Designing for Inevitable Crisis:

Resilient and **Adaptive** Housing Development for **Climate Change** in a Coastal Location

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Abstract

Climate change is globally recognised as the leading problem of the 21st century, with an abundance of scientific evidence to validate the concern. Climate change is a long-lasting shift of the average weather conditions that have come to define Earth's local, regional and global climates. Climate change is caused by both natural and anthropogenic (human-induced) contributing factors. The human activity on Earth has caused a significant inflation in the amount of greenhouse gases emitted, resulting in higher heat retention and rise in surface temperatures. The most disruptive and disastrous impact of climate change is the rapid rise in the global sea level which is currently ascending at an unprecedented rate. As the oceans warm, they expand. This has been the primary contributor to the historic sea-level rise which has recently accelerated from around 1.7mm per year over the 20th century to 3mm since the 1990s. Sea level rise is causing land to become submerged underwater and requires new strategies for the infrastructure to deal with these unavoidable shifts. Because this issue is unprecedented, we as architects and designers must adhere and comply to this new norm by accepting the fact that this is our future, by designing for climate change, instead of trying to 'fix it'. So, this prompts the question,

How can housing developments be designed that are resilient and adaptive to coastal site shifts (sea level rise) caused by climate change?

The role of the design is to respond to the predictions of accelerating sea level rise and elevating threats of coastal flooding by providing an architectural response for safely inhabiting low lying coastal areas. Utilising resilient and adaptive elements within the architectural construct could aid in the future of sustainable living design that effectively reacts to the uncontrollable impediments and challenges the natural world presents.

Acknowledgements

I would like to thank

My family for their continuous support throughout both of my architectural degrees, this has allowed me to thrive in a profession that I wholly enjoy.

My supervisor, Morten Gjerde, for his exceptional support, encouragement, wisdom and guidance, allowing me to produce an architectural solution that I am very proud of.

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Chapter One: Introduction to Research

1.1. Design Problem

Climate change has been singled out as a major challenge currently facing the world (Bicknell, 2009, p77), with an abundance of scientific evidence to validate the concern. Climate change is a long-lasting shift of the average weather conditions that have come to define Earth's local, regional and global climates (Shaftel). Climate change is caused by both natural and anthropogenic (human-induced) contributing factors (Mokhov, 2020, p1). The disruption to Earth's climate equilibrium caused by the increased concentrations of greenhouse gases has led to an increase in the global average surface temperatures (Zillman, 2017). Stabilising the atmospheric concentration of carbon dioxide at 550ppm within the next century will require a 70% cutback in emissions (Schnoor, 2005, p1105).

The most disruptive and disastrous impact of climate change is the rapid rise in the global sea level which is currently ascending at an unprecedented rate. When the oceans warm, they expand. This has been the primary contributor to the historic sea-level rise which has recently accelerated from around 1.7mm per year over the 20th century to 3mm since the 1990s (Soloman, 2017, p409). The ocean is absorbing 90 per cent of the heat added to the climate system. This warming is causing an expansion of ocean water which, in combination with water from the melting of land-based ice, is causing sea levels to rise. The global average sea level rose about 19 cm between 1901 and 2010 (MFE, 2017).

The rising sea levels are not consistent and do not rise uniformly around the world. However, it was identified that New Zealand's oceans have risen at a similar rate as the average global sea levels. Sea levels in New Zealand rose on average by 1.7 mm per year from 1900 to 2008 (MFE, 2017). 30cm of sea level rise is expected to occur in New Zealand over the next 40 years (PCFTE, 2015). According to Wellington City Council, by the year 2100, sea levels in Wellington city could rise as much as 2m, as a result of climate change (2019). It is important to strengthen the link between climate change adaption and development, increase public awareness and understanding of the issues, and pragmatically tackle the challenges posed by the phenomenon (Bicknell, 2009, p77). As global climate change causes sea levels to rise and weather events to become more extreme, the occurrence of severe flooding will become more commonplace around the world (English, 2016, p1).

An adaptive and resilient architectural response is required to overcome this challenge. Resilience in the built environment is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption of some sort (Moon, 2015, p98).

1.2. Research Question & Aims and Objectives

Research Question

How can housing developments be designed that are resilient and adaptive to coastal site shifts (sea level rise) caused by climate change?

Aims and Objectives

The aims and objectives of this thesis are two-fold; firstly, to design and implement a housing development that corresponds with the current coastal location in Wellington; and secondly, to reimagine the architecture as an agent of change by challenging the way in which this self-sustaining infrastructure retaliates and conforms with the inundation caused by climate change. The project will be self-sufficient through the sustainable approaches utilised within the design. The aim is to achieve an energy efficient development by generating energy from renewable sources to compensate for the architecture's own energy demand. This thesis presents an architectural solution for the problem addressed, by exploring and designing a new resilient position housing system that thrives and is adaptive to the undeniable future living conditions, whilst still embodying and catering to the needs and the expectations of individuals and family units. In addition, designing for the people and creating a sense of place and community is just as significant.

1.3. Research Methodology

This thesis focuses on developing and testing a model with regard to the threats and impacts of climate change and will provide an extensive investigation of social, structural and architectural methods that address sea level rise. The three broad approaches for overcoming this issue of sea level rise are explored in the literature review. Each approach will be discussed and the best approach will be further explored throughout the duration of the thesis. The basis of the research framework will be derived from literature reviews and both theoretical and actual precedent case studies. The literature review will provide sound knowledge from journals, articles, books and archives sourced from the library and internet. Precedent case studies that successfully address the issue of sea level rise, through floating architecture, will also be explored. This research is design led.

Research Methodology Diagram

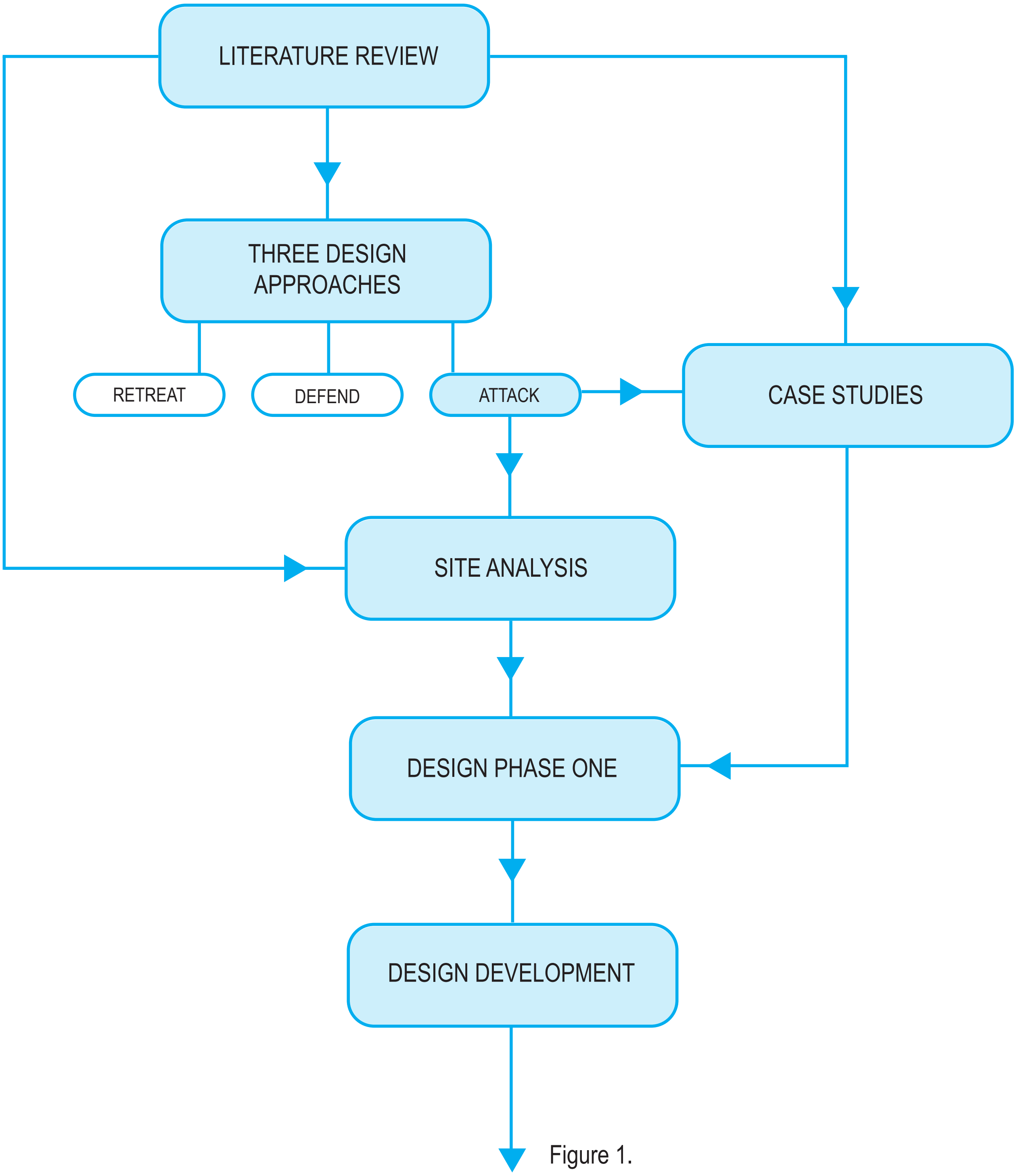


Figure 1.

1.4. Thesis Structure

Introduction to Research

- Design Problem
- Research Question & Aims and Objectives
- Research Methodology

Literature Review

- The Problem: *What is Climate Change*
- Ideas: *Sea Level Rise Preparation Strategies*
  (Retreat, Defend, Attack)
- Possible Solution: *Living on the Water*

Case Study Analysis

Completely floating buildings residing on water

- Floatyard
  Low Rise Housing
- Floating Office Rotterdam
  Self-Sufficient Building
- Waterbuurt
  Separate Dwellings

Designed on land and only floats when required

- Formosa, Amphibious House
  UK's First Amphibious Dwelling

Site Introduction

- Site History
- Present Site
- Future Site with Sea Level Rise

Research Summary

- Summarising research
- Forming a design framework

Design Introduction

- Role of Design
- Engagement with Sustainability
- Other Considerations for Living on the Water

Design Phase One

- Amphibious Design
- Amphibious Values/ Opportunities
- Existing Amphibious Approaches and Physical Modelling
- Innovative Amphibious Design and Physical Modelling

Design Critique One

- Amphibious Technology Development

Design Phase Two

- Architectural Design Development
- Energy Generation and Passive Design
- Sustainable Building Material Selection
- Physical Modelling Final Design
- Sections with Details
- Placing Dwellings on Site
- Floating Jetty Design

Design Critique Two

Final Design

- Renders of Final Design on Site

Research Findings

- Learnings from Design Research

Concluding

- Conclusion: Answering research question, limitations and future research

Chapter Two: Literature Review

2.1. The Problem: *What is Climate Change?*

Climate change is defined as changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties that alter the energy balance of the climate system (Soloman, 2017, p2). Climate change has been singled out as a major challenge currently facing the world. It is caused by the emission of greenhouse gases, largely from energy production and consumption, agriculture and other ecological processes (Bicknell, 2009, p77). The two major causes of global sea level rise are thermal expansion of the oceans and the loss of land-based ice due to increased melting. There is strong evidence that global sea level gradually rose in the 20th century and is currently rising at an increased rate. Sea level is projected to rise at an even greater rate in this century (Soloman, 2017, p409). Because the scope of climate change is immensely extensive, the scope of the thesis is narrowed down to just looking into this issue of sea level rise, caused by climate change.

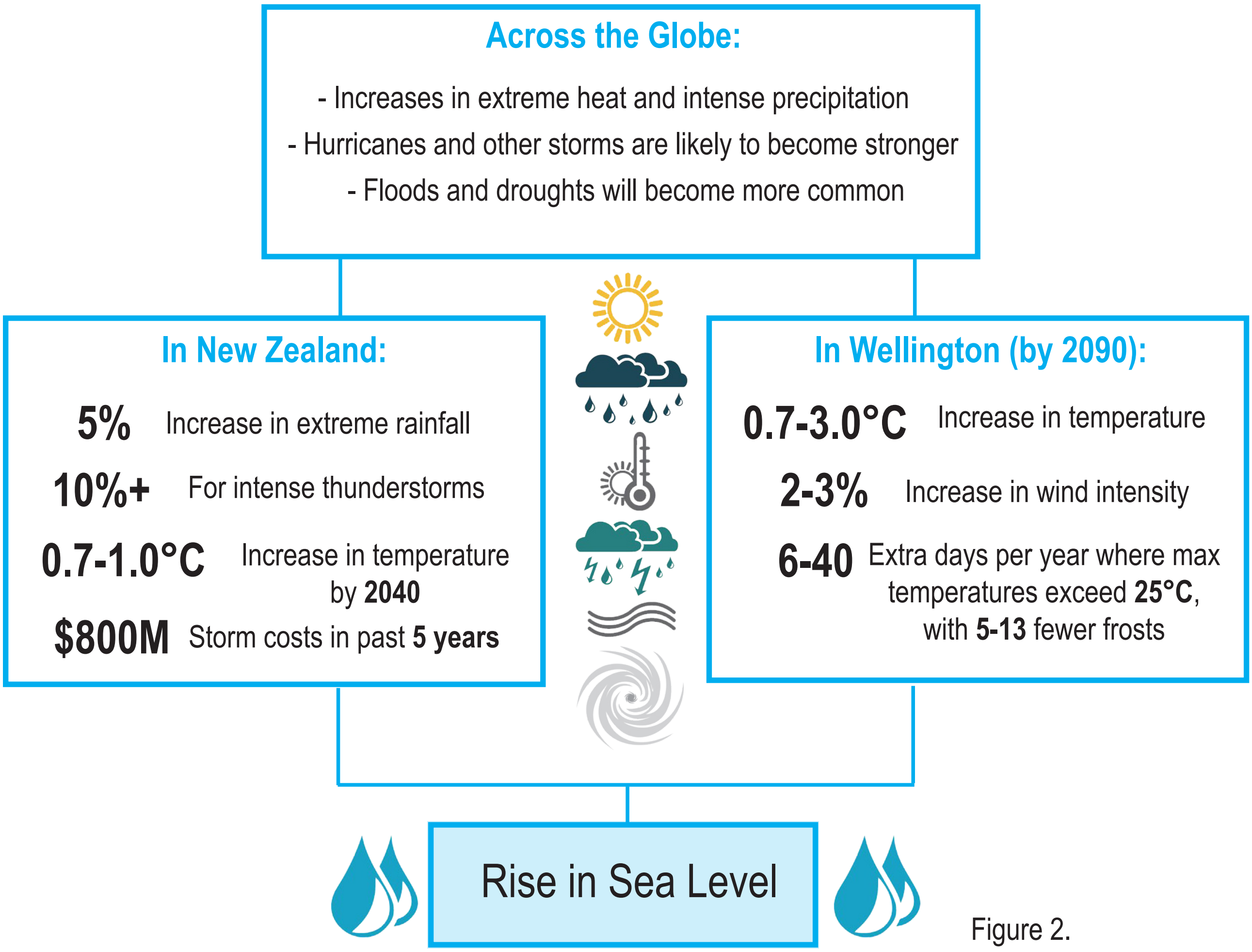

Across the Globe:
- Increases in extreme heat and intense precipitation
- Hurricanes and other storms are likely to become stronger
- Floods and droughts will become more common
In New Zealand:
5% Increase in extreme rainfall
10%+ For intense thunderstorms
0.7-1.0°C Increase in temperature by 2040
$800M Storm costs in past 5 years
In Wellington (by 2090):
0.7-3.0°C Increase in temperature
2-3% Increase in wind intensity
6-40 Extra days per year where max temperatures exceed 25°C, with 5-13 fewer frosts
Rise in Sea Level

Figure 2.

