often used to airdrop basic necessities such as food, clean water, clothing and medical supplies, which can also be done with boats or barges. The problem of traditional architecture is that in cases of flooding, each building must be individually serviced and/or aided in such cases. This is not the case in amphibious architecture.

One advantage to the boatbridge system in amphibious architecture is the utilization of a concept of an amphibious platform, to which the neighbouring amphibious buildings would all connect. This allows the amphibious platform to act as an amphibious hub similar to the function of a neighbourhood square, where a central line of distribution could be established to service all the buildings connecting to it without loss of time and efficiency. Different amphibious hubs would communicate through the use of barges, and the amphibious hubs should be large enough to accommodate the landing of a helicopter in cases of emergency, such as serious injury that must be treated in a hospital.

The advantage here is also in that the inhabitants can walk out onto the 'streets' (boatbridge pathways) and gather on the 'square' (amphibious platform) in order to get in touch with each other and accomplish their tasks, especially in cases when the weather is good but the water level is high enough to impede normal human activity.

For this reason, the author suggests the use of the amphibious hubs system with central amphibious platforms that would also function as docks for barges, heliports, locations for human gathering, serving the purpose of town squares, including possible play areas for children.

Connections in Mixed System Amphibious Architecture Environment

As has been shown in previous sections, each type of amphibious building requires a uniquely suited type of connection between buildings. This raises the obvious questions of how to effectively connect amphibious buildings that belong to different types – what are their similarities and differences that would impose limitations on the design of connections for such a mixed system environment?

Type I (static elevation system) is a static type that naturally imposes lack of movement on the walkways attached to it. In comparison, types II (mechanical system) and III (buoyant amphibious system) are dynamic, adjusting their height depending on the water levels. This difference could be bridged most easily in the areas of stairwells that are required to connect elevated walkways with the ground level, whereby the adjacent rising walkway segments, whether mechanical or buoyant (those associated with types II and III amphibious buildings), would connect to the stairwell at its own level in much the same way as how tourist boats connect to the river shore in Chongqing, the example given in Boatbridge system – 'Amphibious Sidewalk'.

This situation is somewhat easier to bridge in the case of types II and III, which are both dynamic elevation systems. Given that the height of elevated walkways in case of the buoyant system is fully dependent on the water level, the connection between the mechanical and the buoyant elevated walkways would need to be regulated by way of mechanics, either by keeping the type II amphibious buildings (mechanical) on the water level to match that of type III buildings (which, being buoyant, would not have the option of rising higher than the water level), or else some sort of mechanism would need to be developed to bridge the height difference – one possible option is using the escalator machinery as a model.

The one connection that is always a back-up option is simply using barges to ferry anything of need between the different systems.

Amphibious Building Niche

Each type of amphibious building demands its own special niche, defined as a place or position suitable or appropriate for said building. This must be taken into account when connecting amphibious architecture to amphibious urbanism, in that planned buildings must be assigned to proper types, and that they must all be adjusted to each other and their environment, as well as the environment to them, in order to create a harmonious, functional area that will be fully functional when it truly counts – during a flood.

Type I (static elevation system) is most appropriate in regions where the maximum water level can easily be established and expected to not be rising over time – therefore, it is very suitable for waterside locations that are in danger of seasonal flooding, including rivers, lakes and seas. In case of places with more erratic maximum water levels, this type can be implemented for large buildings that would not easily be lifted and lowered when the need arises.

Type III (buoyant amphibious system) is most appropriate in case of small buildings such as private houses or small commercial buildings. These buildings can easily be implemented in small villages, suburban areas, and large cities equally, especially given their affordability. They can easily be situated under type I buildings so long as the height is properly calculated so that the two buildings would not collide with each other, and can therefore serve well for local markets and other outdoor recreational areas such as children's playgrounds, outdoor theatres, pavilions and so on. Type III amphibious buildings are the most efficient in areas that see multiple flooding events each year, and are fast becoming the most popular of the three types.

Type II (mechanical amphibious system) is at present is still not cost-effective enough to be widely implemented, therefore demanding further improvement and research. The best place for implementing type II is in areas where the water flow is extremely fast and turbulent, necessitating the complete lift of the building out of water's reach in order to protect it, and in such places as where there is a danger of type III buoyant systems being unable to handle the speed of flood income, such as in flash floods – a good example of this would be tsunami-prone regions.

Significance of Amphibious Architecture in Urban Area

Amphibious architecture in urban areas can have a different reason for existence. Very often amphibious architecture is the one dealing with 'fixing' the problem in a specific suburban or urban area. It should be noted that amphibious architecture can deal with new areas as well. A good example is Chongqing, which has one of the highest densities compared to various other big cities. In such a city, open space plazas are something that always falls into the category of those things there can never be too many of. The interaction in a public space is necessary. It is difficult to create a space in the city that is already quite densely built with very large buildings. That is the moment when spaces like floodplains and flooding-prone areas can come into consideration.

Open space is always needed in urban areas. Since Chongqing topography is very specific and is already highly developed, the easiest option would be to demolish some buildings, clean and free up room and then add these necessary open public surfaces. However, this is not always the option that should be considered as a solution, as there are places that are empty and waiting for a proper action, which would not necessitate the expenses inherent in the building demolition and site clearing. One such place is the offshore Guangyang Isle in central area of the city located on the Yangtze River.

The Guangyang Isle is a perfect spot for an amphibious city plaza, but it is a floodplains and flooding-prone area as well. It has a tendency for flooding and that brings the need for amphibious architecture in this urban area. The potential of this place is high and it can be a great place for a good experimental project where floating architecture can be combined with amphibious architecture.

A similar island area appears in Shunde District of the Foshan city in the Pearl River Delta, Guangdong Province of China. [see Figure 93, 94 & 95]

Figure 92 | Shunde City Master Plan

The design strategy of SLAD office together with Node Office was to bring back the intensive, small scale, relaxed lifestyle and casual atmosphere to this Lingnan region.

The program of the Shunde City is a Comprehensive Master Plan that unifies Shunde's new city centre with future parks, river fronts, and residential and commercial districts.

Figure 93 | Shunde City Master Plan

Figure 94 | Shunde City Master Plan

Figure 95 | Living by water

5. Amphibious Urbanism of Metropolitan Cities

Figure 96 | Chongqing downtown

Chongqing as a City Suitable for Amphibious Architecture

Chongqing (重庆) is the biggest inland city of China, located on the mountain relief through which flows the Yangtze River. Over the past years, Chongqing has recorded a rapid growth with about half a million new residents every year that forced development of enormous amounts of residential developments , with plans for even more massive growth in the future. Through time spent in Chongqing, the author has had the opportunity to witness the constant appearance of new buildings everywhere in the city.

A major city in Southwestern China, Chongqing is one of five national central cities in China and beside Beijing, Shanghai and Tianjin is one of the four direct-controlled municipalities. It is the only city of this kind located in inland China. This city is a launching point for scenic boat trips down the Yangtze River through the Three Gorges Dam. It has a lot of potential for tourist events and a tendency to become one of important Chinese international cities.

The municipality was created on 14 March 1997 out of what was previously a sub-provincial Sichuan Province city administration. As of 2015, the city's population is just over 30 million with the urban population of 18.38 million. This urban area is spread out between the Chongqing city proper (8.5 million), the Wanzhou District and the Qianjiang District, both of which are cities in their own right Chongqing is the most populous Chinese municipality and also the largest direct-controlled municipality in China, and comprises 21 districts, 13 counties, and 4 autonomous counties.

Compared to Shanghai, Chongqing is not 'too' international, but it has a big potential to become an international city.

Besides the rocky relief that is especially interesting for architecture and urbanism, Chongqing has a lot of floodplains and flooding-prone areas. The author has had the opportunity to visit different floodplains and flooding-prone areas of Chongqing outside of the city, but one especially interesting and appealing flooding-prone area is in the heart of the city. A floodplains and flooding-prone island area in the middle of the urban 'jungle' laying untouched and calling for amphibious urbanism. The name of the island located at the Yangtze River is 'the Guangyang Isle' and more about it will be presented in the following chapters.

Figure 97 | Constant appearance of new buildings

Figure 98 | Launching point for scenic boat trips down the Yangtze River

Chongqing urban structure

The municipality's size is 470 km east-west and 450 km north-south. It borders the Hubei province (east), Hunan province (southeast), Guizhou province (south), Sichuan province (west, northwest), and Shaanxi province (north, northeast). Chongqing is intersected by rivers and mountains: the Daba Mountains (north), the Wu Mountains (east), the Wuling Mountains (southeast), and the Dalou Mountains (south). There is a natural slope to the area in the direction north to south towards the Yangtze River valley, though there are sharp rises and falls in elevation by way of mountains and hills at different heights. Many stone forests, limestone caves and valleys can be found in this typical karst landscape. Chongqing lies on the Yangtze River, which runs west to east (665 km course) through the Wu Mountains at three places. It forms the well-known Three Gorges: the Qutang, the Wuxia and the Xiling gorges. The Jialing River joins the Yangtze River in Chongqing from the northwest, previously running through "the Jialing Lesser Three Gorges" of Libi, Wentang and Guanyin. Known as the 'mountain city' and also the 'city on rivers', Chongqing's topological features are unique and include rivers, forests, waterfalls, springs, mountains, gorges and caves.

The city is located on a big syncline valley. The highest point in downtown is the top of E-ling Hill (379 m), keeping the Yangtze and the Jialing Rivers apart for some kilometres, while the lowest point is Chaotian Gate (160 m), where the Jialing River flows into the Yangtze, with the average height of Central Chongqing being at 259 meters. There are so many bridges on the Yangtze and Jialing Rivers in the urban area that the city is often called the Capital of Bridges of China. The first bridges were built in 1977 (Shibanpo Yangtze River Bridge) and 1958 (the Niujiatou Jialing River Bridge) on these rivers respectively. As of 2014, there are 31 bridges on the Yangtze River and 28 bridges on the Jialing River, with various structures and shapes, thus making Chongqing attractive for the study of bridge architecture.