2.2. Ideas: *Sea Level Rise Preparation Strategies*

Sea level rise is causing land to become submerged underwater and requires new strategies for the infrastructure to deal with these unavoidable shifts. The three strategies retreat, defend and attack, as defined by David Robinson of Building Futures group, are three broad approaches that could be adopted to ensure the sea level rise in a coastal location is managed through a wholly positive manner.

Retreat

To retreat is to step back from the problem and avoid a potentially catastrophic blow. It is to move critical infrastructure and housing to safer ground and to allow the water into the city to alleviate flood risk. In retreating, investment in existing structures and infrastructure is lost as the area is claimed or reclaimed by the sea. New investment must also be made in relocating communities and infrastructure out of harms way (Robinson, 2009, p10). Planning for and implementing relocation requires many years. If a planned relocation is not accomplished while a community experiences these warnings, a subsequent massive storm may overwhelm all defences, providing little time to implement an orderly relocation process (Dannenberg, 2019, p8).

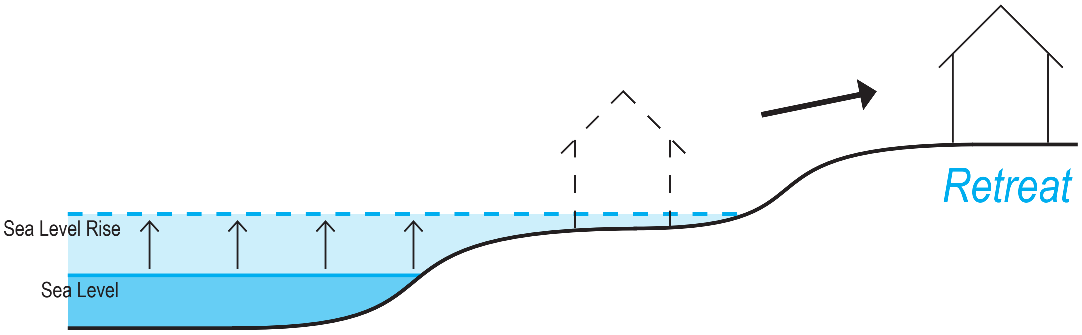
Defend

To defend is to ensure the sea water does not enter the existing built environment. This will require built defences to ensure the standard of protection will be met in the distant future as sea levels rise. By choosing to defend, the existing built infrastructure of a city is protected from floods and does not need to be relocated to higher ground or rebuilt after flooding. (Robinson, 2009, p10). But we must realise that in building hard structures on beaches, we will ultimately lose the beach (which might have been the very reason for building next to the ocean in the first place). Even though this may be an acceptable loss in order to save large cities, it is not acceptable on a large scale. Why protect the homes of the few (and largely wealthy) at the cost of losing the beaches that so many of us enjoy? (Pilkey, 2016, p8).

Attack

To attack is to advance and step seaward of the existing coastline. There is massive development potential to be gained for coastal cities by building out onto the water. We have several means of building out onto the water and they have been practiced for centuries. Strategies of attack could unlock a vital planning tool and give flexibility to our extremely dynamic 21st century cities (Robinson, 2009, p10). The strain and pressure on the global city infrastructure can be efficiently relieved by allowing this infrastructure to step “onto” the water and thus break this ever existing barrier. Apart from the fact that by doing so we manage to create new and attractive public space in the environment which is usually scarcely utilised, floating infrastructure also provides extremely high resilience while minimising the environmental impact (Ronzatti, 2020, p49). In the future, we will not see water as a threat but as new living space with exhaustible potential (Stopp, 2017, p11).

The attack strategy is the most adaptive and resilient of the three as it confronts as well as embraces the issue of sea level rise, as opposed to the other two approaches, which appear to avoid the problem. Therefore, this idea of attack will pose as a testing ground throughout the duration of the thesis.



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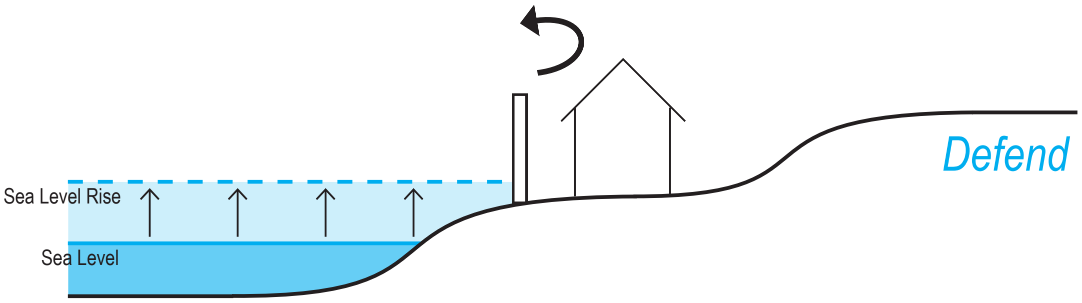

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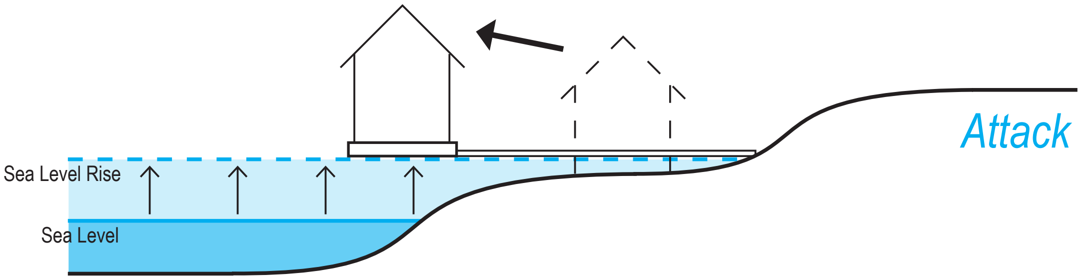

Figure 5.

2.3. Possible Solution: *Living on the Water*

Faced with this reality of sea level rise, the solutions are being discussed not only in tradition view such as accommodation is raised or moved to higher areas or 'living with the water', but also forwards to 'living on the water'. Therefore, the concept of a sustainable floating community with floating houses based on the precious value of long-term historical tradition of water dwellings would be a sustainable solution for adaptation of climate change and sea level rise in the coastal areas (Stopp, 2017, p21). There are several advantages floating architecture provides in terms of sustainable design in addition to overcoming the issues of sea level rise. These include much-needed space replacing the lack of land for agriculture, housing and commercial growth, the certain of new and innovative tourist destinations, a much smaller ecological footprint than land-based constructions, the extension of city centers that are built near the coast and the possibility of green planning at an unclaimed plot (Yung, 2018, p880).

Rising sea levels, overcrowded cities and a desire for freedom are leading some architects to build on water. In a world beset by rising sea levels, where technology and human behaviour seems to be changing faster than ever, a growing number of architects believe floating architecture could change the way we live (Dewolf, 2018).

There is a vast variety of technical, societal and economical drivers that influence the opportunities for floating developments in addition to overcoming this issue of sea level rise. These also provide an insight into the values of living on the water. These drivers include:

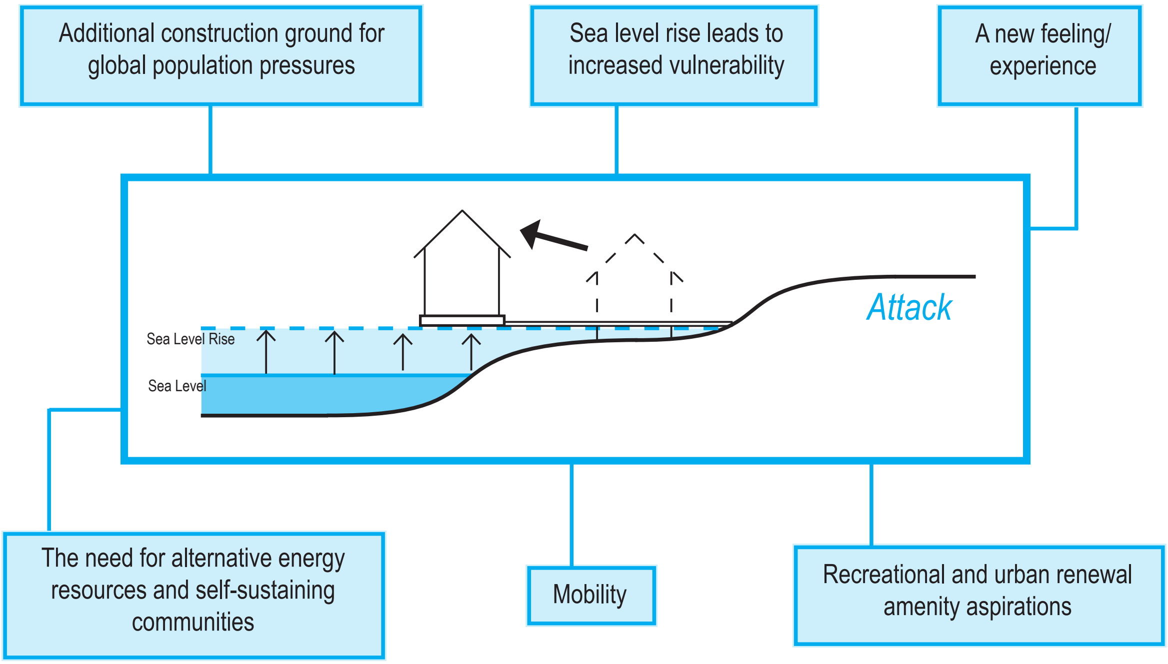

Figure 6.

Additional construction ground for global population pressures

The combination of land scarcity and the intention to convert at least some impermeable urban surfaces into permeable open green space, to increase urban water storage and reduce urban flooding is requiring new forms of urban living to be considered, including floating homes. A more multi-functional approach towards urban floodplain and open water use, for flood water storage plus recreational, residential and other adaptive purposes, might greatly enhance urban resilience for our cities of the future (Penning-Rowsell, 2020, p398). Floating architecture will be a resolution for the future lack of construction ground as a result of the growing and expanding population of the world. In addition, in context with the rising sea level, the marinas of floating houses could be an alternative construction ground (Stopp, 2010, p224).

Sea level rise leads to increased vulnerability

Population growth and environmental aggravation by urbanisation have increased vulnerability to floods (Nekooie, 2017, p1045). Sea level rise will increase the frequency of extreme sea levels and hence the potential severity of coastal flooding (Muis, 2017, p379). The pressure on available urban space is likely to lead to large numbers of people occupying areas vulnerable to sea level rise and more extreme weather events. The consequence is an extensive build-up of wealth and infrastructure in densely-populated coastal flood-prone areas. In developing countries the lowest income groups may have little alternative but to settle in flood-risk areas. In addition to the undesirability of introducing such trends in developed countries, we should avoid the inefficient non-use of such risky areas and provide residential developments there to the highest modern and cost-efficient standards (Penning-Rowsell, 2020, p398).

A new feeling/ experience

The direct experience with the natural environment of water is the base for an attractive property. Many people would like to spend their life in a floating house (Stopp, 2010, p224).

The need for alternative energy resources and self-sustaining communities

Floating houses have the potential to operate to some extent as stand-alone units, reducing peak pressures on traditional energy network/electricity grids, by using the water as an energy resource through processes of evaporation, heat exchange or simply running water through wall spaces for cooling (Penning-Rowsell, 2020, p398). The surrounding water can be used for heating and cooling throughout the year. For this we can utilise the techniques of evaporation, heat pipes or running water through the building envelopes by using the buoyancy and minimised pumps that are available (Stopp, 2010, p223).

Mobility

One advantage of floating architecture over usual buildings is its mobility in view of changing positions or local places. By this the owner can look for other places as desired and to his liking (Stopp, 2010, p224). The mobility aspects of floating units, limited though this may be, should appeal to policy makers from a range of perspectives. It provides vulnerability reduction with the option of relocation in case of anticipatable disasters or recurring levels of unacceptable risk. In an urban renewal perspective, urban areas can be redeveloped when construction units and infrastructure resources are produced off-site and moved into place. Based on specific locations, floating developments can also have the ability to reconnect areas in social decline with the heart of the city. The mobile aspect may also facilitate key spatial planning decisions for building floating houses, because local decision-makers may feel more comfortable permitting a relatively new technology if they consider the temporary nature of floating buildings at any one locale: a decision to allow development there that is not necessarily final (Penning-Rowsell, 2020, p399).

Recreational and urban renewal amenity aspirations

It is recognised that the possibility of using floating architecture as a method for building up real estate value, without sacrificing increasingly scarce land area in densely built-up flood-free urban areas. But the desire to add amenity values can also be an important societal driver here. Firstly, the novelty and innovation aspect of building on water can add visual appeal to cities, whilst also creating a more climate adaptive city. And secondly, some of the recently designed communities are purposefully incorporating both residential and outdoor public spaces into the floating concept (Penning-Rowsell, 2020, p399).

2.4. Summary and Reflection

Global sea levels are ascending at an unprecedented rate as a direct result of climate change. The global sea level has risen at an average rate of about 3.4mm per year. A 30cm sea level rise is expected to occur in New Zealand over the next 40 years. In the case of Wellington City, thousands of residents are likely to be displaced due to their homes being at serious risk of the inundation. It is evident that a solution is required to mitigate this disastrous result of climate change and reduce the mass displacement that will be caused due to the sea levels rising. It is evident that the literature review provides an insight into the fact that sea level rise is causing land to become submerged underwater and requires new strategies for the infrastructure to deal with these unavoidable shifts. The three approaches that could be adopted to ensure this issue is resolved through a wholly positive manner were identified. This idea of *Attack* is the most adaptive and resilient of the three and will be further discussed and explored throughout this thesis.

Chapter Three: Case Study Analysis

3.1. Floatyard - Low Rise Floating Housing Complex

Name: Floatyard
Building type: Multi-family housing development
Architects: Perkins + Will Architects
Location: Charlestown, Boston, Massachusetts, USA
Size: 8,040 square meters
Construction: Proposal

What is ‘Floatyard’?

Floatyard is a low-rise floating housing development designed by Perkins + Will Architects. David McManus discusses in his ‘Floatyard Charlestown: Boston Floating Housing’ that Floatyard will be a floating complex, entirely on water, that will provide both housing and public programming. It will provide over 100 new living units, and 6 generous spaces for commercial use, while further engaging the waterfront with what will be Boston’s first community water center hosting amenities such as pools, a water sport and small watercraft center, diving wells and a number of other water-focused services. Floatyard will use opportunities that exist in the environment of its geographical location to generate energy and prevent energy waste. The building will harvest solar energy from the roof, tidal energy from the mooring columns that anchor it; and given a generous average annual precipitation, the building will also harvest rainwater. As Floatyard rises and falls approximately 9.8 feet with each tidal cycle, mooring columns keep the building in place with each shift. Mooring columns contain air chambers and pistons that compress air with each cycle to generate energy (2013).

Floatyards potential influence in design decision-making

Floatyards technique of generating tidal energy through its anchoring mooring columns could provide for an interesting way of harvesting natural energy within the building. Tidal energy is a type of renewable source that generates power through the natural motions of the water, such as waves and the rising and falling of the tide. Tidal energy is very reliable and highly predictable and therefore is a suitable source of energy that could be harvested through the design to provide for the buildings energy demand. The building also collects and purifies rainwater which could be considered in the design development.

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Figure 7.

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Figure 11.

Floatyard will be constructed out of a system that will allow the entire complex to float and therefore rise and fall with the tide. It will serve as a testing ground for community living on the water and perhaps spur other cities to think more creatively about embracing the sea
– Perkins + Will

Floatyard Construction and Appearance

Floatyard will use opportunities that exist in the environment of its geographical location to generate energy and prevent energy waste (Perkins + Will Architects). The building generates energy through renewable sources, such as solar and tidal to compensate for the architectures own energy demand. What makes Floatyard unique is its central courtyard: a floating wetland island, built above the foundation, to be seeded with native marsh grass and aquatic wildlife. Given the prediction for the ocean to rise between three and five feet by the year 2100, it might be more crazy not to build on floating tubs (Kennedy, 2016).