Since becoming a national-level municipality in 1997, Chongqing has become a major transportation hub in southwestern China, allowed for by the construction of many railways and expressways to the east and southeast, and it is also one of the most important inland ports in China. Luxury cruises are commonly organized along the Yangtze River to other major cities on its banks such as Yichang, Wuhan, Nanjing or even Shanghai. In the past, the waterway was of extreme importance as it was virtually the only transportation option in the river valley, though the rail, expressways and air travel have taken much of the traffic from the waterway, leaving it free for tourism rather than local needs. The construction of the Thre Gorges Dam has improved access to the city for larger cargo vessels, allowing for the bulk transport of goods along the Yangtze River (coal, raw minerals and containerized goods).

Chongqing's Central Business Districts (CBDs)

The urban area of Chongqing is known as Central Chongqing (重庆主城区). Spanning approximately 5473 square kilometres, it includes the following nine districts:

1. *Yuzhong District* (渝中区, *or "Central Chongqing District"), the central and most densely populated district, where government and international business offices are located. It is located on the peninsula surrounded by E-ling Hill, Yangtze River and Jialing River.*

2. *Jiangbei District* (江北区), *located in the north of the Jialing River.*

3. *Shapingba District* (沙坪坝区), *roughly located between the Jialing River and the Zhongliang Mountain.*

4. *Jiulongpo District* (九龙坡区), *roughly located between the Yangtze River and the Zhongliang Mountain.*

5. *Nan'an District* (南岸区, *or "Southern Bank District"), located in the south side of the Yangtze River.*

6. *Dadukou District* (大渡口区)

7. *Banan District* (巴南区, *or 'Southern Chongqing District'). Previously called Ba County, the name was changed in 1994. Its northern area merged into central Chongqing, and its capital town Yudong is a satellite city of Central Chongqing.*

8. *Yubei District* (渝北区, *or 'Northern Chongqing District'). Previously called Jiangbei County, the name was changed 1994. Its southern area merged into Central Chongqing, and the capital town Lianglu Town is a satellite city of Central Chongqing.*

9. *Beibei District* (北碚区), *a satellite city northwest of Central Chongqing.*

Figure 99 | Chongqing's Districts

Yuzhong District

Yuzhong District (渝中区) is the central district and the capital of Chongqing municipality, making it the political, economical, and entertainment centre of Chongqing. The Jiefangbei CBD is a leading business and financial centre of western China and is located in the central portion of Yuzhong. The district itself is effectively a peninsula, as it is surrounded on three sides by water. It conatins some of the tallest skyscrapers in China because of its dense population, hilly nature, limited space and, of course, the fact that it is Chongqing's main business district.

Though there are some green areas contained in its boundaries, Yuzhong lacks enough open public green areas for recreation and public activities.

Figure 100 | Green Area of Chongqing

It is true, however, that Chongqing has the Chongqing Central Park (重庆中央公园), which is one of the largest open public urban parks in China with the territory of ca. 1,53 km^2 and a rectangular shape. It's purpose was to function in much the same way as the New York Central Park or the London Hyde Park – to provide Chongqing people with an open green area for outdoor recreational sports and other activities that allow for nature enjoyment.

The park is found in the Yubei District, relatively close to the Chongqing Jiangbei International Airport. The Central Square, located in the northern half of the park, has an area of 30 hectares and can accommodate more than 100.000 people. An enormous path called the Jieqing Dadao (节庆大道; literally: 'Fiesta

Avenue"; 600 m long, 20 m wide) cuts through this half of the park. In contrast, the southern half consists of forest, hills, grassland and freshwater ponds and is intended to be a natural area.

Nanping to Yuzhong District; A to B

Through three months of living and working as an intern in an architectural office, the author has had the opportunity to meet the city from within by doing the things that local people do from day to day. The road from home (Nanping District) to work (Yuzhong District) has always been a very interesting experience in a different way since the author has to cross the bridge on the Yangtze River in order to reach the commercial centre of the city. Starting from the most complicated and ending with the simplest one, several possibilities were offered to the average person, including walking, bus rides, driving one's own car or car2go , taxi rides and metro rides.

Walking as a pedestrian was both a wonderful and terrible experience. Chongqing is a very nice and interesting city, but availability for pedestrians is very low. The answer to the question 'How to deal with the pedestrian problem and how to improve the pedestrian network in Chongqing?' can be found in the project proposal done by Gehl Architects . In their project proposal 'Chongqing Public Space Public Life Study & Pedestrian Network Recommendations – City of Chongqing November 2010' , the architectural office Gehl Architects have conducted detailed analyses of existing pedestrian networks and activities proposed suitable solutions for Chongqing pedestrian network.

The bus ride was fine, however it was accompanied by overcrowding and the inevitable traffic jam. It is important to point out that residents of Chongqing do not overly respect road signs and often 'fight' for being the first on the road, which makes bus ride time extended and difficult. Moreover, bus lines are not connected well, so one has to wait a long time to switch bus lines.

Driving one's own car or car2go (or any other shared car) is a more complicated solution for those new to and unfamiliar with the city, as they would not easily know where and when traffic jams can happen, and the parking is hard to find.

Taxi ride is maybe an even better solution since one does not have to think about all the responsibilities connected with owning or renting a car. The problem with taxi rides in Chongqing is that taxi drivers are extremely nervous and rash drivers. They often try to pick up as many people as possible in an attempt to 'force them' to ride together. In itself, car sharing is not a negative thing, as it would lower the collective carbon footprint of the group, making the transport 'green and more sustainable'. However, the skill of taxi drivers on the road combined with their often old cars can make rides very unpleasant and in some cases even, which can be doubly uncomfortable if the number of people riding in the car is the maximum capacity of the vehicle.

The metro ride is probably the safest and fastest travel option in Chongqing, as it is not influenced by traffic jams or road rage. The Chongqing metro system (CTR, Chongqing Rail Transit) is a very young system. It was built in 2005 and as of 2016 does not cover the whole city, though it does serve the transportation needs in the city's main business and entertainment downtown areas and inner suburbs. It is the oldest metro systems in operation in the interior west of China. It consists of four lines, with a total track length of 201.6 km. The only problem one can encounter is the hilly relief. Although the metro in Chongqing is able to climb up a hill, some higher parts are still not covered (such as for example 鹅岭, E-ling) so it is very common that one has to walk a long way even after leaving the metro at a specific station. From accessibility point of view, escalators represent a big problem since in China, for an unknown reason, there are always at least five additional steps after the escalator ending.

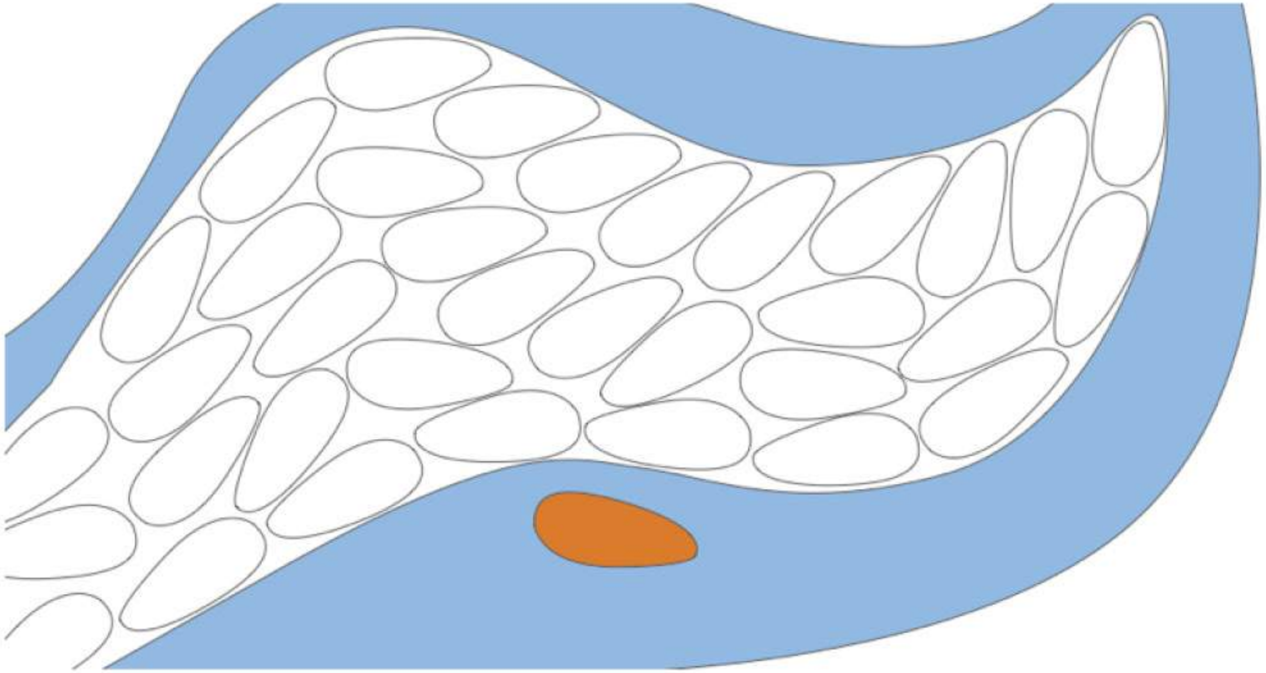
Flooding-prone and Floodplain Area in Urban Part of Chongqing

Flooding-prone and floodplain areas in the urban area of Chongqing are manly situated around the Yangtze River where the city has developed elevated roads and metro infrastructure, some walkways, restaurants, and so on. Residential buildings are not common, but they are present.

Figure 101 | The Guangyang Isle in Past

During the time the author spent in Chongqing, walking from Nanping to Yuzhong Districts, the author has had an opportunity to observe and analyse 'the Guangyang Isle' of the Yangtze river, the island just opposite the Central Business District (Yuzhong District) and a very interesting and historically important abandoned area in the heart of the city. During World War II, it was one of the seven airports in the Chongqing region used for air defence of China's capital city. The Guangyang Isle airport was a military and civil airport (Guangyangba Air Base 重庆广阳坝机场) station for Chongqing region during the rainy season, when the civil airport of Chongqing was not suitable for landing. It was gradually abandoned after the opening of the Chongqing Baishiyi Air Base. The length of the airport runway was 1,100 metres and the width was 40 metres.

Although during World War II the island was very important for aviation, in the period after World War II until today the Guangyang Isle has changed its various functions. It used to be a hippodrome, followed



Legend: ● the Guanqyang Isle

Figure 102 | The Guangyang Isle of Yangtze river

by a more general function of an 'island park' which was and still is occupied by fishermen that have never abandon this place.

For now, the Guangyang Isle is only accessible by small fishermen boats. Fishermen visit the Guangyang Isle frequently, almost every day when there are no major water rises. Communicating with them was difficult, as the author does not speak the Chinese language and the fishermen did not speak any language other than Chinese. With the help of the local people, communication was established. The Guangyang Isle is 6.4 km^2 large, 1 km long and 0,4 km wide at the widest part. The altitude range of the island is from 200 to 280 metres. Compared to the Central Business District (Yuzhong District), the Guanqyang Isle is around 35 times smaller.

In a city such as Chongqing, amphibious architecture and urbanism often find place not only when it is needed as a fixer, but as well, as a tool that can help to populate places that are normally left empty and unused.

The Guangyang Isle of the Yangtze river is located just opposite the Central Business District, hence in a very advantageous position. The Guangyang Isle is 6.4 km^2 big and it used to be an military and civil airport (Guangyangba Air Base重庆广阳坝机场) . The altitude range of the island is from 200 to 280 metres. The length of the airport runway was 1,100 metres and the width was 40 metres. This airport was one of seven used during World War II for Chonqing's defence, and also for civil aviation when the civil airport in Chongqing was closed during rainy season. It was gradually abandoned after the opening of the Chongqing Baishiyi Air Base. Now this place is left empty seeking for the interaction. It is a great spot for amphibious urbanism in this city.

Figure 103 | The Guangyang Isle of Yangtze river II

Figure 104 | Google Earth satellite view of the Guangyang Isle in

Figure 105 shows how large the floodplains and flooding-prone area of the Guangyang Isle actually is. In terms of urban fabric, it is possible to conclude that Guangyang Isle is not small at all.

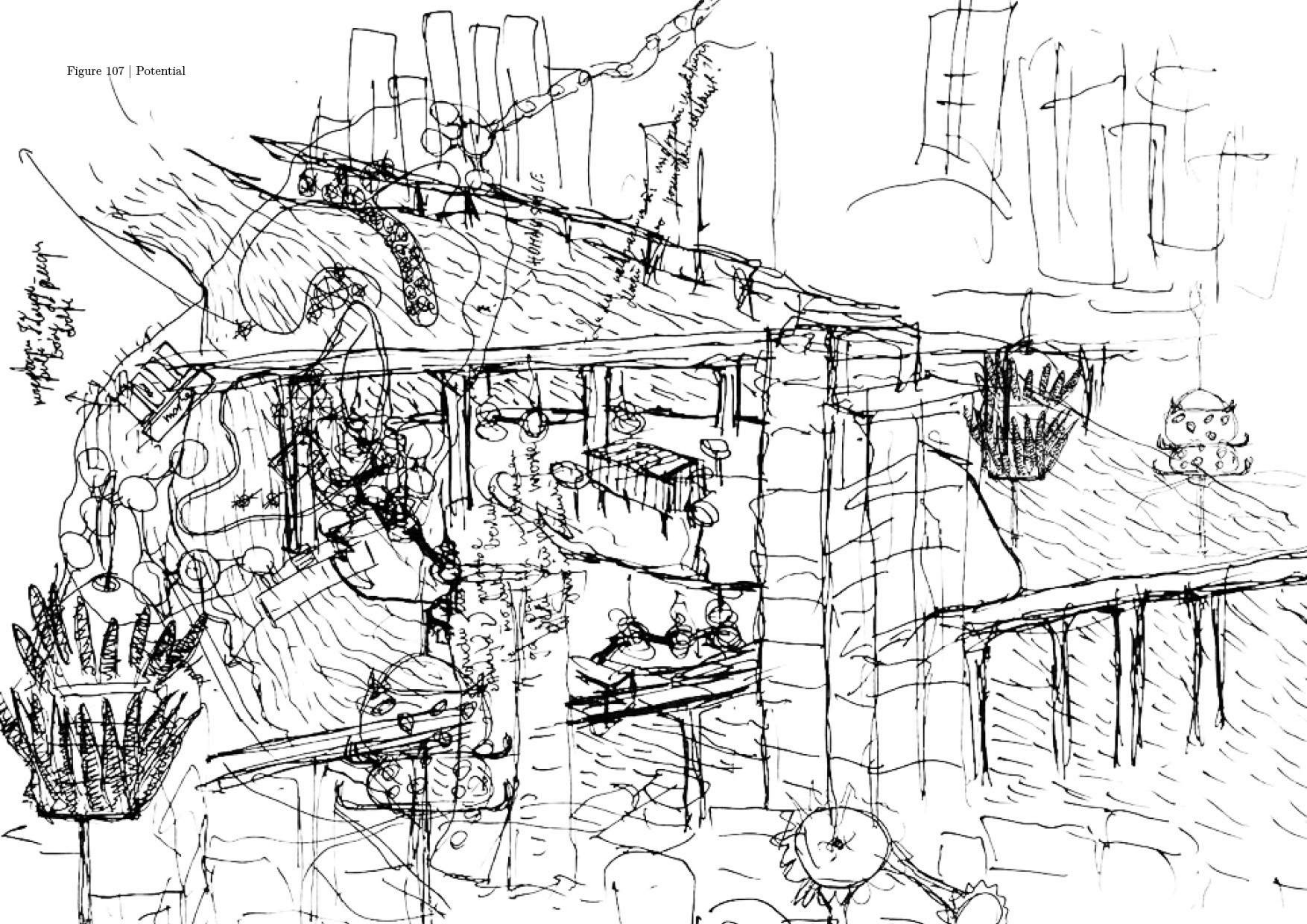
Figure 105 | Urban fabric of Chongqing central area I

Figure 106 shows shows the size of the Guangyang Isle in most of the time during the year, and picture below illustrates the maximum floodplains and flooding-prone area of the Guangyang Isle. It is clear that, compared to the core city center, the Guangyang Isle represents a large surface – about 10%.

Figure 106 | Urban fabric of Chongqing central area II

Figure 107 shows the satellite view of the Guangyang Isle and city core. It is clear that the urban fabric of Chongqing is scattered because of the mountainous natural terrain of the area. In any case, we can see that buildings are large and very high inside the core sections, and smaller and lower as one goes nearer to the river.

Figure 107 | Potential



Potential of Flooding-prone and Floodplain Areas in an Urban Area

The potential of a floodplain and flooding-prone area can be shown in the example of Chongqing, where the author spent three months living and analysing the downtown floodplain area.

The first to be presented will be the potential of the floodplain area in Chongqing, after which the collected data and projects from this thesis will be applied in the form of a collage on a master plan that will at the same time demonstrate how amphibious architecture together with amphibious buildings can find a place in urbanism.

Through the below listed examples, it will be easy to understand the importance of defining and understanding amphibious urbanism, which until now has not been mentioned in these contexts.

It is important once again to emphasize that amphibious doesn't mean directly 'floating', as there already exist numerous examples of suggestions and scenarios for floating cities etc. Amphibious is that which is capable of functioning both on the earth and on water in a fully functional combination.

There are many things that are amphibious in nature. One important thing is that architecture by itself should not clash and fight nature, especially not in large dimensions such as urbanistic differences in cities.

Future cities will most likely begin taking amphibious urbanism increasingly into account. With the listed examples of how to implement amphibious architecture on a large scale into the urbanistic planning, the author will conclude this thesis with the hope that after him, as it was before him, there will continue to be those who will recognise the importance of amphibious buildings, architecture and urbanism, and will continue to offer suggestions and realise their ideas and solutions for amphibious cities.

The masterplan presented below will offer an idea for the new amphibious city plaza. Considering it is a suggestion, this thesis will not be going into exact detail. Firstly, on the basis of gathered data that the author has noted during his time in Chongqing, the behaviour of water around The Guangyang Isle will be presented.