Floatyard Section

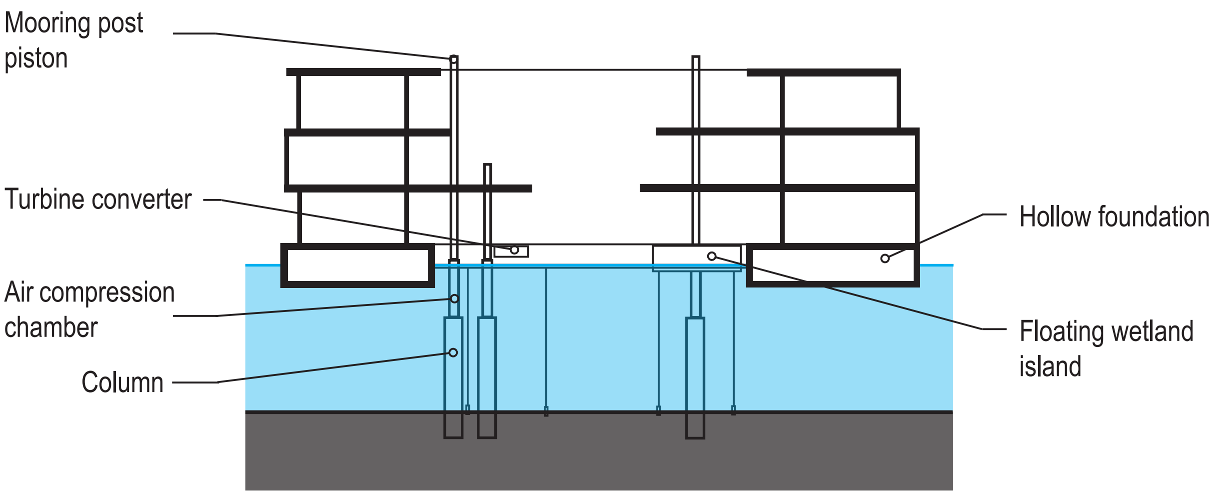

Figure 12.

Floatyard's Strengths

This precedent has an inner courtyard that provides a space that not only provides a sense of community for the residents to come together and interact, but also reinforces that connection with the water. Giving the occupants that option to interact with the water by providing a close proximity to it could encourage this interaction. The building appears to extend outwards from the land and occupy the water this way. In doing this, the vital relationship with the land is maintained.

Floatyard's Weaknesses

The inner courtyard space does not appear to provide a very inviting experience. The lack of sun exposure due to the surrounding building lessens the desire to occupy the space. If this was extended seaward, the experience of engaging with this area could heighten and create a more desirable indoor/ outdoor connection. The construction design of the floating system appears to have only considered calmer waters. Thought has been put into the vertical motions of the rising and falling of the tide, but what about the lateral movements? This precedent presses the questioning of how stable and comfortable the residents would be whilst occupying the building during harsher weather conditions. How would this building cope with higher weather severity and choppy waters? How would the inner courtyard area respond to this shift in weather conditions? If part of the building is fixed to the land, how much would the ocean occupying part of the building displace?

Analysis based on Floatyard

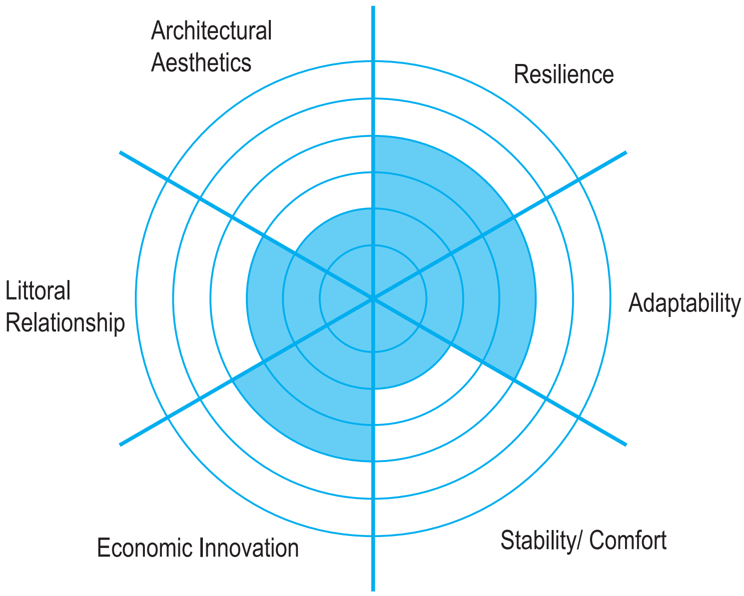

Figure 13.

Architectural Aesthetics: How visually appealling the building is

Resilience: How well the building prevents damage (ie flood damage) from its environment in which it resides

Adaptability: How well the building adapts to the issue (sea levels rising) through its floatation system

Stability/ Comfort: How well the floating design aids in providing a stable living situation and therefore comfort

Economic Innovation: How well the design considers the environmental impacts through construction and materiality selection

Littoral Relationship: How well the building relates to the shore/ land to provide adequate means of access

3.2. Floating Office Rotterdam (FOR) - Self-Sufficient Floating Building

Name: Floating Office Rotterdam
Building type: Office building
Architects: Architecture Office Powerhouse Company and RED Company
Location: Rijnhaven harbour, Rotterdam
Size: 2,160 square meters
Construction: Completed

What is 'FOR'?

Floating Office Rotterdam is an energy-efficient, self-sustaining office building. Moored at Rijnhaven port in Rotterdam, the floating office for the Global Center on Adaptation is a building for a new age. Off grid and carbon-neutral, it will float, rather than flood, if water levels rise due to climate change. Fun as well as functional, it also forms a key element in a newly redeveloped port environment by providing public waterside space and even a swimming pool. The floating office is designed to reflect the values of its inhabitants: the Global Center on Adaptation. This Rotterdam NGO aims at promoting planning, investment and technology to mitigate climate change. The climate-resilient office is therefore both an illustration of the center's mission and an inspiration for others. With its own solar energy source and water-based heat-exchange system, it's completely self-sufficient. Built entirely of timber, to minimise its carbon footprint, the building has three stories and is accessed via a boardwalk. The building contains overhanging balconies around each floor plus a pitched roof to provide shade (Powerhouse Company).

FOR's potential influence in design decision-making

This building is made completely of timber, to provide for a lightweight construction, due to the fact it is completely floating, as well as reduce its carbon footprint. The sustainable material selection has been carefully considered to mitigate climate change and poses as an excellent case study for when it comes to material selection for the final design. North facing solar panels are also evident in this building as another way of generating natural energy through a different renewable source - the sun. Because the aim is to design a completely self-sufficient housing development, this case study will be referred back to, to aid in some of the sustainable design decisions and considerations.

Figure 14.

Figure 15.

Figure 16.

Figure 17.

Designing a sustainable, floating office building was a very challenging commission and we approached it in an integrated way. By using the water of the Rijnhaven to cool the building, and by using the roof of the office as a large energy source, the building is truly autarkic – Nanne de Ru (Powerhouse company founder and Architect)

FOR Construction and Appearance

Paul Sanders, FOR's project leader and architect and Powerhouse Company outlined that the building structure is designed in wood and can easily be demounted and re-used. It's ready for the circular economy (2021). Karl Van Es discussed in 'Construction on Powerhouse's Floating Office in Rotterdam Underway' that the use of wood as a main construction material reduces the carbon footprint of the building dramatically. Overhanging floors balconies create permanent sun shading which allows for large windows with plenty of daylight flooding into the office floors. Besides the offices, FOR also features public facilities: a restaurant with a large outdoor terrace, with as a special addition a floating swimming pool in the Maas river (2021). RED Company, the developer of FOR, said the mission to manage the effects of climate change are embraced by the GCA, the city of Rotterdam, as well as RED Company. In order to achieve this, a sustainable and circular building is designed. The building is circular since the structure can be disassembled. The office will be self-sufficient and energy-neutral thanks to 800m² of solar panels and the use of water from the Rijnhaven for the cooling of the building.

FOR Section

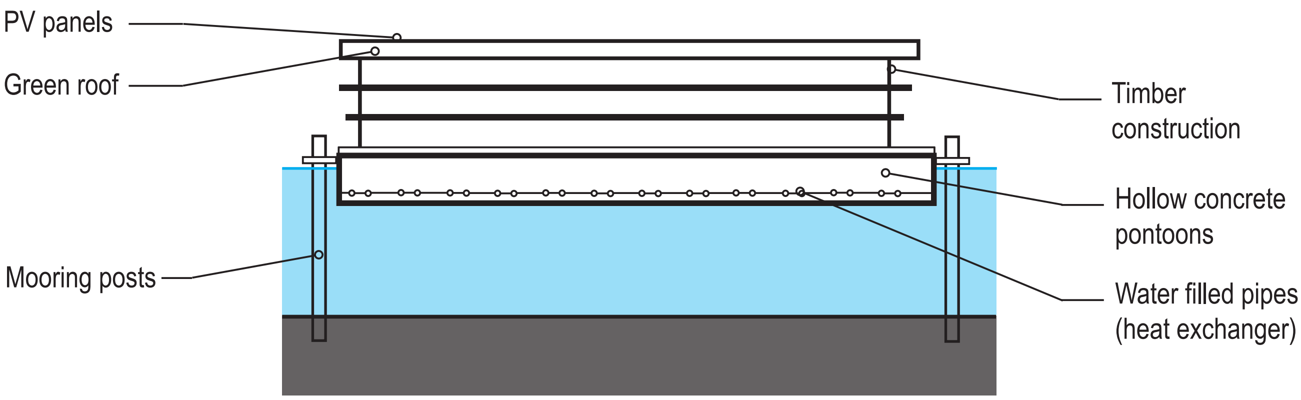

Figure 18.

FOR's Strengths

This precedent provides a dynamic relationship with the users of the space and water in which they occupy. The building, designed with large windows, provides the occupant with the constant reminder that they are residing on the water. The outdoor spaces provide that close proximity to the water and reinforces the desire of occupying a floating building. The way in which the building is completely self-sufficient by supplying its own energy through renewable sources and is completely self-reliant is one of the main goals of this thesis. Similar self-sustaining methods and sustainable approaches could help inform the design process.

FOR's Weaknesses

The architects of this design pride themselves on the fact that this is an "off-grid" building that is completely self-sufficient. However, this creates a sense of separation between the land and floating building, in which is only connected through a floating walkway. Is this enough to provide the occupants with that sense of connection with the land, or was the main idea of living on the water, away from the city the main driver and completely intentional?

Analysis based on FOR

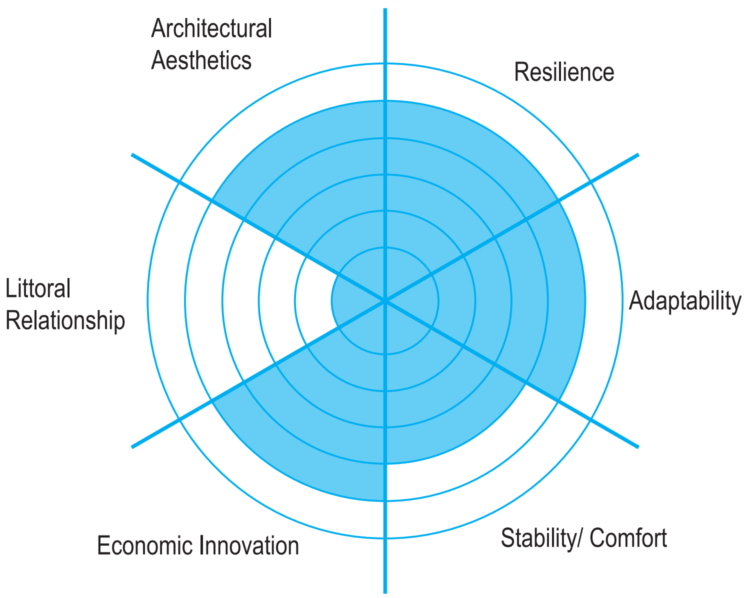

Figure 19.

Architectural Aesthetics: How visually appealling the building is

Resilience: How well the building prevents damage (ie flood damage) from its environment in which it resides

Adaptability: How well the building adapts to the issue (sea levels rising) through its floatation system

Stability/ Comfort: How well the floating design aids in providing a stable living situation and therefore comfort

Economic Innovation: How well the design considers the environmental impacts through construction and materiality selection

Littoral Relationship: How well the building relates to the shore/ land to provide adequate means of access

3.3. Waterbuurt - Floating Houses

Name: Waterbuurt
Building type: 55 floating homes
Architects: Marlies Rohmer Architects and Urbanists
Location: Amsterdam, IJburg
Size: 12,000 square meters
Construction: Completed

What is 'Waterbuurt'?

Waterbuurt is a floating housing development designed by Marlies Rohmer Architects, that consists of separate habitable dwellings that float on jetties. It is the largest floating housing district in Europe. Shawn Mcnulty-Kowal stated in 'These Floating Homes in Amsterdam are Designed to Beat the Rising Sea Levels and Escape the Growing City Population', that Waterbuurt sets the stage as a water-based solution for Holland's modern housing needs. The Netherlands actually means, 'the low-lying country,' indicating the country's close proximity to water. In fact, much of the country's land is either below sea level or just slightly above it. In order to go with the flow of the approaching tide and avoid the surging population in urban centers, Waterbuurt adapts to the rising sea levels and finds calm away from the congestion of the city (2020).

Wterbuurt's potential influence in design decision-making

The idea of creating a detached floating dwelling development provides for more freedom and privacy through the experience of occupying your own separate house, as opposed to a floating housing complex, for example, where there are shared spaces, and do not obtain as much privacy. The idea of having separate dwellings will be explored in the design process as privacy is an important aspect to consider.

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Figure 20.

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Figure 21.

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Figure 22.

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Figure 23.

Here, we have the ultimate freedom of the water. We have a comfortable detached house of our own, and the city center of Amsterdam is only 15 minutes away - Waterbuurt resident (Marlies Rohmer Architecture and Urbanism)

Waterbuurts Construction and Appearance

Upon completion, 18,000 homes will comprise Waterbuurt, but for now, more than 100 of them float on jetties. The houses, which are permanently fastened to steel pylon-enforced moorings, resemble attractive shipping containers and share more in appearances with land-based housing than the familiar houseboats dotted along Amsterdam's canals. With similar architecture to that of land-homes, each Waterbuurt floating house has to be connected to the floor of Lake Eimer, which distinguishes Waterbuurt's homes from Amsterdam's docked houseboats. Two mooring posts also anchor each home for optimum stability and the material used to construct the homes is chosen with careful consideration for the environment and health of Lake Eimer, so the building material does not leak pollutants into the water. Constructed from wood, the homes rest above a concrete caisson, a large watertight chamber, in order to attain a low center of gravity, further enhancing the home's stability (Mcnulty-Kowal, 2020). The slender jetties along which the floating houses are moored provide public access. Waterbuurt is after all part of the city, not a gated community. Each house is separated from its ajoining jetty by a meter wide gap of water, thereby, accentuating the watery context (Marlies Rohmer Architecture and Urbanism). The foundations are floating concrete tubs. Each house is designed to weigh 110 tons and displace 110 tons of water, which causes it to float. The bottom floor is half submerged, to prevent rocking in the waves, the house is fastened to two mooring posts—on diagonally opposite corners of the house—driven 20 feet into the lake bed. The posts are telescoping, allowing the house to rise and fall with the water level. Flexible pipes deliver electricity and plumbing (Kennedy, 2016).