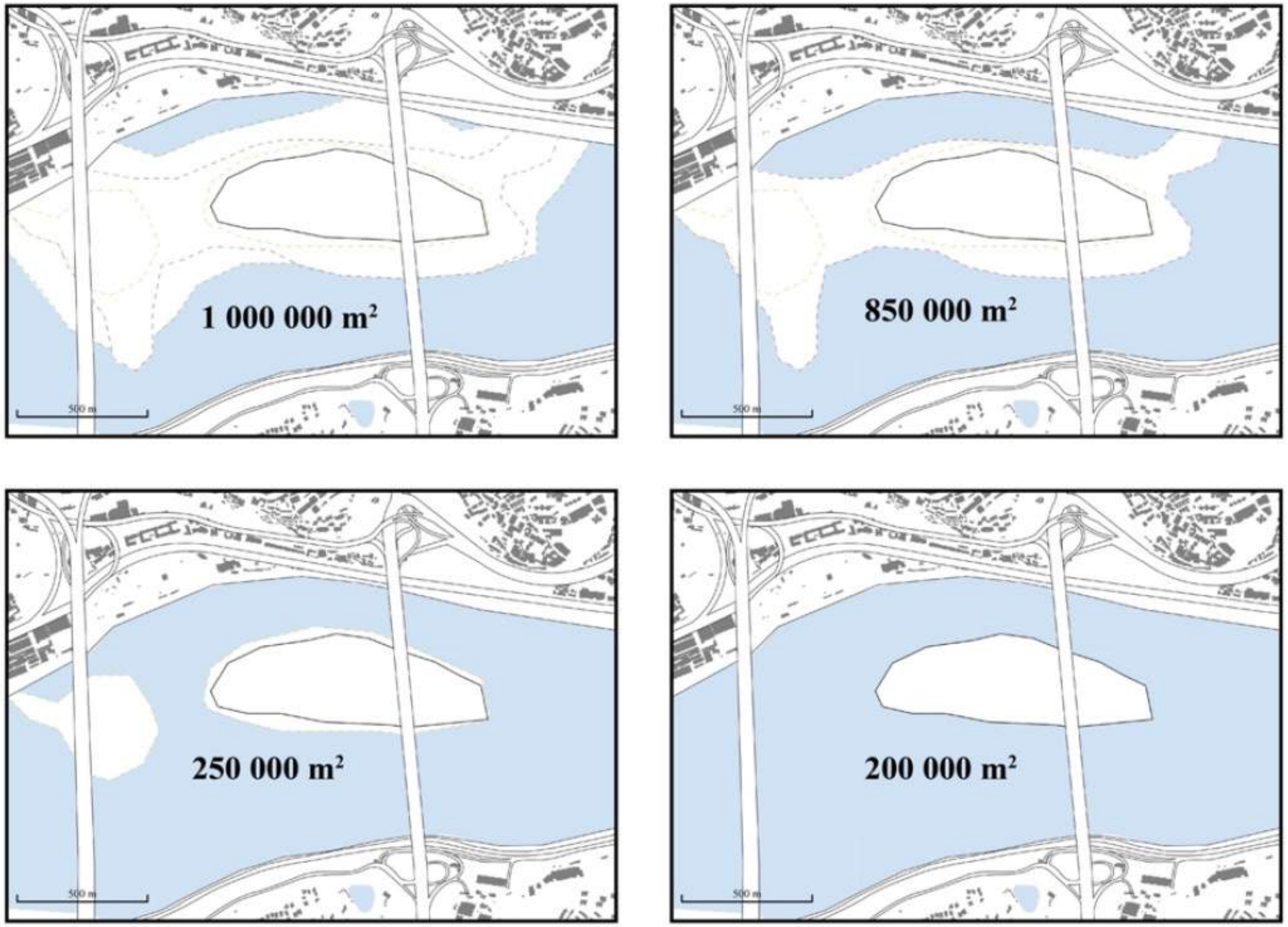


Figure 108 | The Guangyang Isle Different States

From Figure 133, it can be seen that floodplain and flooding-prone area in Chongqing downtown area is considerably large. When the water is the most receded, the surface achieved is up to 1 000 000 m^2, while at high water level, there is only the island with the area of 200 000 m^2.

Geil Architects offered a proposal in their Chongqing Public Space Public Life Study that the shore opposite the Guangyang Isle should be a Riverfront Park. .

This project proposal will build on the idea suggested by Geil Architects, therefore their suggestion for a Riverfront Park will be taken into account.

The behaviour of the Yangtze River is based on satellite pictures of the isle through the years (from 2003 untill 2016). The water level demonstrates four distinct states of this area, with an additional one being when the Guangyang Isle is itself completely submerged.

The panels in Figure 110 are not consistent with respect to the time of capture, but they serve as a good indicator of the drastic changes in terrain. From those satellite pictures spanning thirteen years, it is easy to conclude that at the whole the Guangyang Isle floods on average once a year.

The author had the opportunity to speak with different local people form Chongqing, who have also corroborated that it is common knowledge that the Guangyang Isle floods in its entirety at least once a year, as well as that it reaches the state of around 850 000 m^2 in area from Figure 133 in about the same time average. The state of 1 000 000 m^2 area is rarer, but not excluded.

One can easily see that this large area is in its entirety unused. In section Flooding-prone and Floodplain Area in Urban Part of Chongqing, a small history of this island has been presented. It was used as an airport, with no reason for it to be used as anything else so far. However, Chongqing is developing with incredible speed and demands with each day more downtown area, where the Guangyang Isle offers itself for exactly this purpose.

Geil Architects, in their urbanistic suggestion for Chongqing, emphasized the importance of free outdoor activities necessary for people who inhabit the downtown area, as well as a need for green surfaces. They have shown through their research that Chongqing has a very impractical access to the riverfront, which can be used as a city attraction if well implemented. In the case of Chongqing, new pedestrian routes are required to allow for easier access to the water, and the Geil Achitects suggestion is to construct a riverside park on the peninsula edge so that the water can be accessed from all points. The park would include high overlooks, river access and floating structures, and would allow for a multitude of outdoor activities, green spaces, food courts and other public gathering spaces that would include vendor businesses, making it a perfect place for families and tourists to spend a relaxing several hours while still being offered a taste of the city's culture.

This project would build from the Geil Architects idea in that it will take their plan and round it out with the inclusion of amphibious architecture, as is fully ap-

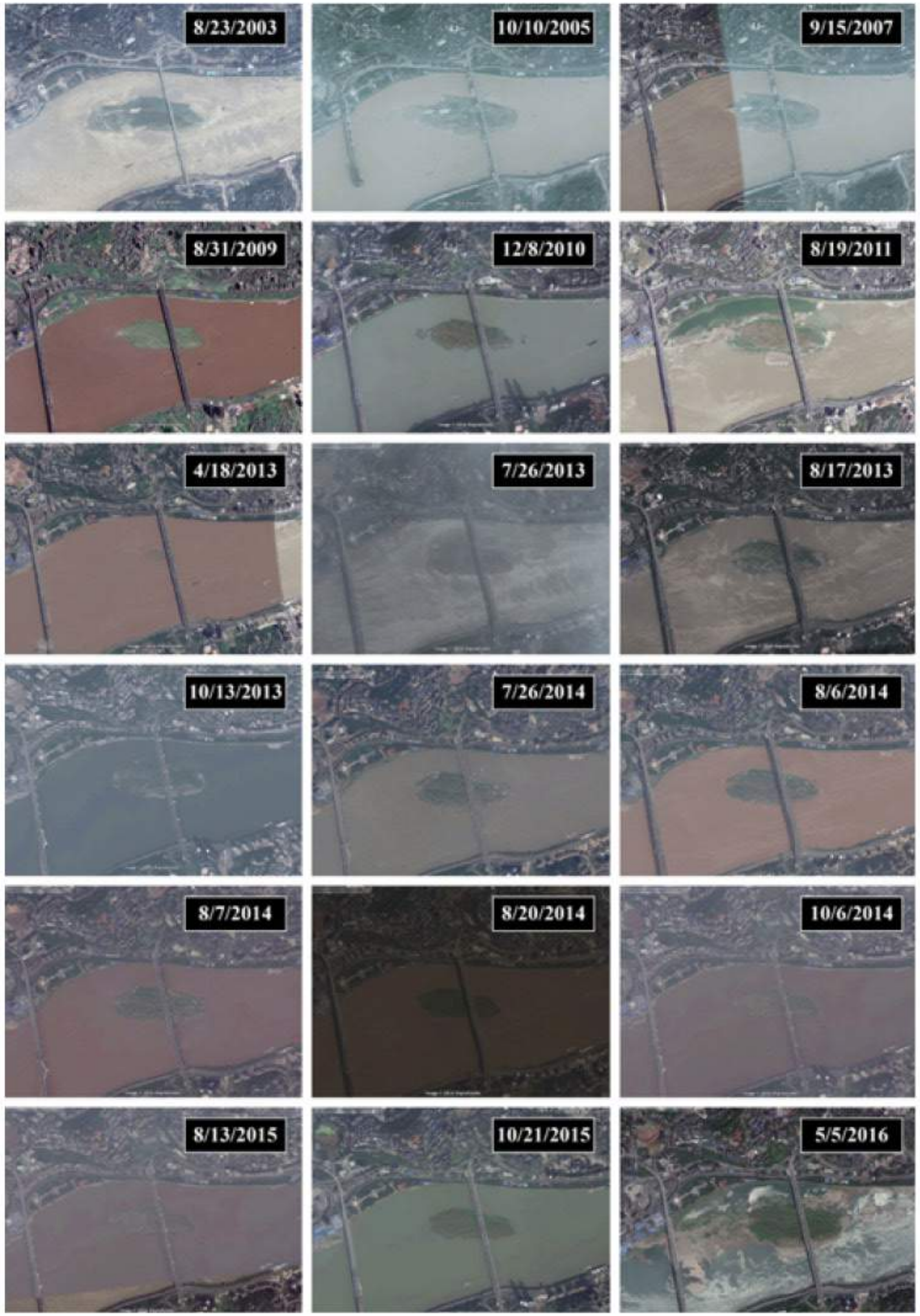


Figure 109 | Google Earth Satellite Picture of The Guangyang Isle from 2003 to 2016 [copyright google.com] propriate for a waterfront park. This approach would enrich the city with new surfaces that would be interesting to all visitors as well as the city's residents, and in addition, this approach of combining the Geil Architects proposal with amphibious architecture would also be a prime example of real amphibious urbanism.

It would be a new and experimental approach, but it would open the doors for the future of architecture and lift the professional conversation on a wholly new level.