Waterbuurt Dwelling Section

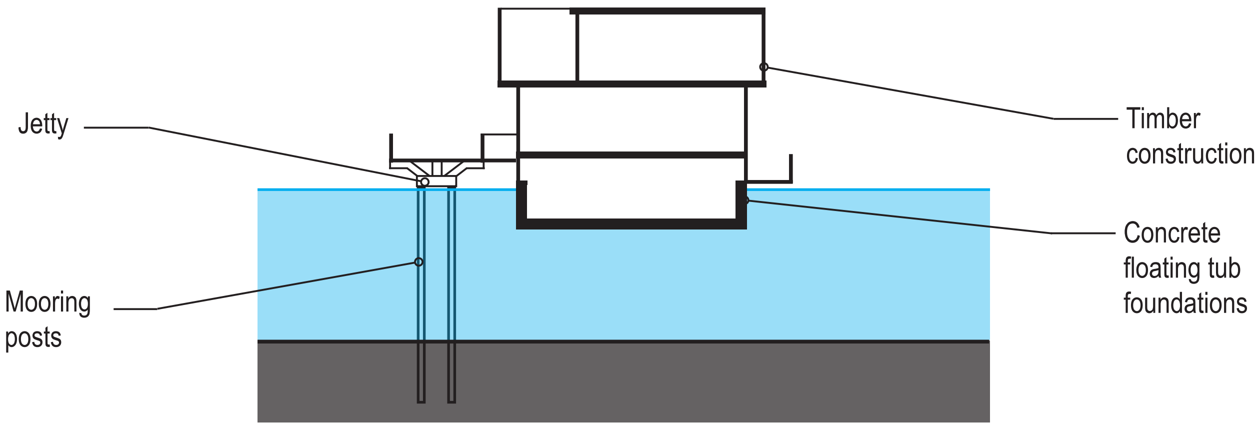

Figure 24.

Waterbuurt's Strengths

This precedent provides a strong connection to the land through the use of bridging. The meter wide gap of water between the jetties accentuating the watery context is a constant reminder to the user that they are residing on the water. The relationship with the land is a vital one that needs to be taken into consideration when designing a floating community that does not reside on land itself. The occupants privacy and freedom is met by providing each with their own detached dwelling. The close proximity of the dwellings and the connections through the bridges heighten the experience of a floating community that thrives on its own.

Waterbuurt's Weaknesses

This precedent presses the questioning if the occupants are met with maximum stability and comfort. Ensuring that the height of the floating dwelling is in proportion to its width in order to maintain stability, and therefore comfort, is very significant, in not only calm waters, but also on choppy waters. It has been evident that the dwellings "bottom floor is half submerged to prevent rocking in the waves", but is this enough to stabilise the building during a severe storm? How much difference would it make if the whole basement/ bottom floor was submerged? Would this provide more stability?

Analysis based on Waterbuurt

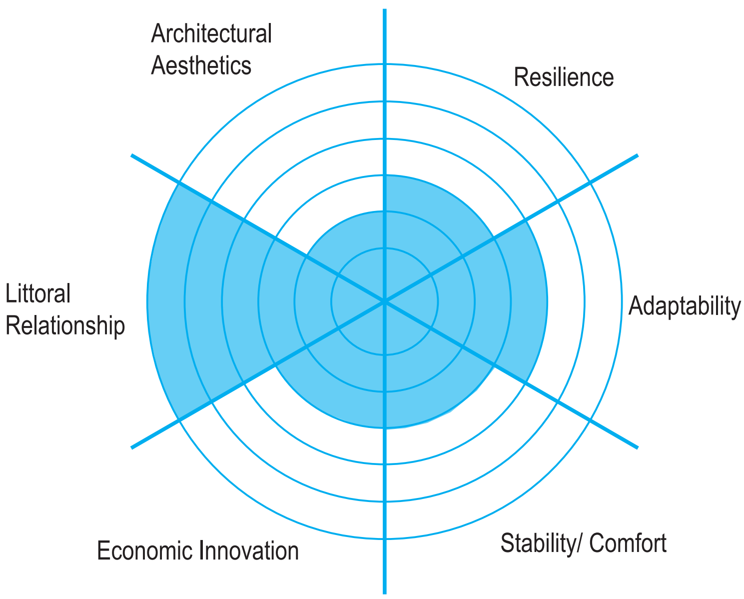

Figure 25.

Architectural Aesthetics: How visually appealling the building is

Resilience: How well the building prevents damage (ie flood damage) from its environment in which it resides

Adaptability: How well the building adapts to the issue (sea levels rising) through its floatation system

Stability/ Comfort: How well the floating design aids in providing a stable living situation and therefore comfort

Economic Innovation: How well the design considers the environmental impacts through construction and materiality selection

Littoral Relationship: How well the building relates to the shore/ land to provide adequate means of access

3.4. Formosa, Amphibious House - UK's First Amphibious Dwelling

Name: Formosa, Amphibious House
Building type: Single Amphibious Dwelling
Architects: Baca Architects
Location: Buckinghamshire, UK
Size: 225 square meters
Construction: Completed

What is the Amphibious House?

The amphibious house is located adjacent to the River Thames in Marlow is a UK first. Based on the practices pioneering non-defensive approach to make space for water within the built environment - the house marks a valuable and critical contribution to both architectural design and flood resilience discourse (Couttes, 2018). An amphibious house is a building that rests on the ground but whenever a flood occurs, the entire building rises up in its dock, where it floats, buoyed by the floodwater. Amphibious construction brings together standard components from the construction and marine industries to create an intelligent solution to flooding. The house itself sits in the ground and the floating base is almost invisible from the outside. Amphibious designs can vary to suit the location and owners' preferences (Baca Architects, 2014). The Amphibious House is a highly innovative approach to tackle extreme flooding. The 250 ton house, which sits on the ground within a purpose made dock, is able to rise up to 2.7m when a flood occurs, buoyed by the flood water; whilst remaining connected to all utilities through flexible servicing. Built on the banks of the River Thames in Buckinghamshire, the house is the first to secure Planning, Building Regulations and to be constructed in the United Kingdom. (Couttes, 2018).

Amphibious House potential influence in design decision-making

The amphibious house is an excellent flood mitigating design that allows the users of the space to still occupy the land whilst it is available and maintain that living situation once the waters begin to rise. The amphibious solution is a more suitable and appropriate climate change response as opposed to completely floating houses, in terms of providing a more comfortable living situation as the house only floats when it needs to. Because this house however, was designed for mitigating floods, as opposed to sea level rise, which is a constant acceleration of water rise, this design, as well as other amphibious designs will be explored through the design process and will become a base framework for the design development. The external cladding consists of zinc shingles that work well for the natural elements in which the house is exposed and the internal construction consists of timber and steel framing to provide for lightweight construction. These materials could be considered through the design process.

Figure 26.

Figure 27.

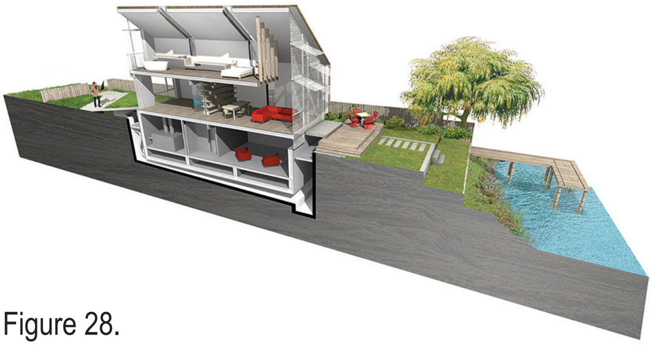

Figure 28.

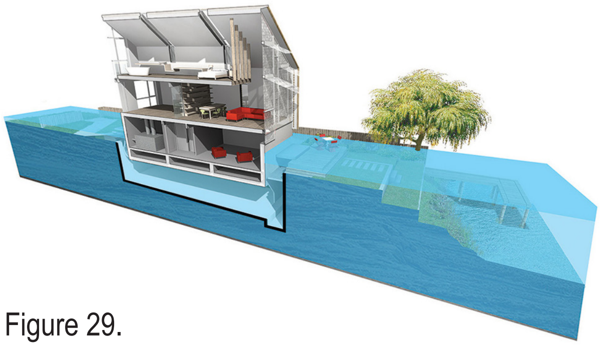

Figure 29.

The Amphibious house demonstrates that architecture, engineering and flood strategies can be holistically combined to create beautiful buildings that allow occupants to enjoy living near water safely - Richard Coutts (Baca Architects co-founder)

Amphibious House Construction and Appearance

The house is covered in zinc shingles and has a glazed gable that faces a small garden, which slopes up from the edge of the river and is designed to provide an early warning of flooding. The site does not regularly experience severe floods, so every few years the dock will be pumped full of water to test the movement. (Mairs, 2016). The house uses technology from marine and bridge construction as well as conventional building to create an elegant solution to flooding that is also attractive and complimentary to the setting. The floatation attributes, including the guide-posts, slide-gear and flexible services are expressed in the architecture as is the industrial weather screen skin. The triple height glazed facade allows views of the river from all floors. The northern elevation provides a simple complement to neighbouring houses. The unique 22m² house, which is located just 10m from the river's edge and within a Planning Conservation Area the house, also provides an intelligent and contextual response to its setting. The design was tailored to overcome the challenges of having no vehicular access to the site, limited space to work and needing all plant and materials to be brought across the river via a lightweight chain ferry. This pioneering prototype house passed a full float test before client occupation (Couttes, 2018). The amphibious house is connected to its utilities via elephant cabling. These flexible service pipes are designed to extend up to 3m, allowing all of the services to remain clean and operational during any flood event. Crucially, this also allows the occupants to return to the property immediately after a flood, maximising the continuity of their daily lives (Baca Architects).

Amphibious House Sections

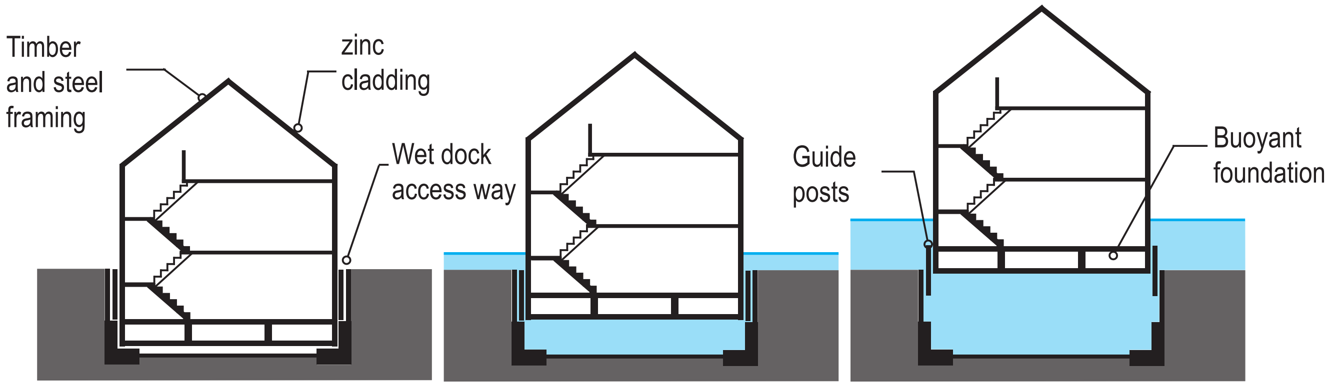

Figure 30.

Amphibious House Strengths

The amphibious house allows the house to only float when it is required and therefore allows the users of the space to occupy the land before it becomes submerged by the rising waters. Because sea level rise is not as much of an issue today as we know it will be in the future, this design accommodates both our living needs today as well as our future needs. The overall form of the building is very simplistic, yet elegant. Assuming this is due to maintain the stability by keeping the form simple and symmetrical as it is a building that begins to float on the surface of rising floodwater.

Amphibious House Weaknesses

This design is excellent for mitigating floods, which is not a permanent increase in water level and is only temporary. However, because this design only allows the house to float just up out of its dock, it does not necessarily accommodate for the constant acceleration of sea level rise.

Analysis based on Amphibious House

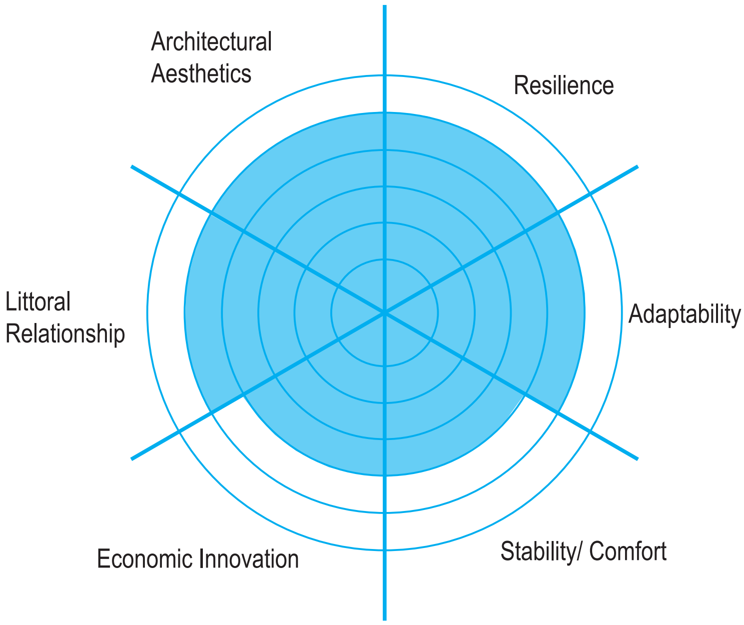

Figure 31.

Architectural Aesthetics: How visually appealling the building is

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3.5. Summary and Reflection

After analysing both actual and theoretical architectural resolutions of floating architecture, it is evident through the analysis radial diagrams that the Floating Office Rotterdam (FOR) appears to be the most successful of the three completely floating precedent case studies. Due to its self-sustaining approach and sustainability integration it is completely self-reliant. Its location, Rijnhaven port in Rotterdam, in which it is moored, provides for calmer waters, therefore the floatation system could be simplistic. The floating pontoons in which the building is situated on, provides for adapativeness and resilience for this issue of sea level rise, and allows the building to rise and fall with the water. The mooring posts keep it anchored in place, so it does not float off. Each case study that was explored, excel in their own right, and contain their own strengths and weaknesses. The strengths could be considered and incorporated into the design process and the weaknesses avoided.

It was discovered when exploring case studies for floating accommodating architecture that the majority of them have been designed for locations that provide somewhat of a sheltered environment. No case studies that have been discovered were designed for exposed, open ocean situations.

The amphibious house case study provides for more of an appropriate response when taking into consideration the intense weather conditions in which Wellington offers. Building straight onto the water is not the suitable solution as sea level rise today is not as much of an issue as we know it will be in the future. Therefore, if amphibious solutions are explored and developed to work within the site parameters, this solution will not only be more suitable to provide for our housing needs today as well as our needs in the future as sea levels rise, but also allows the site to be used whilst it is still available. Building out onto the water is not necessary as of yet, but may become a more popular choice in the foreseeable future.

Chapter Four: Site Introduction

4.1. Site History: Shelly Bay

Martene Loves 'Te Ara o Nga Tupuna Heritage trail' (2006) outlines a clear history of Shelly Bay before European settlement. The former Air Force Base at Shelly Bay was once the Te Atiawa village called Maru-Kai-Kuru. Settlement of this site dates back from the earlier migration (heke) from Taranaki when Maru-KaiKuru was populated by the Ngati Mutunga kin of Te Atiawa. The village was situated at the north end of Shelly Bay and was connected to other settlements of the Whataitai peninsula (western side of Miramar Peninsula). These areas were occupied by Te Atiawa people until the time of colonisation, when they moved north around the harbour. In much earlier times the area was occupied by the Ngati Kahukura-awhiti and Rakiwhiriwhiri. At the southern end of the bay was the village of the descendants of Whatonga, the ancestor of Rangitane and Ngati Ira (Love, 2006).

The article, 'Iwi buy Shelly Bay' (2009), states that in 1839 the bay was sold to the New Zealand Company along with most of Wellington. In 1907 the land was transferred to the Royal New Zealand Navy and in 1946 it was transferred again to the Royal New Zealand Air Force to accommodate up to 300 staff. The New Zealand Defence Force owned land on Shelly Bay until 1995 when the then Air Force Base was closed (Stuff, 2009).

The article, 'Historic Wellington land handed to Iwi', outlines that on 14 February 2009, the land was handed over to Taranaki Whanui ki Te Upoko o Te Ika as part of a Treaty of Waitangi settlement (Stuff, 2009).

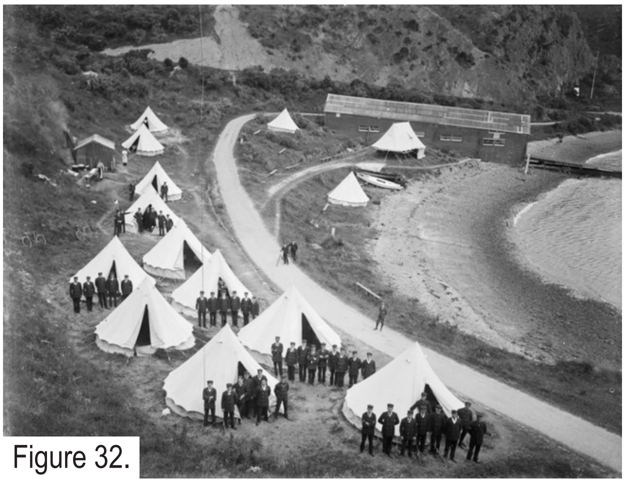


Figure 32.

Submarine and Torpedo Mining Corps annual camp, Shelly Bay, Wellington. Photo taken around 1899.

Figure 33.

Overlooking Shelly Bay air force base, Wellington. Photo taken 1948.

Shelly Bay Development Timeline of Infrastructure

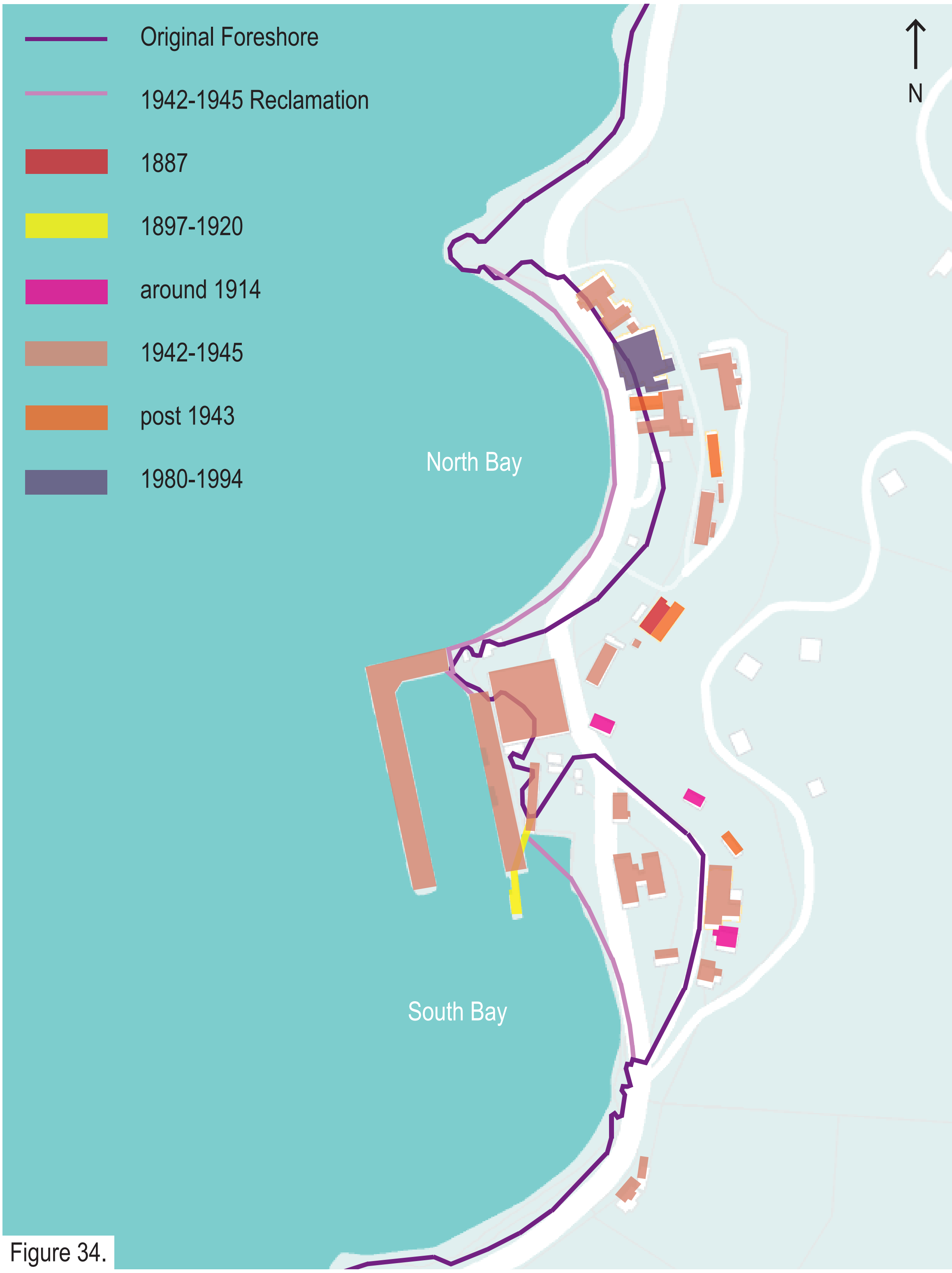


Figure 34.

Shelly Bay Historical and Physical Context Timeline (1880 - 2017)

1880

The name Shelly Bay is first recorded in use in newspapers

The bay is popular for summer picnics and excursions

1881

A 60 year old man is living in Shelly Bay in a tent

1885

Construction of a road linking coastal defence installations at Halswell and Gordon Points begins and a camp for military road builders is set up at the bay

1886

The two bays that make up Shelly Bay (May Port and Port Janet) are taken for defence purposes in 1886 and gazetted a defence reserve

1887

Shelly Bay proposed as the new site for submarine mining facilities to replace those at Mahanga Bay and Thorndon Quay, with the permanent New Zealand Torpedo Corps to maintain the depot and equipment

First annual camp of the volunteer submarine mining corps

1888

Construction of a road linking coastal defence installations at Halswell and Gordon Points begins and a camp for military road builders is set up at the bay

1889

The Shelly Bay submarine mining depot base has a Whitehead torpedo shed, mine store, general store, offices, blacksmith's shop, carpentry shop, barracks, 18m long L-shaped jetty with a 2-ton crane and a tramway connecting the two bays

Maori prisoners put to work beginning the construction of a small ship

1891

A fatal explosion occurs at the blacksmith's shop and an investigation is held at Shelly Bay

1892

Permanent Militiamen from the lower Mt Cook barracks are accommodated at Shelly Bay in tents while the sewers to Mt Cook are cleansed of typhoid

1894

Construction of the road connecting Shelly Bay to Evans Bay

1898

The foreshore road from Shelly Bay round Point Halswell to Worser Bay is completed by the Defence Department with the aid of prison labour, but is closed to the public

1902

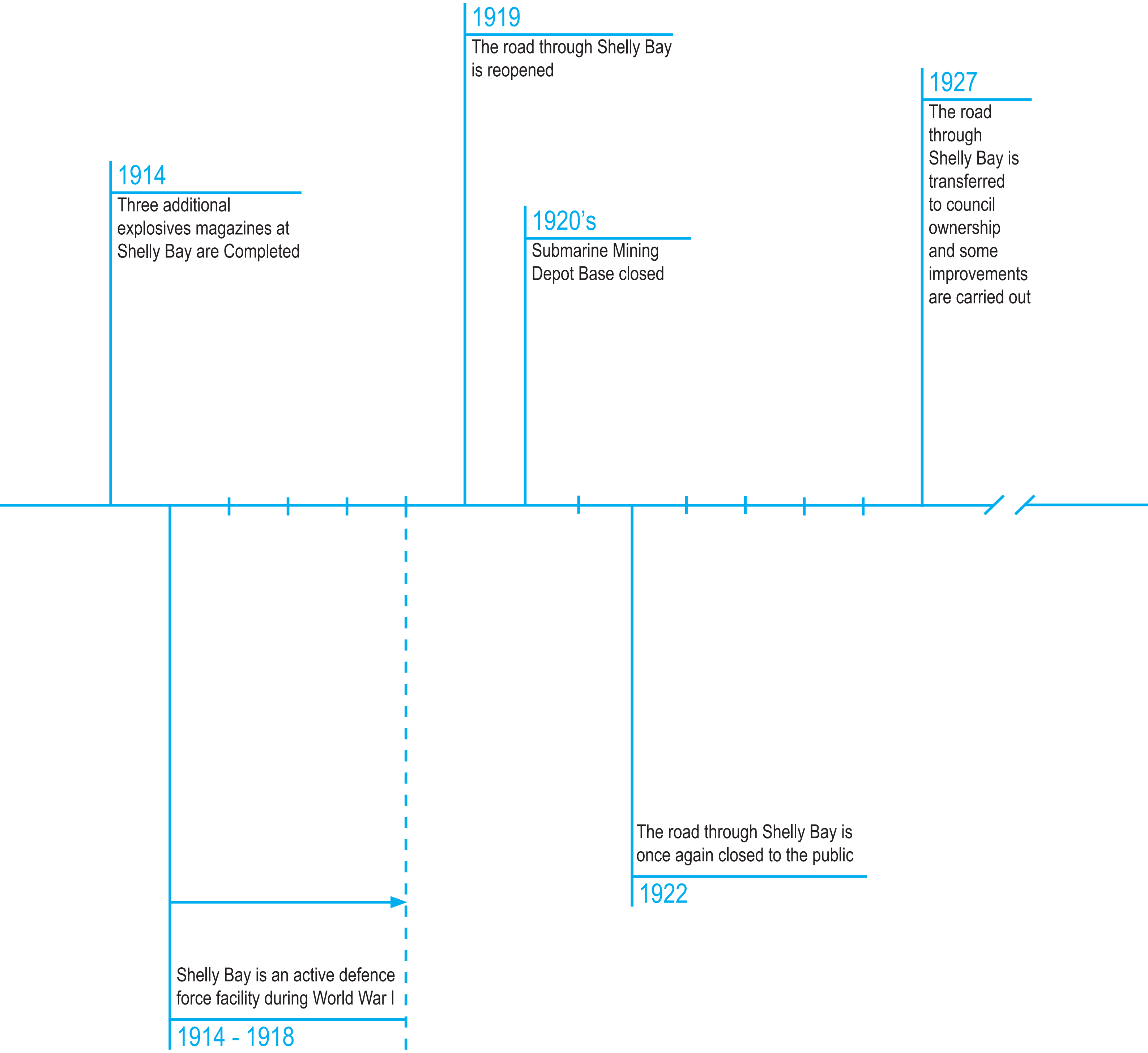
The wharf is extended, losing the L-shape

1907

Submarine mining as a weapon is disestablished, meaning that the facilities to store, test and arm the explosive mines, and wharves to load the mine-laying vessels, are no longer required

1908

Removal of buildings to other bases begins


1914
Three additional explosives magazines at Shelly Bay are Completed
1914 - 1918
Shelly Bay is an active defence force facility during World War I
1919
The road through Shelly Bay is reopened
1920's
Submarine Mining Depot Base closed
1922
The road through Shelly Bay is once again closed to the public
1927
The road through Shelly Bay is transferred to council ownership and some improvements are carried out

1936

Proposal to utilise Shelly Bay as a commuter wharf with a tunnel or cutting connecting the suburban residents in the valley behind the hill

1941

Shelly Bay becomes Wellington's main (and only) naval base, HMNZS Cook, housing Wellington's anti-submarine and minesweeping forces

The road through the base is closed and the tramway is re-laid

Work begins on reclaiming 27 hectares of land

1941 - 1943

The wharves are considerably extended, a slipway, accommodation blocks, a mess, recreation hall/ canteen, hospital, laundry, two boiler houses, store, workshop, shipwright's shop, offices and officers' quarters are constructed

A Naval Ammunition Depot, magazines and laboratory are built above Shelly Bay using prison labour

1944

HMNZS Cook is formally commissioned

1945

The base is finally completed as World War II ends

Public pressure is put on the Navy to reopen the road and they agree to allow public traffic to pass through during daylight hours

1946

Base operation taken over by the Royal New Zealand Air Force

1947

The wharves, slipway and Shipwright's building are advertised for lease and let to the Shipbuilder Barney Daniel

1950 - 1952

TEAL flying boats are using the Shelly Bay wharf

1961

Barney Daniel vacates his lease

1965

A fire destroys the other ranks' kitchen, mess and YMCA library which stood in front of the submarine Mining Depot barracks (then known as the YMCA Flats)

1973
The gymnasium is converted to a squash court

1976
Warrant Officers’ & Senior Non-Commissioned Officers’ Mess building constructed

1995
The base is decommissioned and officially closed

2003
The slipway is used for the last time

2005
Ownership of the road and land to the seaward side is transferred to Wellington City Council ownership

2008
Government sells land at Shelly Bay to the Port Nicholson Block Settlement Trust as part of its Treaty settlement

2009
The Airmen's Accommodation building is demolished or removed

2017
The council agreed to enter into an agreement to sell and lease land with Shelly Bay Limited as part of a planned development by The Wellington Company in partnership with Port Nicholson Block Settlement Trust. The council agreed to to sell 0.3ha and lease 0.6ha. The decisions for the new development proposal are still underway as of 2021.

Figure 35.

4.2. Site Context at Present

Shelly Bay is a bay located on the Mirimar peninsula in Wellington, New Zealand. It is comprised of two bays; a north bay and a south bay.

Buildings previously part of the defence bases have had little or no maintenance since the base ceased operations. Shelly bay is essentially falling apart. The buildings are in a sorry state, paint is peeling off, the wharf is collapsing into the sea and there is rust everywhere (Jackman, 2014). The defence base buildings, used by small businesses and as artists' studios, are not registered with the Historic Places Trust but considered historically significant by the council. The chocolate fish cafe became the cafe of choice for stars and crew from the Lord of the Rings trilogy. Wellington Mayor Kerry Prendergast said the Chocolate Fish was iconic and had been used by Positively Wellington Tourism to promote the city (Burgess, 2009). According to Heritage New Zealand Pouhere Taonga (HNZPT) and in the Wellington City District Plans Heritage List in history items (2013), neither the site, nor the buildings on the site are listed as heritage buildings. Chessa Stevens' 'Shelly Bay Heritage Effects Assessment' (2019) created her own assessment of the heritage significance of the buildings and structures within Shelly Bay.

The Precinct's flat land is a heavily modified coastal environment, primarily consisting of an asphalt coastal edge footpath and road, timber wharf structure and buildings, loose gravel parking bays and flat lawn areas. The flat coastal promenade and Shelly Bay/ Massey Road are built upon reclaimed land with concrete and battered stone seawall jutting out into the harbours edge approximately 2.5m above sea level (Wraights + Associates, 2019). The east side of shelly bay consists of a steeply vegetated escarpment. The subsoil of Shelly Bay is classified as 'C - Shallow Soil' (Semmens, 2011). This may require site modifications for when the land becomes submerged underwater and eventually becomes the seabed.

Wellington, New Zealand

Figure 36

Site: Shelly Bay

Figure 37

Shelly Bay Today

Site: Shelly Bay

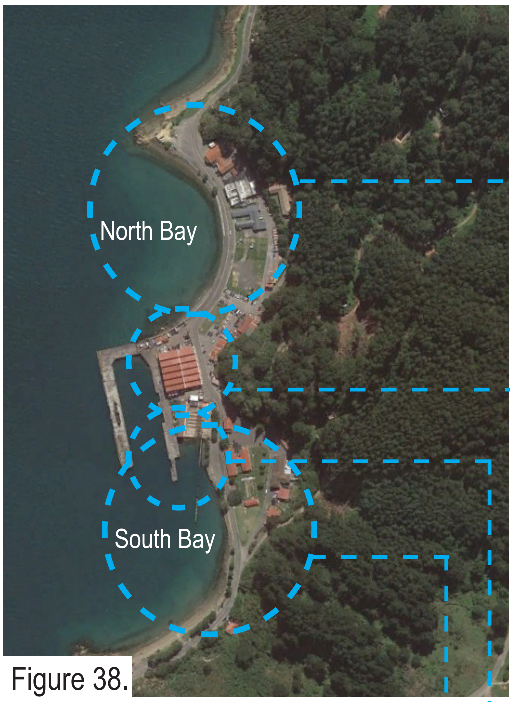


Figure 38.