Figure 110 | Geil Architects | Principal plan of Riverfront Park

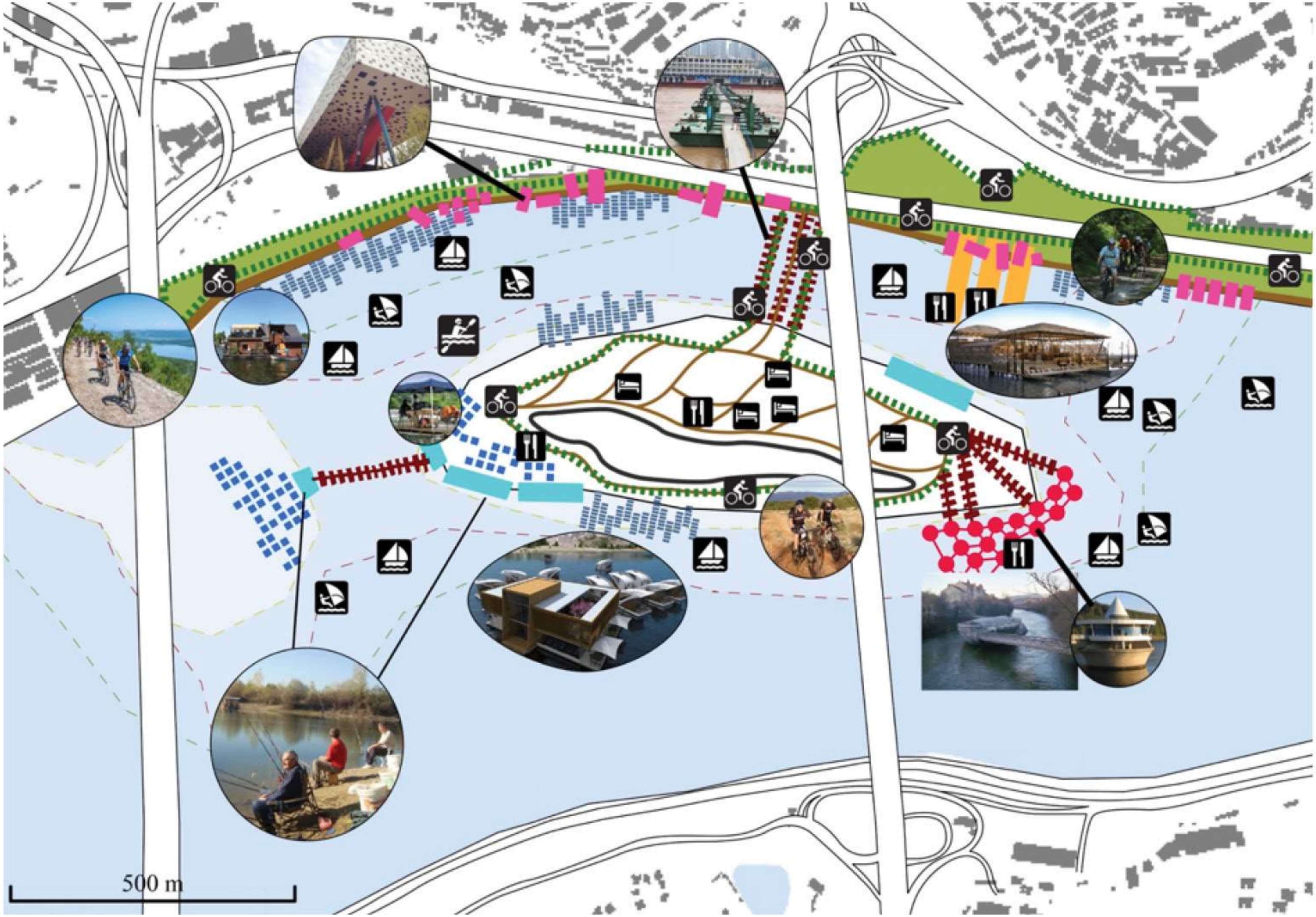


Figure 111 | Amphibious Masterplan

As can be seen from the Amphibious Masterplan in Figure 112, different urban functions and public activities are combined into an amphibious city plaza.

Several of the former activities that had been held on the island have been kept in the proposal (e.g. horse racing). New running paths have been created, which can be flooded without any difficulties in the case of the rising water level. With the aid of amphibious bridges, the amphibious plaza is also successfully connected to the Riverfront park.

In this case, amphibious urbanism not only serves to protect the people from floods and safeguard against avoidable economic losses, it also serves to turn 'suffering' into fun and at the same time draw the best out of nature and architecture.

In amphibious urbanism, nature and architecture work together, rather than against one another.

In the following illustrations, several architectural solutions will be demonstrated, as well as how the amphibious architecture fits into these types of areas.

Figure 112 | London in Future

Figure 113 | Houseboat community, Alameda, California

Figure 114 | Structures of Coastal Resilience: Designing for Climate Change

Figure 115 | Floating and Amphibious

Figure 116 | Amphibious Hotels

6. Final Words

After looking at the historic development of water dwellings, followed by the description of amphibious building behaviours and amphibious buildings, as well as amphibious architecture and urbanism, this thesis helps clarify the meaning and definition of amphibious behaviour that is more and more presented and needed in architectural design from day to day. The gap that appears between the final architectural/urban designs and technical design of amphibious buildings is closed. It is clear that the amphibious building is possible and that this kind of building by the definition of 'amphibious' belongs to one of three types, defined in this thesis as: 'static elevation system', 'mechanical amphibious system' and 'buoyant amphibious system'.

It has been made clear that amphibious buildings are affordable and feasible. The fear of overpriced building has been removed. They can of course be expensive and non-affordable, especially in the case of the 'mechanical amphibious system', but examples presented by Prof. Elizabeth English and Baca Architects are the real proof that the 'buoyant amphibious system' is affordable. The table in chapter Buoyant amphibious system presents several existing 'buoyant amphibious systems', which have been covered in chapter Case studies.

An urban proposal in Chongqing points out the importance of amphibious architecture and urbanism even in big urban areas. It shows that amphibious is not only for non-urban areas as many may though at the first. The lack of open public spaces and activities in the case of Chongqing can be solved easily with amphibious thinking.

It is now clear that amphibious architecture is beneficial not only for solving the problem of dealing with flooding, but also the problem of flood prevention, as well as for the expansion to the floodplains and flooding-prone areas that may be very necessary in big cities situated by the big water sources.

As the effects of climate change have started to become more prominent, China and many other Asian countries, as well as countries in various other parts of the world, have been hit by more and more frequent floods (as shown multiple times in this thesis), the necessity of taking action has become extremely urgent, and amphibious architecture and design is one of the most viable and successful possible solutions, one that should be considered today rather than some time in the future, especially if the goal is to protect and preserve not only the country's economy and human lives, but also the environment. This thesis strongly and clearly emphasizes the importance of the water cycle in nature as well as the vast impact that humans are effecting on it with the massive expansions of the urban areas. LID (Low Impact Development) demonstrates exactly which problems have arisen due to sudden, fast and drastic urbanization, the lack of planned asphalting and the layering of an enormous impermeable concrete cover on the ground surface that prevents the ground from naturally 'breathing', meaning that it disrupts the natural flow and exchange of water that exists between the ground, the water bodies and the atmosphere.

This thesis also demonstrates that LID has a large impact and importance in China (locally called 'sponge cities'), and that the Chinese government is both aware of the significance of this, and is taking steps in order to properly address the possible negative impact of LID.

The floods that are occurring as this thesis is being written, as evidenced by various sources such as chinadaily.com.cn, are the true indicator that the time is running out and that adequate action must be taken to deal with what promises to be an ever worsening issue.

Results Collected During Amphibious Case Studies

Amphibious buildings are not cheap, but they are not unaffordable either. The Lift house in Bangladesh, built in 2010, is the best example of a cheap amphibious house. It can float up to 1,5 m and it is 40 m^2. It cost 3.600 EUR to build. It is constructed from various materials such as bamboo, masonry, ferrocement, plastic water bottles for buoyancy, with the slotted steel tubes cast into the masonry base for vertical guidance.

It is hard to present the highest price of an amphibious building, but it is important to note that they usually cost at least a little bit more than a standard house.

The mechanical amphibious system is still in a developmental phase and it is not yet perfectly clear if such buildings will be accessible to the general public in the near future. However, it must be noted that they are expensive and difficult to maintain, which makes them the least appealing of the three amphibious systems.

The static elevation system has been present for a long time, and by its very nature, it is the best of the three systems for large buildings. In addition to protecting the upper levels from flooding, it creates new spaces under the building that allow for new opportunities for pedestrian activities.

The buoyant amphibious system is the one that is very often considered to be the 'only' true amphibious systems, in the sense that the buildings can exist on both ground and water equally successfully. Such buoyant amphibious systems have been made functional in the Netherlands, the USA state of Louisiana, the City of Sausalito in California, Thailand and the UK among others, and they have demonstrated and proven that the buoyant amphibious systems are at the same time more convenient and more reliable than the static elevation system.

Moreover, buildings belonging to the buoyant amphibious system of amphibious architecture are low-cost and environmentally low-impact ways of flood protection, and can ensure that in the case of disaster, the communities existing in floodplains and flooding-prone areas have the proper resilience to survive flooding without significant damage or loss of life.

Contribution to Amphibious Architectural Development

For the advancement of any scientific research, it is extremely important to define proper classification, in order to be able to work within proper parameters and definitions to ensure the consistency and productivity of the research remain high. This thesis has set some basic theoretical rules and definitions of amphibious buildings and amphibious architecture. It has indicated the importance of amphibious urbanism in a wider context and shown which relationship exists between amphibious urbanism and LID – while LID attempts to offer quick solutions to the increasing need for urbanization at the cost of the natural water cycle, amphibious urbanism emphasizes the importance of water as a force of nature, the water cycle as its natural direction of movement, as well as the relationship between water and urban contents such as buildings, roads, parks and other urban elements.

The very definition of amphibious behaviour therefore sets the parameters that divide buildings with certain water and/or flood dealing solutions into three systems: 'the static elevation system', 'the mechanical amphibious system' and 'the buoyant amphibious system'. The definition of these three systems is of vital importance for proper further research into the topic, as well as the future expansion of amphibious design that will soon become an unavoidable part of architectural conversation.

The connection between these three systems is also of key importance given the complexity and variety of elements contained with any single urban area, and determining which amphibious system should be utilized for which type of building, as well as how to create a functional and effective interplay between the buildings of the three systems is another important step if amphibious urbanism is to be implemented in the most impactful and beneficial way possible.

Conclusion

Whether or not any individual chooses to acknowledge that climate change is part of Earth's current existence, the effects of it – rising sea level, change of weather patterns, increased precipitation and more drastic temperature extremes – are being felt all around the world. One of the most devastating ones is flooding, the spillage of excess water out of waterbeds (rivers, lakes or seas) into human inhabited areas, which causes massive material damage and often dramatic loss of life and livelihood for all those who reside in these floodplains and flooding-prone areas. Therefore, finding ways of dealing with this issue within the context of architectural design and urbanism is becoming a priority-one issue, especially given the quite real possibility that those urban areas that exist today or are being planned for construction in the near future may wind up being permanently flooded, or may continue to experience severe and constant flooding. Fighting against water is a losing battle that saps our resources and ultimately causes more problems than it solves. Instead, we should view water as offering opportunities, and work with it instead of against it through the expansion of amphibious architecture, the development of amphibious design and the planning of amphibious urbanism. Such an amphibious lifestyle can become extremely necessary as early as in the next decade, and certainly within the century.

Amphibious buildings are an effective way of overcoming the problem of water's destructive power by allowing the human dwellings to rise vertically in tandem with the changing water levels and thereby remain safe from that destructive power until such a time when they can be lowered back into place (as water recedes). These buildings are low-impact ecologically and are often relatively low-cost, but are certainly the best choice when it comes to ensuring any flood-affected community's continued existence and resilience in the face of disaster.