Figure 40.


Figure 41.

Shelly Bay Flood Risk


Figure 39.


Figure 42.


Figure 43.

Urban Analysis

Sun Solstices and Wind Direction

- Sun Exposure
- Wind Exposure

Urban Patterning and Existing Infrastructure

- Urban alignment
- Buildings

Vehicular and Pedestrian Circulation

- Main Road
- Other Roads

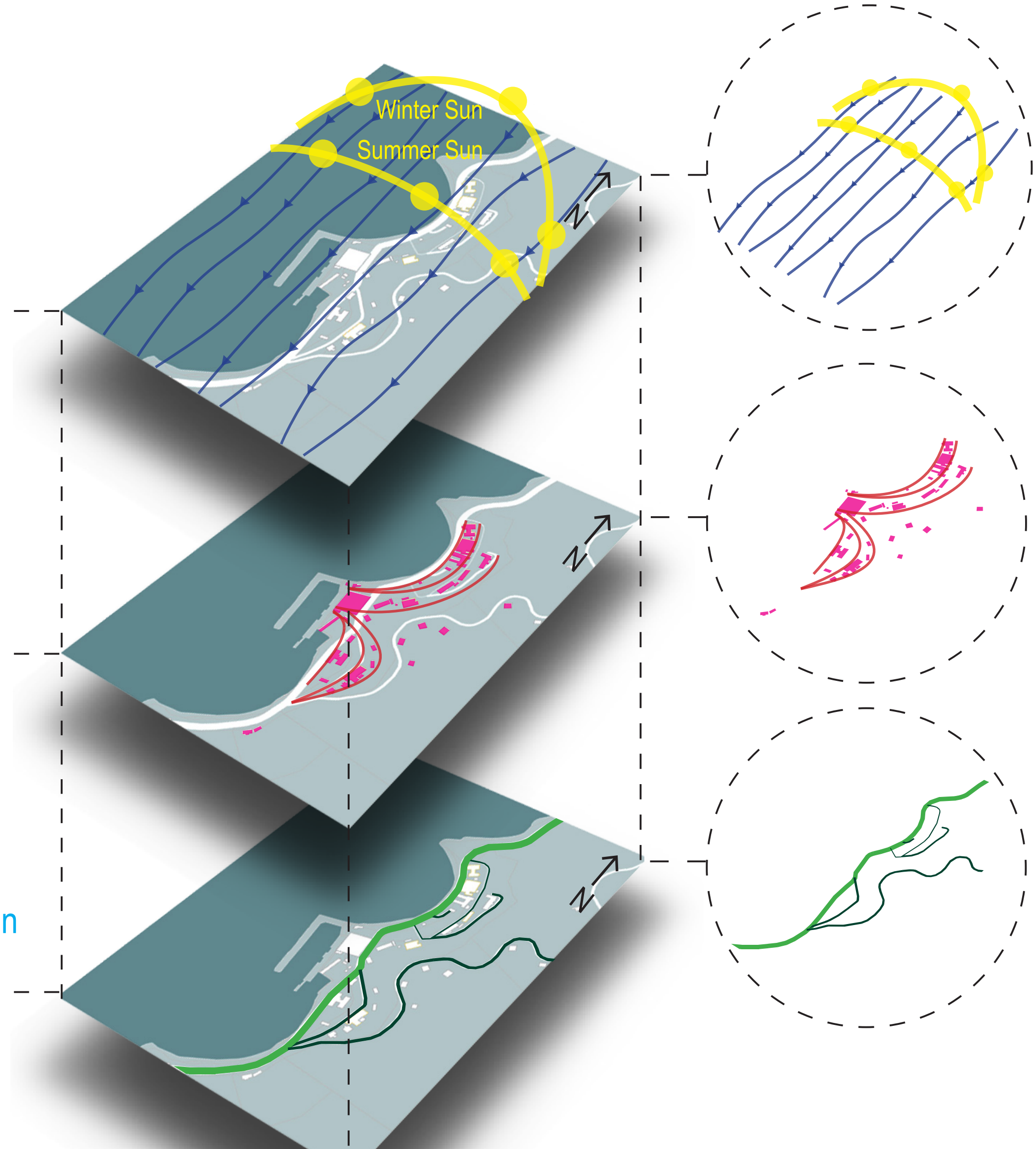


Figure 44.

The site tends to get a lot of sun exposure, in the afternoon in particular and due to the site being quite exposed in the west, the site is somewhat unprotected from the wind.
The existing buildings on the site and the urban alignment follow the shape of the two the bays.
There is a main public road that runs a long the waters edge, with a couple of secondary roads that lead up the hill on the east.

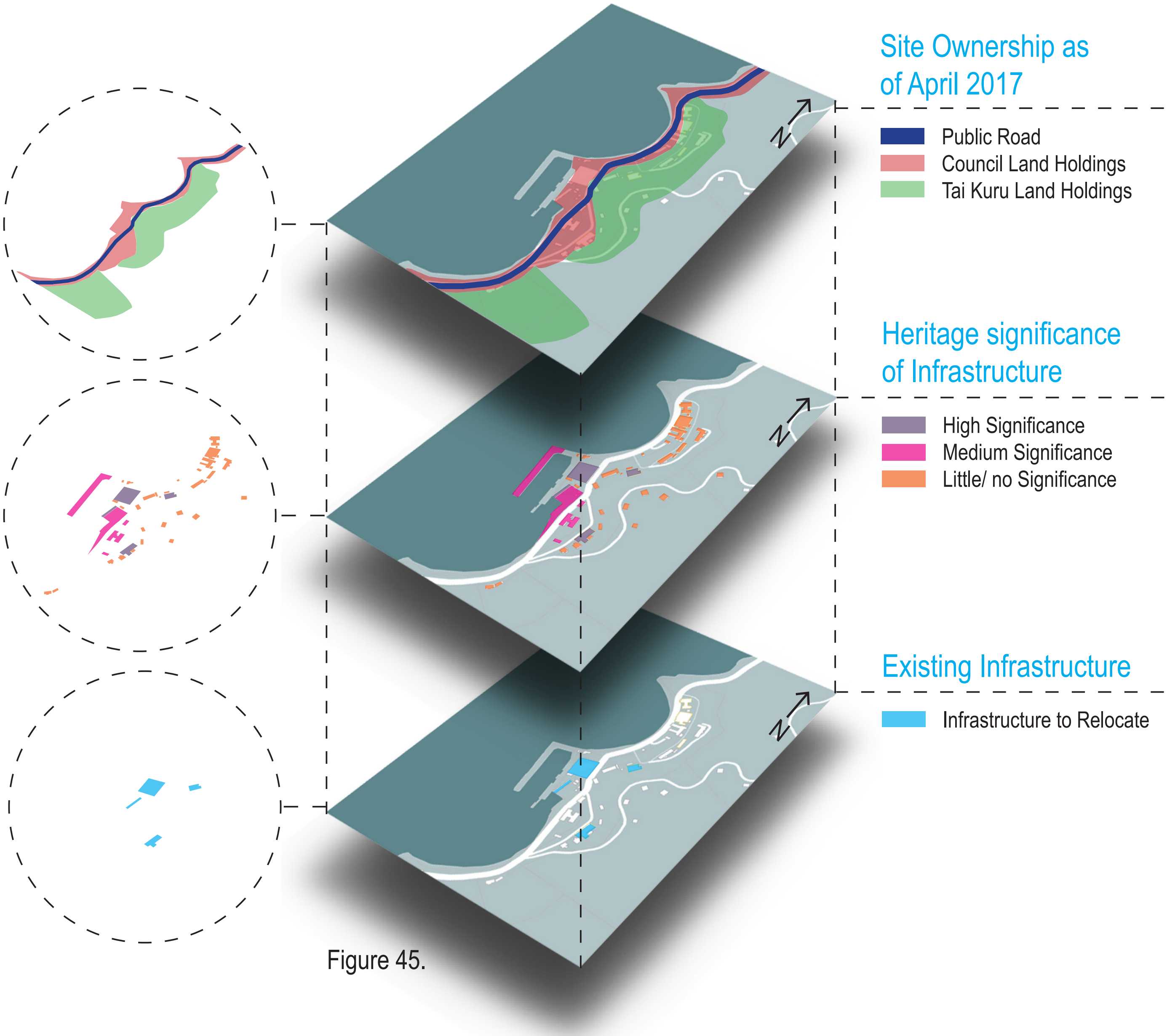


Figure 45.

The council owns about a third of Shelly Bay, and the other two thirds are Tai Kuru land holdings - as of April 2017 (Wellington City Council, 2017).
According to Chessa Stevens' 'Shelly Bay Heritage Effects Assessment' (2019), the heritage significance of the existing buildings on the site have been made evident.
However, because none of these building are legally identified as heritage buildings, all existing buildings and structures will be removed as the majority of them are run down and unoccupied. The buildings that have been identified to obtain "high heritage significance" could potentially be relocated to higher ground to eliminate the risk of flood damage once the sea levels begin to rise.

Existing Infrastructure

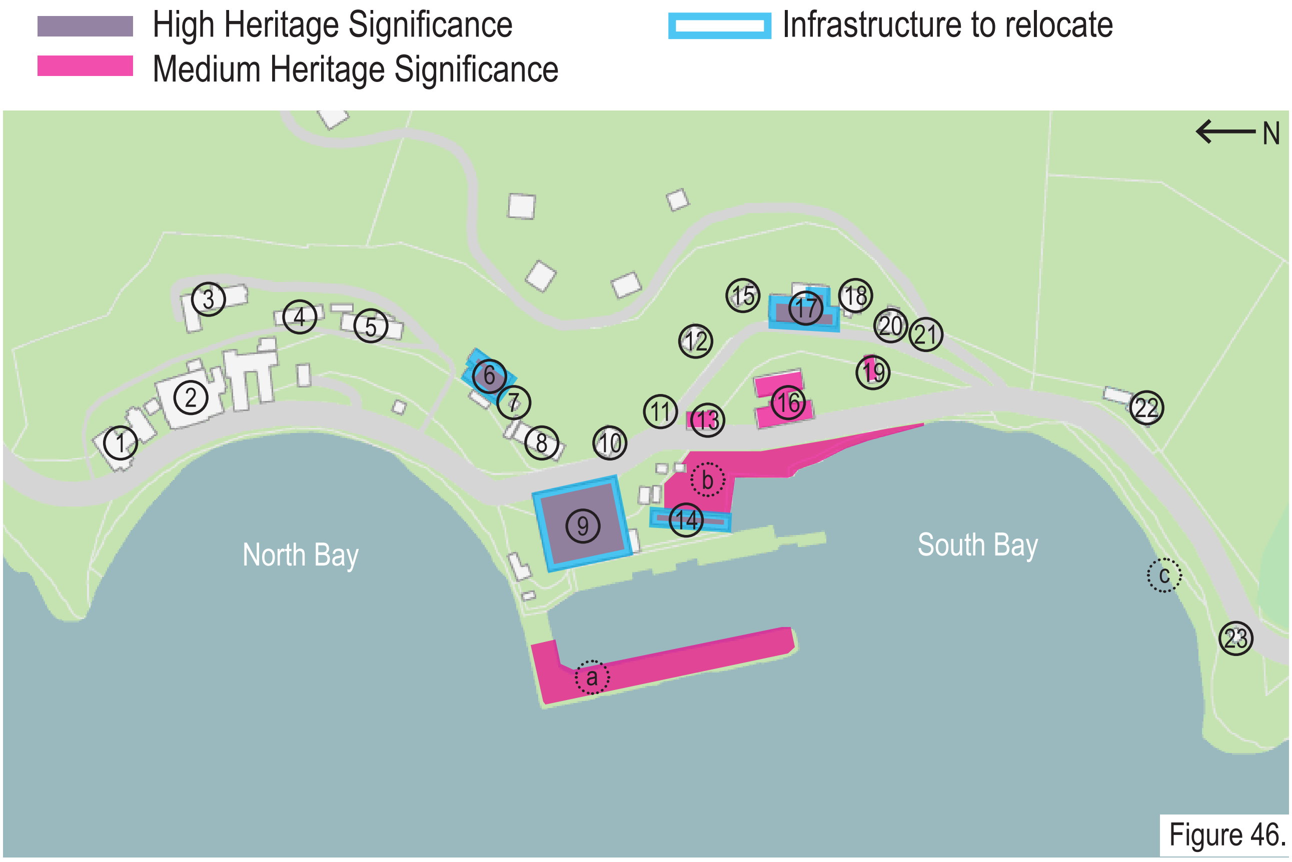


Figure 46.

Buildings

1 Whirlwind Designs & Theacrobatic Design Ltd.

2 Blackmore and Best Gallery

3 Old Hospital - Bayview Art Studios

4 North Bay Garages

5 Laundries and Boiler House

6 Chocolate Fish Cafe

7 Transformer Building

8 Studio 3 - Artisan Screen Prints

9 Shed 8 - Propeller Studios

10 Barack Warden Store

11 Out Building

12 Library

13 Squash Court - Pixel Paint

14 Shipwrights Building

15 South Bay Garages

16 Studio 2 - HQ Studios

17 Officer's Quarters and Mess

18 Officer's Mess Games Room

19 Officer's Mess Laundry Building

20 Officer's Mess Accommodation Annex

21 Other Ranks Transit Hut

22 Base HQ and Officer's Accommodation

23 Guard House

Structures

a Finger Pier

b Slipway

c Boat Ramp

Indicative Building Height Diagram

An indicative building height diagram for new developments on Shelly Bay was presented by the Wellington City Council (Wellington District Plan: Volume 2). The majority of the site requires buildings no higher than 8m above ground level. Therefore the design will stay within this height restriction. Assuming once the sea levels rise these restrictions will become void.

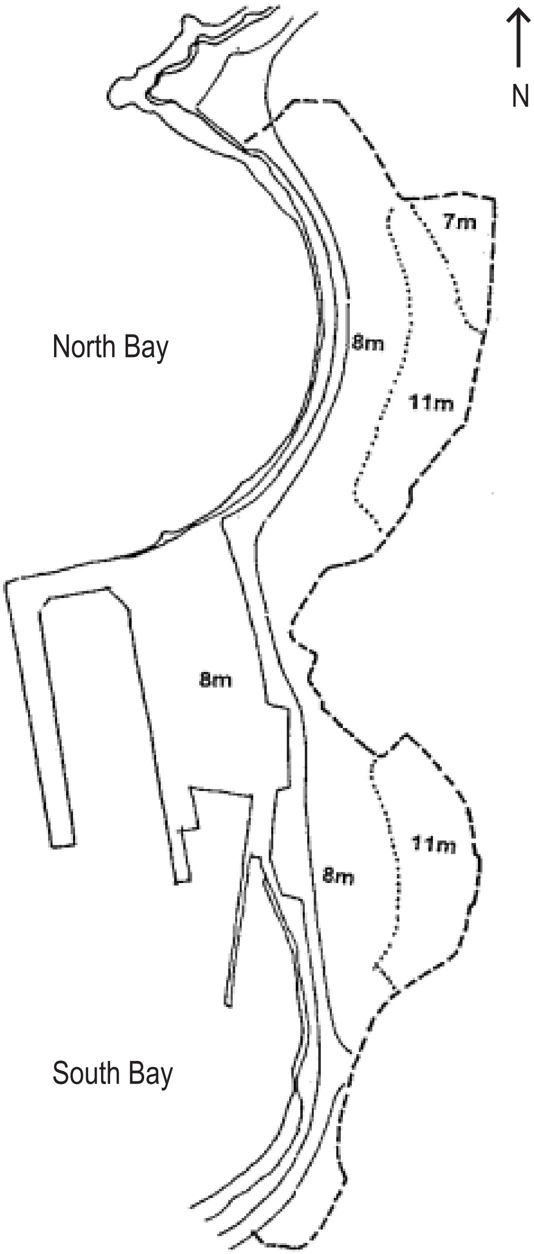


Figure 47.

Special Housing Area

A large area of Shelly Bay was identified as a Special Housing Area in the Wellington Housing Accord under the Housing Accords and Special Housing Areas Act 2013 in June 2015. The pink and blue outlined area was the Special Housing Area as of June 2015, and the black dotted line indicates the extension of the area, later on in the same year. As defined by New Zealand Legislation in the 'Housing Accords and Special Housing Areas Act 2013', the purpose of the Special Housing Area Act is to enhance housing affordability by facilitating an increase in land and housing supply in certain regions or districts (2013). Therefore, Shelly Bay requires more housing to meet the demand.

Schedule 3
Shelly Bay Extension special housing area

Map of special housing area

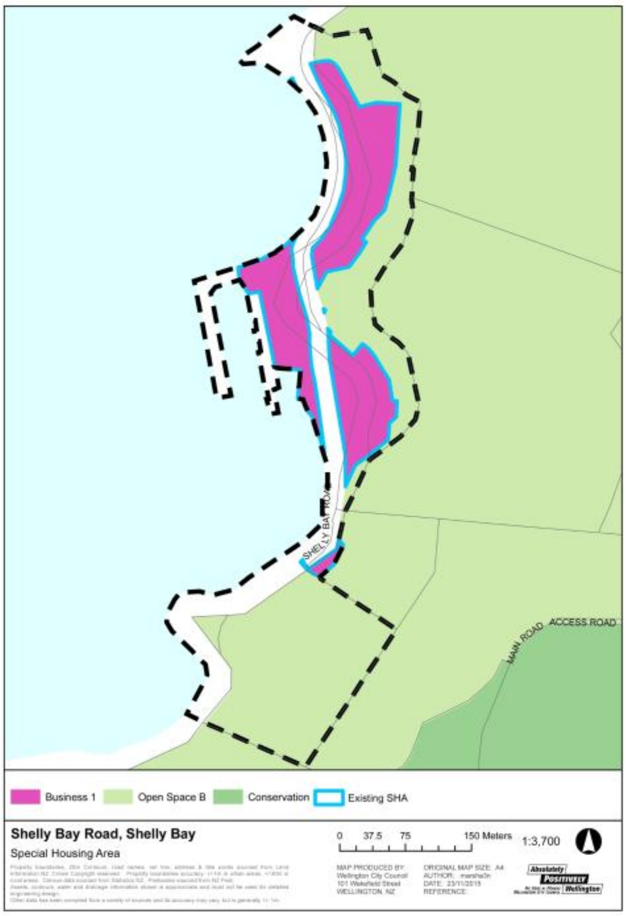


Figure 48.

Shelly Bay Proposal - Ongoing

The Council granted resource consent in April 2017 to The Wellington Company for a plan that would develop Shelly Bay into a new neighbourhood with housing and a range of public spaces and facilities. The development is an opportunity for the Council to resolve the future of Shelly Bay, enhance the open space and public access to the waterfront, and tackle deferred maintenance to its infrastructure and buildings there. There are plans including a waterfront walkway; green space; parking and seating; cafes, bars and shops; a microbrewery and a 50-bed hotel. The development would add 350 homes to Wellington's housing stock, providing more choice in housing and bringing in rates revenue of $1.5 million a year to the city.
The vision of Shelly Bay Limited for the bay incorporates new high quality housing, public facilities located in a mix of new and refurbished premises, and improved infrastructure. The development would complement existing local attractions such as Scorching Bay, Massey Memorial and the proposed heritage reserve above Shelly Bay on the Miramar Peninsula Te Motu Kairangi.
It is proposed the new homes would comprise 280 apartments, 58 townhouses and 14 standalone homes. The front row of houses would be three level townhouses and detached homes with front doors and gardens facing the road. Behind these, at the base of the steep hill, would be apartment buildings up to six storeys. A road would separate the two levels of housing and provide vehicle access and parking (Shelly Bay Development Proposal, 2017).

This proposal however, has not taken into consideration the effects of sea level rise and is actually one of the reasons why some people voted no for this proposal to go ahead. The housing solution for Shelly bay in which is being presented in this thesis will provide housing for the area as well as mitigate the effects of sea level rise caused by climate change, by providing an adaptive and resilient architectural response for safely inhabiting the low-lying coastal site. The design in the thesis provides a means to avoid the high costs associated with flood damage. This current ongoing $500M proposal could potentially be catastrophically flood damaged within 80 years or so.

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Figure 49.

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Figure 50.

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Figure 51.

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Figure 52.

4.3. Site with Sea Level Rise

The site was explored in relation with sea level rise to investigate how the site responds to the different levels of rising waters and which areas of Shelly Bay will eventually become completely submerged. An analysis of Shelly Bay and the Mirimar Peninsula with sea level rise was derived from the Greater Wellington Regional Councils 'Sea Level Rise' analysis (2017). This program however, does not provide dates for each level of water rise, and therefore is a speculative analysis. Some sectional diagrams and three dimensional visual representations were created to explore the severity of this issue further.

Mirimar Peninsula and Shelly Bay with Sea Level Rise

Shelly Bay in comparison to its surrounding context of the peninsula appears to be quite vulnerable to this issue and will succumb to severe inundation from a two meter sea level rise. To explore the severity of this issue further, three dimensional diagrams were created as a speculative tool to assess how the existing buildings on the site respond to the rising and waters and when the existing infrastructure will eventually become completely submerged.

Surrounding Context (Mirimar Peninsula) with Sea Level Rise

1m Sea Level Rise

Figure 53.

2m Sea Level Rise

Figure 54.

3m Sea Level Rise

Figure 55.

4m Sea Level Rise

Figure 56.

5m Sea Level Rise

Figure 57.

Shelly Bay with Sea Level Rise

1m Sea Level Rise

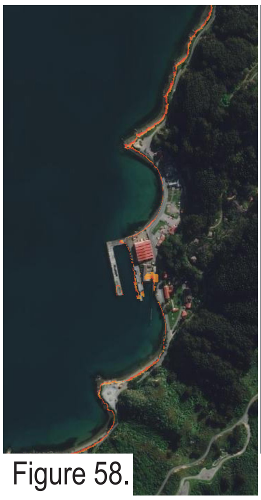


Figure 58.

2m Sea Level Rise

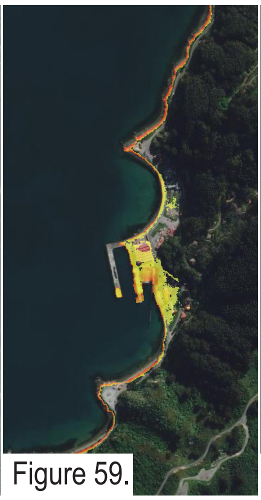


Figure 59.

3m Sea Level Rise

Figure 60.

4m Sea Level Rise

Figure 61.

5m Sea Level Rise

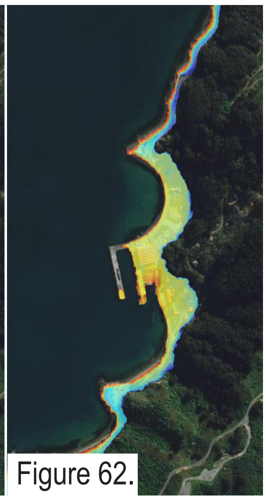


Figure 62.

Shelly Bay with Sea Level Rise

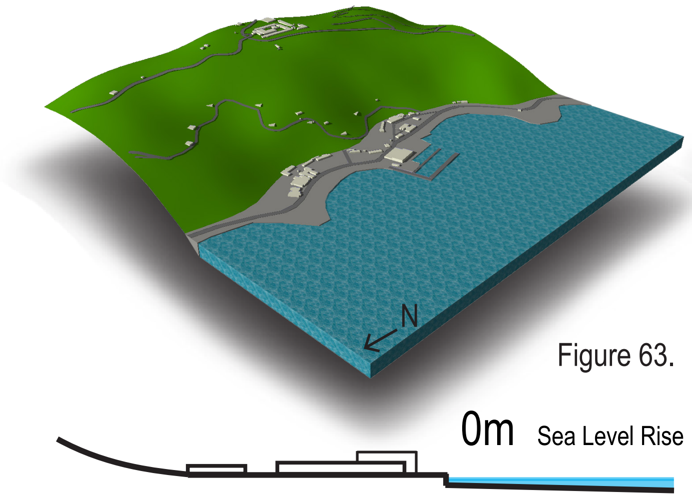


Figure 63.

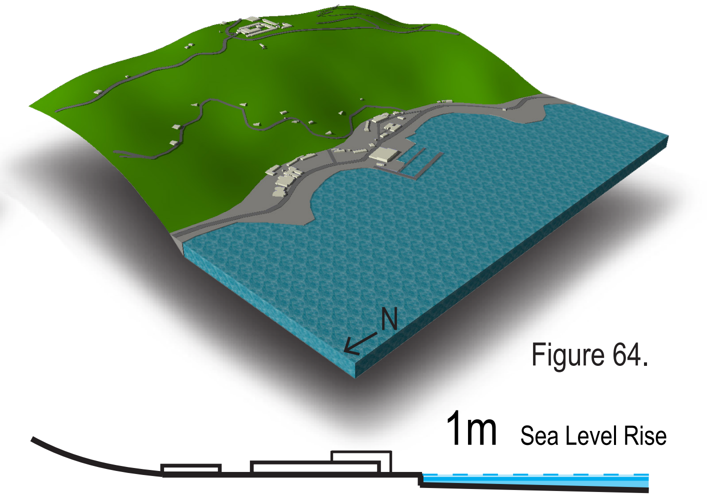


Figure 64.

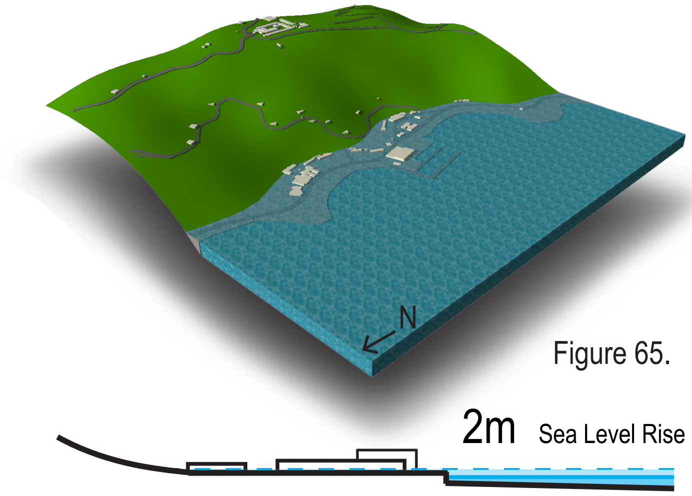


Figure 65.

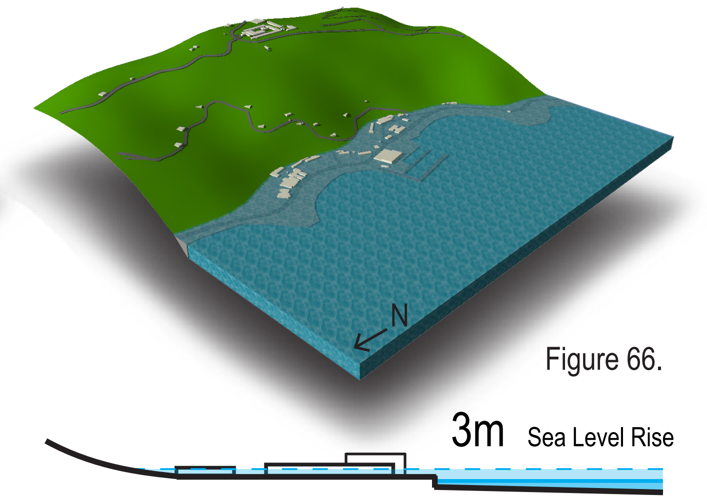


Figure 66.

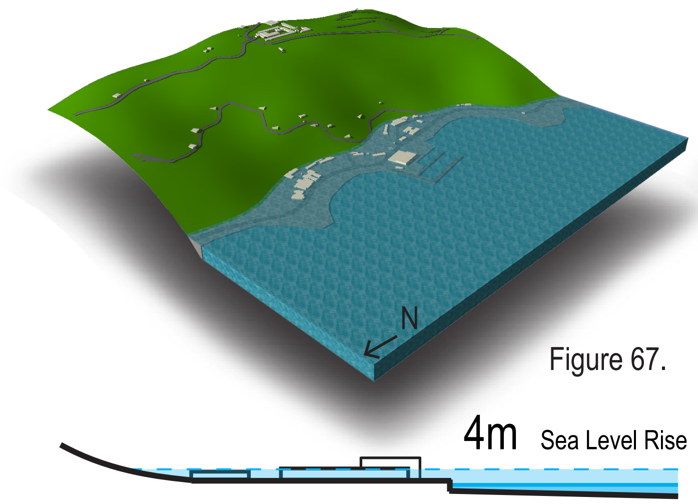


Figure 67.

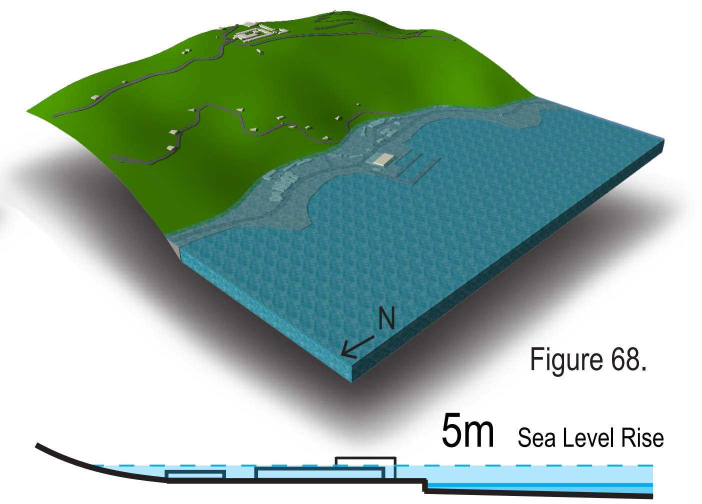


Figure 68.

4.4. Summary and Reflection

With reference to Stevens' 'Shelly Bay Heritage Effects Assessment' (2019), a determination of which buildings possess high, medium and no heritage significance were derived and therefore was able to determine which buildings would be relocated to higher ground to ensure they are not affected by the rising waters.

Shelly Bay in comparison to the extended context of the peninsula, appears to be quite vulnerable to this issue of sea level rise and will succumb to severe inundation from a two meter sea level rise. Shelly Bays typography slightly slopes up towards the north end of the site, therefore the water does not rise uniformly along the entire site. Some areas are also more prone to flooding than others, which will need to be taken into consideration during the design phase.

Shelly Bay holds a lot of significant history as the physical and historical timeline represented. Once the sea levels rise and the site is claimed by the sea, this design is an opportunity for the Iwi to reclaim that space once it is lost by the sea. The land may no longer be available, but the area above the land will still be used as a place to occupy and live on and therefore will not lose as much of its sacredness nor significance.

Chapter Five: Research Summary

5.1. Summarizing Research

It was identified in the literature review that sea levels rising require an adaptive and resilient architectural solution for safely inhabiting low lying coastal areas. The three strategies identified by David Robinson, Retreat, Defend and Attack, are three ways the architecture can overcome this issue. The idea of Attack, is the most adaptive and resilient of the three and therefore will form the basis for the design framework. Through the case study analysis, the amphibious house implements the most appropriate construct to deal with this issue and through the analitical diagram, suggesting this resolution would be most suitable to work with in a Wellington context. The completely floating case studies also obtain construction, materiality and sustainable energy generation systems that could be implemented in the design. The selected low lying coastal site, Shelly Bay, holds a lot of historical significance and therefore also plays a vital role throughout the design implementation.