Moreover, water is in many other contexts considered as not only beneficial to attractive urban design, but essential, especially in tandem with urban green areas. Humans gravitate to the water naturally, as can be seen from the earliest times – all ancient human dwellings have been found on or very near a water source. This increased attractiveness of living on or near the water can very efficiently be combined with and exploited through amphibious architecture, as it demonstrates that the human populace does not have any true fear of water, even when the risk of extremes such as floods, hurricanes, tsunamis and so on is high. Water is to be embraced as a quintessential and unavoidable part of urbanism and architectural design. This is why amphibious buildings will easily find acceptance in everyday use, and why amphibious architecture should be considered in all future cases.

Another appeal of amphibious buildings is that they are essentially similar to buildings on land, with the only true difference being in their foundations, which are fully static in buildings on land, but in amphibious buildings are key parts of their amphibious mechanisms. Cost-wise, amphibious buildings are appealing as well – their cost does not necessarily have to be much higher, or even higher at all, than the cost of construction for buildings on land, and considering their dual nature, they allow for construction on water as well, something extremely important in areas where land is limited either financially or spatially and at is therefore at its premium.

Amphibious architecture not only serves to solve the already existing problems of flooding in urban areas, but also offers opportunities for the future of urbanism and architectural design, as can be demonstrated by the examination of the Chinese city Chongqing, whose central urban area consists of a large a floodplain and flooding-prone area that is largely unused, whose enormous potential can only be properly exploited by the application of this amphibious way of thought as applied to architecture, design and urbanism

Taking all this into account, there is a clear gap in the planning, design and construction in many areas that are at risk of flooding, which can be filled by amphibious architecture. Given the demonstrable attractiveness of amphibious buildings with respect to cost, efficiency and environmental impact, the stage is set for amphibious architecture to take off 'full sail'. The problems that architecture will be facing in the near future caused by climate change opens avenues for innovation and alternative and new thinking that can easily be expanded not only to this fascinating branch of architectural design, but also to wider fields of urbanism: spatial planning, infrastructure development, settlement location, flood defence and protection of environment.

Bibliography

Literature

Books

[01] Alan W. 2008. *Toward an Understanding of Europe: A Political Economic Précis of Continental Integration.* USA: Universal-Publishers.

[02] Bell S., Paskins J. 2013. *Imagining the Future City: London 2062.* London: Ubiquity Press Ltd. Gordon House 29 Gordon Square London WC1H 0PP.

[03] CIBSE. 2005. *TM36 Climate change and the indoor environment: impacts and adaptation.* London: CIBSE

[04] CIBSE. 2006. *Guide A Environmental design.* London: CIBSE

[05] DCLG. 2006. *Planning Policy Statement 25: Development and Flood Risk.* London: The Stationery Office

[06] DCLG. 2007. *Improving the flood performance of new buildings.* London: Department For Communities and Local Government

[07] FEMA. 2000. *"Coastal Construction Manual", Determining Site-Specific Loads* USA: Federal Emergency Management Agency

[08] Foster+Partners. 2016. *International Commerce Centre Masterplan* 世界新地标 — 国际商业中心项目修建性详细规划. Chongqing: Institute of Tongji University (Group) Co., Ltd

[09] Ganter C. 2008. *Vom Bach zum Bachkanal. (From a Stream to a Canal. own translation.)* Vienna: Stadt Wien/MA30 - Wien Kanal

[10] James, H.P. & Tufts University. Department of History. 2001. *Up on stilts: the stilt house in world history.* United States: Tufts University.

[11] Krajci H. 2004. *Expedition in die Kulturgeschichte des Abwassers.* Vienna: Stadt Wien/MA30 - Wien Kanal

[12] Menotti F. 2004a. *Living on the lake in prehistoric Europe: 150 years of lake-dwelling research.* Psychology Press.

[13] Menotti F. 2004b. *Living on the lake in prehistoric Europe: 150 years of lake-dwelling research.* Psychology Press. (Prehistoric Lacustrine Villages on The Austrian Lakes)

[14] Pelsmakers S. 2012. *Thee Environmental Design Pocketbook.* London: RIBA Publishing

[15] Stadler H. 1966. *So baut man Kanäle. (This is How Canals are Constructed. own translation.)* Vienna: "Österreichischen Abwasser-Rundschau" Ges. m. b. H., Wien

[16] Watson D, FAIA and Adams M. 2011. *Design for Flooding.* Canada: John Wiley & Sons, Inc., Hoboken, New Jersey

Academic Papers

[17] Ali. A. 2005. *Floating Transshipment Container Terminal. PhD Thesis.* Delft: Delft University of Technology.

[18] Anderson H. C. 2014. *Amphibious Architectures: Living with a Rising Bay.* San Luis Obispo: The Faculty of California Polytechnic State University

[19] Andrianov A. 2005a. *Hydroelastic Analysis of Very Large Floating Structures. Master Thesis.* Ukraine: Dnepropetrovsk Nationale Universiteit.

[20] Andrianov A. 2005b. *Hydroelastic Analysis of Very Large Floating Structures.* PhD Thesis. Delft: Delft University of Technology.

Bibliography

[21] Arafati N., Fazli A.H., Mousavi S. M., Rouzmehr F. 2012. *Construction and maintenance of concrete piles in corrosive and destructive marine environments, based on study of the Persian Gulf marine installations. Construction Research Congress.* [Online]. Available at: http://rebar.ecn.purdue.edu/crc2012/papers/pdfs/-37.pdf

[22] Bemis C. 2013. *Above the flood: Reassessing Delta Urbanism After Hurricane Katrina.* Thesis Research and Analysis. New Orleans: Tulane School of Architecture

[23] De Boo M. 2005. *Living on Water: A floating town on an unsinkable foundation complete with gardens, streets, and squares.* Technical Report. Delft: Delft University of Technology.

[24] English E. 2009. *Amphibious Foundations and Buoyant Foundation Project: Innovative Strategies for Flood-Resilient Housing.* Available at: http://www.buoyantfoundation.org/pdfs/ECEnglish_ParisUFMpaper_nov2009.pdf

[25] Fenuta E. V. 2010. *Amphibious Architectures: The Buoyant Foundation Project in Post-Katrina New Orleans.* Ontario: University of Waterloo

[26] Graaf, R. E. D. 2009. *Innovations in urban water management to reduce the vulnerability of cities; Feasibility, case studies and governance.* PhD Thesis. Delft: Delft University of Technology.

[27] Graaf, R. E. D., Fremouw, M., Bueren, B. V., Czapiewska, K., & Kuijper, M. 2006. *Floating City Ijmeer.* Technical Report. Delft: Delft University of Technology.

[28] Mohamad M. I., Nekooie M. A., Ismail Z. B. 2012. *Amphibious House, a Novel Practice as a Flood Mitigation Strategy in South-East Asia.* Available at: http://iiste.org/Journals/index.php/PPAR/article/download/1258/1179

[29] Official Journal of the European Union. 2007. *Directive 2007/60/EC Chapter 1 Article2.* [ONLINE] Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:288:0027:0034:EN: PDF.

[30] PROVIDENCE Journal. 2015. *Houseboats: Livin' on the dock of San Francisco Bay.* [ONLINE] Available at: http://www.providencejournal.com/article/20150712/NEWS/150719956.

Brochures

[31] h1arch. 2015. *mitmischen! Betonkanuregatta Team TU Wien.* Vienna: TU Wien.

[32] Gehl Architects. 2010. *Chongqing: Public Space Public Life Study & Pedestrian Network Recommendations.* Chongqing: Gehl Architects

Directives

[33] European Parliament, Directive 2003/35/EC. 2007. *DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on the assessment and management of flood risks.* DIRECTIVES. [Online]. 2007/60/EC, 27. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:288:0027:0034:EN:PDF

Internet Sources

[34] achi daily. 2012. *2012 Pritzker Prize: Wang Shu.* [ONLINE] Available at: http://www.archdaily.com/211941/2012-pritzker-prize-wang-shu. [Last Accessed 15 December 2015].

[35] AEIOU Encyclopedia. 2001. *Donaukanal.* [ONLINE] Available at: http://www.aeiou.at/aeiou.encyclop.d/d687058.htm;internal&action=_setlanguage.action?LANGUAGE=en. [Last Accessed 11 January 16].

Bibliography

[36] AoWeiBang. 2014. 王澍的新作--宁波东钱湖田螺山的茶室. [ONLINE]
Available at: http://www.aoweibang.com/view/33397774/.
[Last Accessed 16 October 2015].

[37] Archikey.com. 2004. *Sharp Centre for Design* [ONLINE].
Available at: http://archikey.com/building/read/2930/Sharp-Centre-for-Design/
[Last Accessed 25 May 2016].

[38] ATLAS HLS. 2016. *ATLAS HLS* [ONLINE].
Available at: http://www.failsafehouselifting.com/
[Last Accessed 5 May 2016].

[39] Baca Architects. 2016. *Amphibious House* [ONLINE].
Available at: http://baca.uk.com/
[Last Accessed 5 May 2016].

[40] BBC. 2014. *Forget houseboats, try floating communities.* [ONLINE]
Available at: http://www.bbc.com/capital/story/20140917-floating-real-estate/.
[Last Accessed 6 February 2016].

[41] BUSINESS INSIDER. 2014. *UK Architects Have Built An Amphibious Home That Floats During A Flood.* [ONLINE]
Available at: http://www.businessinsider.com/baca-architects-amphibious-house- 2014-10/.
[Last Accessed 20 October 2015].

[42] CNN international. 2014. *Record flooding in Balkans.* [ONLINE]
Available at: http://edition.cnn. com/2014/05/16/europe/gallery/balkans-flooding/.
[Last Accessed 17 November 15].

[43] FloodSmart.gov. 2010. *Flood Facts.* [ONLINE]
Available at: https://www.floodsmart.gov/floodsmart/pages/media_resources/fact_floodfacts.jsp.
[Last Accessed 30 March 15].

[44] FloodSmart.gov. 2015. *How Levees Work.* [ONLINE]. Available at: https://www.floodsmart.gov/
[Last Accessed 19 June 2016].

[45] GEO co-authors. 2015. *International New Landscape Magazine* [ONLINE].
Available at: http://www.greenearthops.com/sponge-city/
[Last Accessed 9 June 2016].

[46] Glancey J. 2004. *Sink or Swim: In Times of Flood, These Houses Rise To The Occasion.*
Available at: http://www.guardian.co.uk/artanddesign/2004/may/24/architecture
[Last Accessed 11 May 2016].

[47] House Raising, International Association of Certified Home Inspectors. 2016. *House Raising.* [ONLINE]
Available at: https://www.nachi.org/house-raising.htm.
[Last Accessed 1 April 2016].

[48] James G. Collin, PH.D., P.E. The Collin Group, Ltd. 2015.
Foundation Design Process. Timber Pile Design and Construction Manual. [Online].
Available at: http://timberpilingcouncil.org/wp-content/uploads/2015/08/TimberPileManual.2015.pdf
[Last Accessed 1 April 2016].

[49] K2S Architects. 2013. *Arctia Headquarters / K2S Architects* [ONLINE].
Available at: http://www.archdaily.com/431501/arctia-headquarters-k2s-architects/52425d81e8e44e67bf000074-arctia-headquarters-k2s-architects-section
[Last Accessed 11 November 2015].

[50] Kaushik. 2011. *The Floating Islands of Lake Titicaca.* [ONLINE]
Available at: http://www.amusingplanet.com/2011/10/floating-islands-of-lake-titicaca.html.
[Last Accessed 10 March 2016].

[51] National Weather Service Weather Forecast Office. 2008. *Definitions of flood and flash flood.* [ONLINE]
Available at: http://www.srh.noaa.gov/mrx/hydro/flooddef.php.
[Last Accessed 15 April 15].

[52] NL Urban Solutions. 2015. *LID* [ONLINE].
Available at: http://nlurbansolutions.com/ [Last Accessed 19 June 2016].

[53] Site-Specific Co. Ltd. 2016. *Amphibious House Prototype* [ONLINE].
Available at: http://asitespecificexperiment.wordpress.com
[Last Accessed 15 May 2016].

[54] SLAD. 2015. *Shunde City Master Plan, Shunde, Guangdong, China* [ONLINE].
Available at: http://www.slab-a.net/shunde-city-master-plan
[Last Accessed 15 May 2016].

[55] Sumitra. 2013. *The Floating Man-Made Islands of Lake Titicaca.* [ONLINE]
Available at: http://www.odditycentral.com/pics/the-floating-man-made-islands-of-lake-titicaca.html.
[Last Accessed 10 March 2016].

[56] TAKTL. 2016. *What Is UHPC?.* [ONLINE]
Available at: http://www.taktl-llc.com/What-Is-Ultra-High-Performance-Concrete/.
[Last Accessed 30 March 2016].

[57] Tang A. 2015. *Thailand Floods Archives.* [ONLINE]
Available at: https://www.yahoo.com/news/thailand-tests-floating-homes-region-grappling-floods-103739720.html?ref=gs.
[Last Accessed 13 April 2016].

[58] TECHNIKER. 2016. *Amphibious House* [ONLINE].
Available at: http://techniker.co.uk/portfolio-item/amphibious-house/
[Last Accessed 15 May 2016].

[59] The Architectural Review. unknown. *Floating Houses, The Netherlands by Marlies Rohmer Architects & Planners.* [ONLINE]Available at: http://www.architectural-review.com/today/floating-houses-the-netherlands-by-marlies-rohmer-architects-and-planners/8649745.fullarticle.
[Last Accessed 6 February 2016].

[60] Thomas and Archikey.com. 2004. *Sharp Centre for Design - Alsop Architects, Robbie/Young + Wright Architects Inc.* [ONLINE].
Available at: http://archikey.com/building/read/2930/Sharp-Centre-for-Design/1180/
[Last Accessed 25 May 2016].

[61] TIMBER PILLING COUNCIL. 2015. *Design & Construction Manual.* [ONLINE]
Available at: http://timberpilingcouncil.org/timber-piling-design-construction-manual/.
[Last Accessed 3 April 2016].

[62] University of Maryland's Integration and Application Network. 2014. *LID* [ONLINE].
Available at: http://managingstormwater.blogspot.com
[Last Accessed 9 June 2016].

[63] Waterstudio.NL. 2016. *Watervilla De Hoef — The Netherlands* [ONLINE].
Available at: http://www.digitaltrends.com/home/the-best-houseboats-in-the-world/
[Last Accessed 9 June 2016].

[64] Wikipedia: Kelong. 2014. *Kelong.* [ONLINE]
Available at: https://en.wikipedia.org/wiki/Kelong.
[Last Accessed 31 March 2016].

[65] Xinhua. 2015. *China to boost 'sponge city' program* [ONLINE].
Available at: http://en.people.cn/n/2015/1010/c90000-8959864.html
[Last Accessed 9 June 2016].

[66] Xinyi Floating Dock. 2016. *Floating Dock.* [ONLINE]
Available at: http://www.pontoon-cubes.com/.
[Last Accessed 31 March 2016].

[67] Zhangjiajie. 2016. *Stilt house (diaojiao house) along the River* [ONLINE].
Available at: http://www.zhangjiajietravelclub.com/fenghuang-ancient-town/
[Last Accessed 9 June 2016].

[68] ZINC & COPPER. 2016. *Amphibious House* [ONLINE].
Available at: http://www.sigzincandcopper.co.uk/amphibious-house-zinc-shingle-roof-cladding/
[Last Accessed 15 May 2016].

Bibliography

Websites

[68] www.bacahomes.co.uk
[69] asitespecificexperiment.wordpress.com
[70] www.maasvilla.nl
[71] www.waterstudio.nl
[72] www.lifthouse.ca
[73] morphopedia.com
[74] www.architectenweb.nl
[75] www.buoyantfoundation.org
[76] www.icaade2015.com
[77] www.jamesdavidsonarchitect.com.au
[78] www.duravermeer.nl
[79] www.dutchdocklands.com
[80] water.uwaterloo.ca
[81] uwaterloo.ca
[82] www.tudelft.nl
[83] www.tuwien.ac.at
[84] ar.tuwien.ac.at
[85] en-caup.tongji.edu.cn
[86] all-worldwide.com

Video Sources

[87] ACO Technologies plc. 2014. *The role of water in architecture: Robert Barker, Director, Baca Architects.* Available at: https://www.youtube.com/watch?v=1baKaIwY4eQ [Last Accessed: 31 August 2016].

[88] ACO Technologies plc. 2014. *Water based design - Robert Barker, Director, Baca Architects.* Available at: https://www.youtube.com/watch?v=cyDNEyQkx6E [Last Accessed: 31 August 2016].

[89] The Architectural Review. 2014. *Architecture & Water documentary. Part 1: A river runs through it.* Available at: https://www.youtube.com/watch?v=oeEuXrT-cCA [Last Accessed: 31 August 2016].

[90] The Architectural Review. 2014. *Architecture & Water documentary. Part 2: Gentrification machine?.* Available at: https://www.youtube.com/watch?v=FvgrKzvlWKU [Last Accessed: 31 August 2016].

[91] The Architectural Review. 2014. *Architecture & Water documentary. Part 3: Water park.* Available at: https://www.youtube.com/watch?v=awUAgTTimgE [Last Accessed: 31 August 2016].

[92] Baca. 2014. *Baca Architects - BBC News Flood Resilience Amphibious House January 2014 Flooding.* Available at: https://www.youtube.com/watch?v=I6hUOWDoc5o [Last Accessed: 31 August 2016].

[93] Chad Whiting. 2013. *AmphiBios - Cal Poly Landscape Architecture Senior Design Project.* Available at: https://www.youtube.com/watch?v=NaV3L7tGUIk [Last Accessed: 31 August 2016].

[94] Clockwork Digital Visuals. 2015. *Grand Designs - Floating House.* Available at: https://www.youtube.com/watch?v=16scx81p2w4 [Last Accessed: 31 August 2016].

[95] Elizabeth English. 2014. *Buoyant Foundation Project Assembly Animation.* Available at: https://www.youtube.com/watch?v=WdTCU8_A7wk&feature=youtu.be [Last Accessed: 31 August 2016].

[96] evfenuta. 2009. *The Buoyant Foundation Project Movie.*
Available at: https://www.youtube.com/watch?v=-qQWbtug32E
[Last Accessed: 31 August 2016].

[97] ft47. 2010. *Anti-Flood House for New Orleans - Julio Torres Santana - Spring 09 Cornell University.*
Available at: https://www.youtube.com/watch?v=Z2uo9yAvk9A
[Last Accessed: 31 August 2016].

[98] The Guardian. 2013. *Britain's first "amphibious house" designed to resist flooding.*
Available at: https://www.youtube.com/watch?v=1SM6eZ-QuV8
[Last Accessed: 31 August 2016].

[99] ICAADE2015. 2015. *Amphibious House Prototype* [Online Video].
Available at: https://vimeo.com/105636425
[Last Accessed: 31 August 2016].

[100] Jim Janossy Sr. 2009. *Floating foundations vs. caisson (pile) foundations.*
Available at: https://www.youtube.com/watch?v=N3msAkpUumI
[Last Accessed: 31 August 2016].

[101] Journeyman Pictures. 2014. *Tokyo's Incredible Underground Flood Defence Systems.*
Available at: https://www.youtube.com/watch?v=o85teh1vU_0
[Last Accessed: 31 August 2016].

[102] Practical Action. 2013. *Beat the flood: flood resistant homes in Bangladesh.*
Available at: https://www.youtube.com/watch?v=GICQpTOsxS8
[Last Accessed: 31 August 2016].

[103] Priscilla Talley. 2010. *Flood Proof Floating House Winston Intl.*
Available at: https://www.youtube.com/watch?v=MT7FTNzRDH0
[Last Accessed: 31 August 2016].

[104] TEDx Talks. 2016. *Build on the water: the future of architecture* | Alexander Remizov | TEDxUniversityofMacedonia.
Available at: https://www.youtube.com/watch?v=kFlqkpS0SWE
[Last Accessed: 31 August 2016].

[105] travelshorts. 2012. *Uros Islands on Lake Titicaca, Peru.* [Online Video]. 21 July 2012.
Available from: https://www.youtube.com/watch?v=5cYUvm3xT1A.
[Last Accessed: 31 August 2016].

[106] Waterstudionl. 2010. *Building a floating house, showing the concept of construction.*
Available at: https://www.youtube.com/watch?v=3qJV5SINA74
[Last Accessed: 31 August 2016].

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Figures

Sources of the following figures are included in this list. Figures without sources are author's own figures.

List of Tables

Sources of the following tables are included in this list. Tables without sources are author's own Tables.

List of Acronyms

Atlas HLS 5.0 (Atlas House Lifting System 5.0)
Atlas House Lifting System 5.0 is safe and very efficient house lifting system that provides contractors with the confidence and versatility to lift one, two and three story houses ranging from around 50 to 300 m2. - ATLAS. 2016. House Lifting Systems.

CBD (Central Business District)

EU Floods Directive (The European Union Floods Directive)

FEMA (The Federal Emergency Management Agency)
The Federal Emergency Management Agency is an agency of the United States Department of Homeland Security, initially created by Presidential Reorganization Plan No. 3 of 1978 and implemented by two Executive Orders on April 1, 1979. The agency's primary purpose is to coordinate the response to a disaster that has occurred in the United States and that overwhelms the resources of local and state authorities. The governor of the state in which the disaster occurs must declare a state of emergency and formally request from the president that FEMA and the federal government respond to the disaster.

ICAADE (The International Conference on Amphibious Architecture, Design and Engineering)
The International Conference on Amphibious Architecture, Design and Engineering (ICAADE) was established to promote the development of amphibious architecture, including the collection and defining of various amphibious systems, the consolidation of literature on this topic available in many different forms including digital papers and university publications, published books, social networks, official web pages, etc. Its goal is to allow for the evolution of innovative and useful ideas in this area.

LID (Low-impact development)
Low-impact development (LID), as it is called in Canada and the United States, is a design approach to land planning and engineering specifically targeting the handling of and dealing with stormwater and other water runoffs as part of a city's infrastructure, with the main aim to work with the natural resources to conserve the landscape and protect water quality. This approach in China is defined as a 'sponge cities'. 'Sponge cities' are more and more popular every day given that all the world's countries, and especially China, are facing rapid development of big cities. This development's negative impact on the nature is in large part the cause of a rising number of floods in human-populated areas – the so-called new development floods.

OCAD University (Ontario College of Art and Design)

UHPC (Ultra High Performance Concrete)
Ultra High Performance Concrete is distinguished from normal concrete due to its increased compressive strength and durability, has been proven to be the most convenient concrete type. UHPC was developed in Europe in the 1980 for applications that demand superior strength and corrosion resistance. Compressive strength of UHPC is bigger than 150 kPa.

UNESCO-IHE
UNESCO-IHE is the largest international graduate water education facility in the world and is based in Delft, the Netherlands. The Institute confers fully accredited MSc degrees, and PhD degrees in collaboration with partner universities. - https://www.unesco-ihe.org/

Glossary

amphibious
relating to, living in, or suited for both land and water: an amphibious vehicle.

barge
a long flat-bottomed boat for carrying freight on canals and rivers, either under its own power or towed by another.

buoyancy
"In science, buoyancy (also known as upthrust) is an upward force exerted by a fluid that opposes the weight of an immersed object. In a column of fluid, pressure increases with depth as a result of the weight of the overlying fluid. Thus the pressure at the bottom of a column of fluid is greater than at the top of the column. Similarly, the pressure at the bottom of an object submerged in a fluid is greater than at the top of the object. This pressure difference results in a net upwards force on the object. The magnitude of that force exerted is proportional to that pressure difference, and (as explained by Archimedes' principle that states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.) is equivalent to the weight of the fluid that would otherwise occupy the volume of the object, i.e. the displaced fluid."

(Wells, John C., 2008)

canal
An artificial waterway whose main purpose is to allow for the inland passage of boats or ships, or for the purposes of irrigation – the Oxford Canal.

channel
A natural body of water that is in size larger than a strait, and connects two even larger bodies of water, usually two seas – the English Channel.

channel capacity
The maximum amount of water that can flow through a channel without the banks being overtopped.

elevation
The vertical distance from a point in a plane (e.g. mean sea level) to a point of interest on the surface of the Earth – height above sea level. Water depth (sea floor elevation below the mean sea level) is often shown as positive numerals, though in reality it should be marked as a negative value.

Federal Emergency Management Agency (FEMA)
USA Federal agency created in 1979 whose purpose is to be oversee all federal activities with respect to disaster mitigation and emergency preparedness, response and recovery. FEMA administers the National Flood Insurance Program (NFIP).

flash floods
Flash floods are usually caused by heavy rain. When rain falls continuously every day without stopping, it is able to bring large amounts of water, which eventually become serious floods. Flash floods can be distinguished from any other flood by a timescale of less than six hours. With excessive rainfall, they can occur within minutes.
Flash floods must not only be caused by heavy rain. Watershed of the river can be overwhelmed and peak, generating flash floods.
All in all, flash floods are the most dangerous of the four kinds of floods (snowmelt floods, new development floods, flash flood, dams/levees break). They often appear too fast and the inhabitants as well as government are not ready to react properly.

floating reeds
a tall, slender-leaved plant of the grass family that grows in water or on marshy ground. a tall straight stalk of a reed plant, used especially as a material in making thatch or household items.

flood control
The restriction and/or prevention of an overflow of a large amount of water beyond its normal limits.

flood, flooding
A temporary or permanent condition of complete or partial inundation of usually dry land areas from tidal waters or overflow of inland waters; rapid and unusual accumulation or runoff of surface waters from any source.

Glossary

floodplain
area that is flooded periodically by the lateral overflow of rivers. in hydrology, the entire area that is flooded at a recurrence interval of 100 years. under the NFIP, synonymous with 100-year floodplain, any land area susceptible to being inundated by water from any source, with a 1% probability of being equaled or exceeded in any given year.

floodway
Part of the floodplain, the stream that conveys most of the water flow during overbank flood events.

global warming
An increase of Earth's temperature, which results in the increase in the volume of water, thereby contributing to sea level rise.

high water (HW), also high water line
Maximum height reached by each rising tide. It can be only due to the common periodic tidal forces, or it can be influenced by either prevailing or current meterological conditions – also called high tide.

mound
A mound is an artificial heaped pile of earth, gravel, sand, rocks, or debris. The most common use is in reference to natural earthen formation such as hills and mountains, particularly if they appear artificial. The term may also be applied to any rounded area of topographically higher elevation on any surface. Artificial mounds have been created for a variety of reasons throughout history, including ceremonial (platform mound), burial (tumulus), and commemorative purposes (e.g. Kościuszko Mound). (wikipedia: Mound., 2016)

precipitation
In meteorology, precipitation is any result of atmospheric water vapor condensation that subsequently falls under gravity – includes drizzle, rain, sleet, snow, graupel and hail.

resilience
The capability of a system (social or ecological) to handle disturbances while at the same time retaining the and the capacity to adapt to stress and change, the capacity for self-organization, and primarily the same basic structure and ways of functioning.

static elevation
a common system for flood-protection. It can be defined as an evolved version of stilt-houses. Here, static elevation does not only imply buildings that are laying on stilts, but means in general buildings that are not moving or have no ability to move in any direction.

tsunami
One or more ocean seismic waves that are caused by the displacement of a large volume of water through subduction related to earthquakes, volcanos, landslides, and other disturbances above and below ocean waters. On the open ocean, tsunamis have small wave height (amplitude) and long wave length (period), with the opposite being the case as they approach a shoreline.

vertical guidance system
System applied in amphibious architecture, whose main function is to regulate the stability of the building during the flood event. It prevents the building from leaving the 'dock' after being lifted by the buoyancy system and thus exposed to the various forces inherent in the movement of overflow water. The vertical guidance system blocks vertical movements of the amphibious building.

water cycle
The natural transport path that water takes in nature between Earth's lithosphere and atmosphere, encompassing various states of states of liquid, frozen, and vapor.

1 in 100 flood event
A flood event with a 1% probability of occurring in any given year. The 100-year flood is also referred to as the 1% flood, since its annual exceedance probability is 1%. - Holmes, R.R., Jr., and Dinicola, K. (2010) 100-Year flood–it's all about chance U.S. Geological Survey General Information Product 106

500-year flood
Flood that has as 0.2% probability of being equaled or exceeded in any given year.

Sources for Definitions

American Meteorological Society. AMS Glossary of Meteorology, 2nd ed. Boston: Author, 2000, www.ametsoc.org/pubs/glossary_index.htm.

FEMA. Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas (FEMA 55), 2005, www.fema.gov/rebuild/mat/fema55.shtm.

Federal Register Code of Federal Regulations. CFR Title 40—Protection of Environment. 2009, www.gpoaccess .gov/ECFR/.

IPCC Fourth Assessment Report. Appendix I: Glossary. United Nations Framework Convention on Climate Change, ed. A. P. M. Beade, 2007, www.ipcc.ch/ ipccreports/tar/wg1/518.htm.

NOAA Coastal Services Center. Vulnerability Assessment Techniques and Applications (VATA). Glossary, ed. B. Wayne Blanchard, www.csc.noaa.gov/vata/glossary.html.

U.S. Army Corps of Engineers. Coastal Engineering Manual Appendix A—Glossary of Coastal Terminology, ed. Andrew Morang and Andre Szuwalksi, 2003, http:// chl.erdc.usace.army.mil/cemglossary.

U.S. Geological Survey National Wetlands Research Center, World Meteorological Organization. Coastal Terminology. www.flowmeterdirectory.com/coastal_ terminology.html.

Wells, John C. (2008), Longman Pronunciation Dictionary (3rd ed.), Longman, ISBN 9781405881180; Roach, Peter (2011), Cambridge English Pronouncing Dictionary (18th ed.), Cambridge: Cambridge University Press, ISBN 9780521152532; NASA; Carol Hodanbosi; Jonathan G. Fairman - August 1996. 1996. Buoyancy: Archimedes Principle; A set of mathematics problems dealing with buoyancy.. [ONLINE] Available at: https://www.grc.nasa.gov/www/k-12/WindTunnel/Activities/buoy_Archimedes.html.

wikipedia: Mound. 2016. [ONLINE] Available at: https://en.wikipedia.org/wiki/Mound. [Last Accessed 31 March 2016]