5.2. Forming a Design Framework

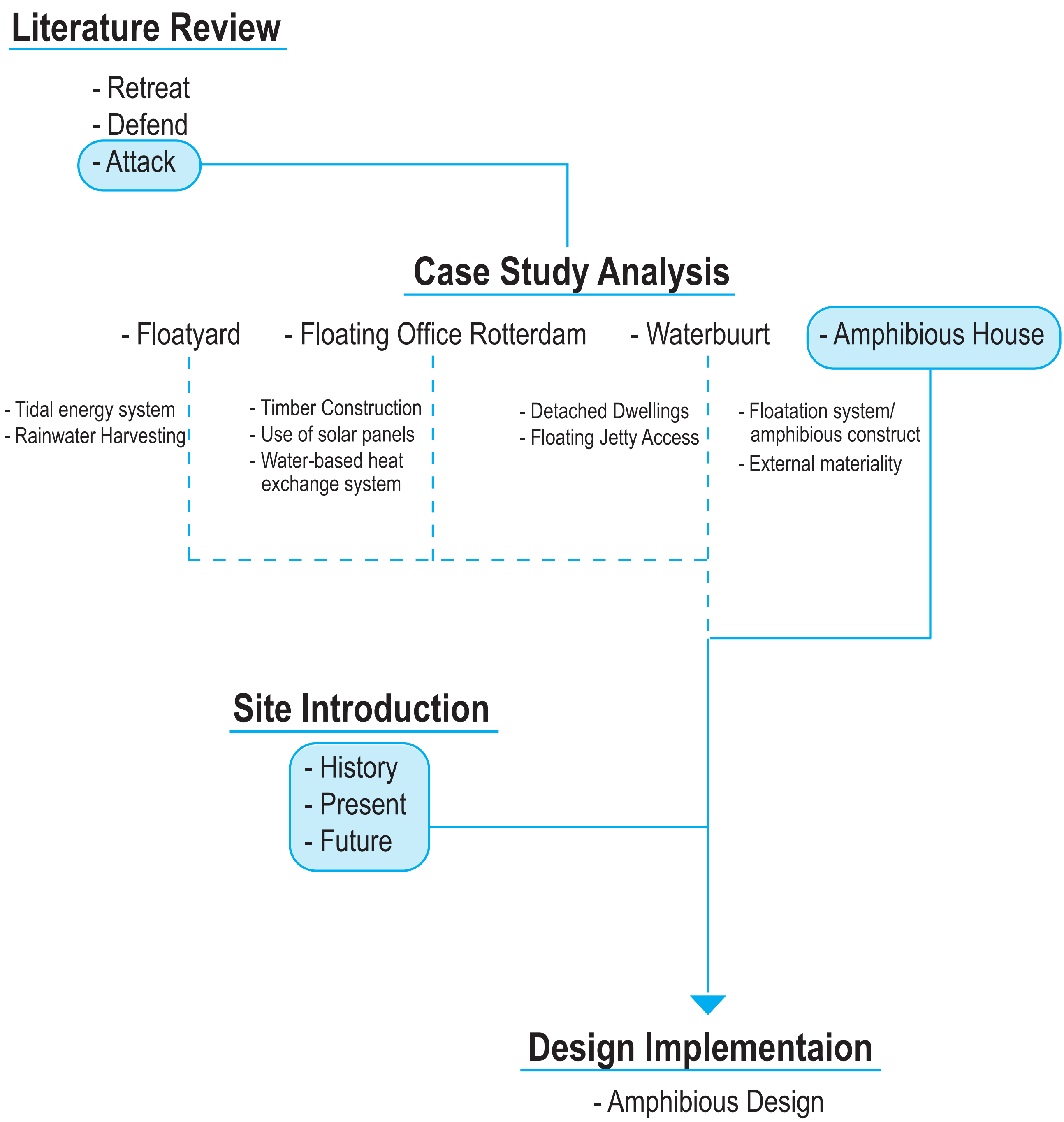


Figure 69.

Chapter Six: Design Introduction

6.1. Role of Design

The idea is to create a new way of living on the water by composing a floating development that accommodates the occupants through sustainable and autarkic construct. This climate-resistant floating resolution will allow the architecture to rise and fall with the tide, therefore provide a solution for the inundation caused by climate change by eliminating the flood risk. The concept is also a solution to the land constraints that may become a problem in the future as well as population overcrowding. The notion of an innovative floating housing system is an exciting method that could advance to the future of living and possibly the impending built environment.

6.2. Engagement with Sustainability

The architecture will be designed with sustainable materials to aid in the mitigation of climate change and minimise its carbon footprint. The aim is to achieve energy efficient development by generating energy from renewable sources to compensate for the architecture's own energy demand. Its own solar energy source and water-based heat exchange system to allow self-sufficiency could be incorporated. The water could be integrated as a natural cooling mechanism for the building and energy could by derived from the water's movements. The idea here is to create a net zero energy building, or as close to net zero as possible.

According to Shahryar Habibi in her 'Floating Building Opportunities for Future Sustainable Development and Energy Efficiency Gains' (2015), to create a sustainable floating building, it needs to take key design points into consideration. But, there is not any prominent standard related to design it. For example, Queensland Development Code 2006 is the only reference that provides recommendations and design criteria for permanently moored floating buildings. According to the mentioned guideline, the main principles and concepts of environmental design process in floating buildings are as follows:

Access: A floating building must have adequate means of access to and from the shore appropriate to the likely number of people accommodated in the floating building.
Flotation system: A floating building must have a floatation system which maintains an acceptable level of stability appropriate to the use or likely use of the building and which will not be affected by minor impact; and is capable of withstanding the most adverse combination of loads it is likely to be exposed to.
Mooring piles: Mooring piles must be designed to adequately and safely resist all lateral loads resulting from the most adverse combination of loads which are likely to act on the flotation system and superstructure of the floating building and any vessel attached to the floating building or mooring piles.
Materials (generally): All materials used in a floating building or any structure associated with a floating building must be suitable for the conditions to which they are exposed.
Materials (fastenings): All fastenings used in a floating building or any structure associated with a floating building, must be appropriate for the conditions to which they are exposed taking into account their ability to be maintained or replaced if necessary.
Location: The location of a floating building must maintain an acceptable level of amenity between any other building and any proposed building.
Safety equipment: Floating building must have appropriate life safety devices suitable for marine use.
Firefighting equipment: Floating building must have access to appropriate levels firefighting equipment to safeguard against fire spread.
Minimum water depth: Water depth under a floating building must at all times be sufficient to prevent grounding of the building
(Habibi, 2015)

6.3. Other Considerations for Living on the Water

Sustainability and environmental considerations to consider include an integration of ethical perspectives, with regard to safety and codes, stability, air quality, environmental impact, cost, systems selection, and material use (Steidl, 2009). Construction on the water as a possible solution to the problem requires complex approaches. It includes risks regarding material stresses, environmental pollution and social safety, on the other hand it also offers opportunities in terms of the mobility of structures and the utilisation of alternative energy sources (Stopp, 2017, p9). Koen Olthuis and David Keuning suggest in their 'Float! Building on Water to Combat Urban Congestion and Climate Change' (2010), there is a gap where if people had the choice to live on land or water they would choose land. In order to "close the gap" floating houses will need to become equal of traditional houses on land, in every respect: in comfort, quality and price. Comfort means the stability and building physics must meet the same requirements imposed on houses on land by the building regulations. With the help of the right technology, listing and noticeable increases in building movement can be minimised to such an extent that they can measure up to the relevant requirements placed on (p49).

Chapter Seven: Design Phase One

7.1. Amphibious Design

What is Amphibious Architecture?

Amphibious Architecture refers to an alternative flood mitigation strategy that allows an otherwise ordinary structure to float on the surface of rising floodwater rather that succumb to inundation (English, 2016, p2). Generally, amphibious technologies consist of a foundation that is resting on the ground during normal conditions but it allows a building or infrastructure to rise as high as necessary when a flood occurs (Nilubon, 2016, p477). A key feature of this technology is that it allows to “work together” with the natural hydrological cycle as it tolerates fluctuating water levels, instead of attempting to stop or divert water (Nilubon, 2016, p478). Amphibious Architecture provides for a resilient and adaptive solution for sea level rise.

7.2. Amphibious Design Values

Performance Values

Amphibious houses can easily accommodate varying levels of floodwater (English, 2016, p3). The buoyancy system beneath the house displaces water to provide floatation as needed and a vertical guidance system allows the rising and falling house to return exactly the same place upon descent. It works based on Archimedes principle: The mass and the volume of the house is less than that of water and what determined its buoyancy (Adithya, 2021, p3).

Social Values

Amphibious systems are less disruptive to residents' everyday lives. Buildings with permanent static elevation remove their occupants from street level, requiring long flights of stairs or the expense of installing an elevator. This presents an ongoing inconvenience to residents as well as creating a significant impediment for the elderly and others with impaired mobility. Amphibious buildings, conversely, are only slightly elevated off the ground to accommodate buoyancy elements, thereby enabling a greater degree of accessibility (English, 2016, p3).

Economic Values

This amphibious system provides a cheaper solution to mitigate disasters and solves economic challenges (Nekooie, 2017, p1045). In new construction, an amphibious system represents an additional cost over conventional construction due to the need for a more elaborate foundation system. As a percentage of the total cost of new construction, this represents an additional 5-10%, but it provides a means to avoid the much greater costs associated with flood damage (English, 2016, p4).

7.3. Amphibious House Approach One: House in Fixed Dock

Existing Design

House in Normal Position

The waterproof concrete hull of the house rests inside a fixed dock

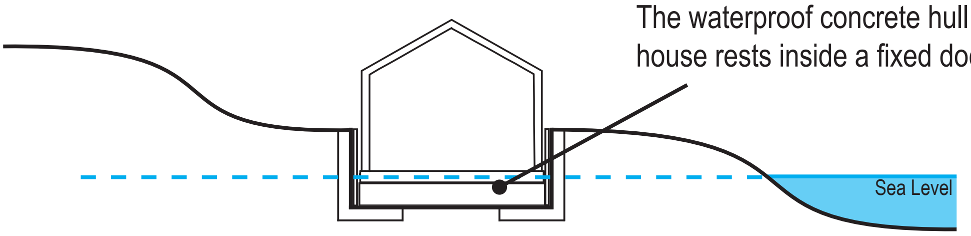


Figure 70.

House During Flood/ Rising Waters

Rising water pushes the house up to float in its dock

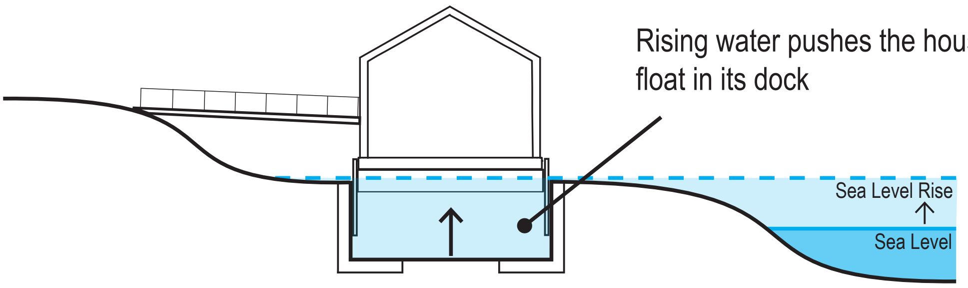


Figure 71.

House at Maximum Rise

The design only allows the building to rise just out of its dock

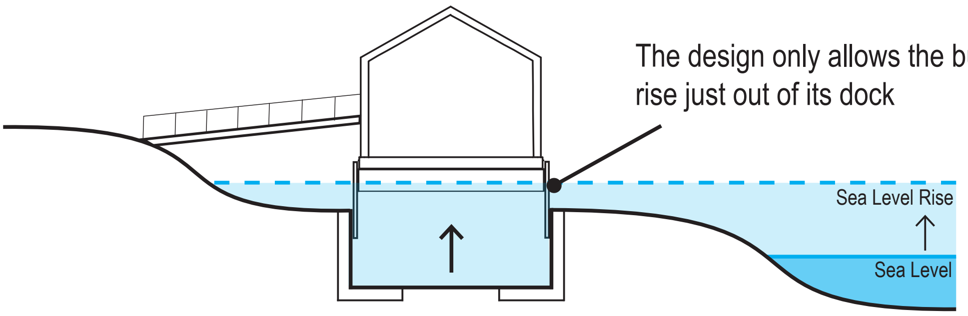


Figure 72.

The first existing amphibious approach is designing the house to be situated inside of a fixed dock and as the water rises, the dock fills with water, pushing the building up to float out of its dock. This approach is often used as a flood mitigation strategy and therefore is only designed to allow the dwelling to rise to a certain height. This design approach may not be the most appropriate for overcoming sea level rise, as the dwelling can only rise to a certain point and from there would act as a traditional land-based dwelling that would succumb to inundation.

Strengths:

- The dock allows for a stable and comfortable living situation
- Adaptive and resilient for the first few meters of sea level rise

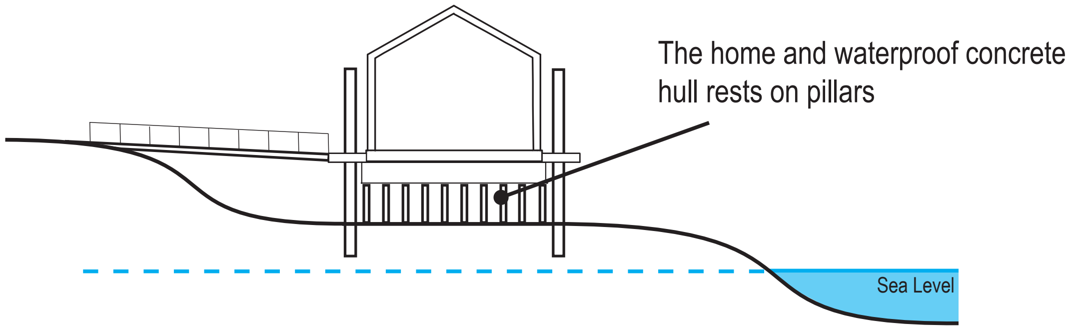
Weaknesses:

- The water would often need to be pumped out of the dock to allow the dwelling back to its normal resting position
- This approach is more appropriate for flooding, but not the constant acceleration of sea level rise, as the dwelling can only rise a certain amount.

7.4. Amphibious House Approach Two: House Guided by Mooring Posts

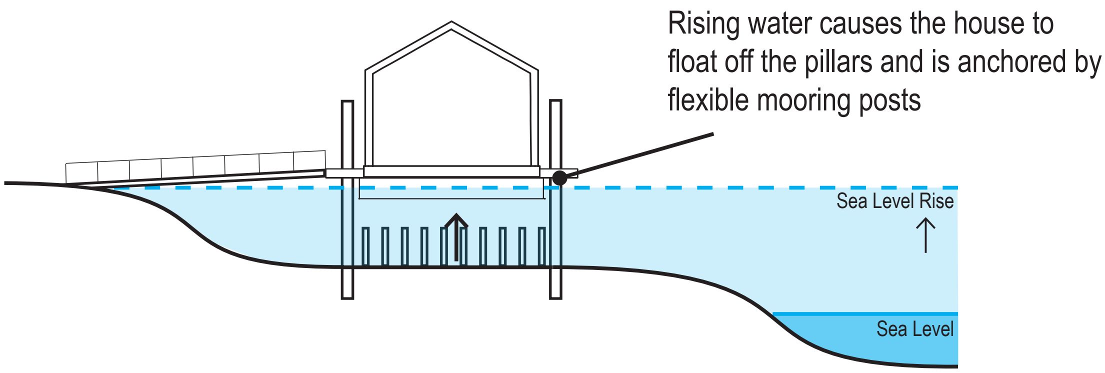
Existing Design

House in Normal Position



House During Flood/ Rising Waters

Figure 73.



House at Maximum Rise

Figure 74.

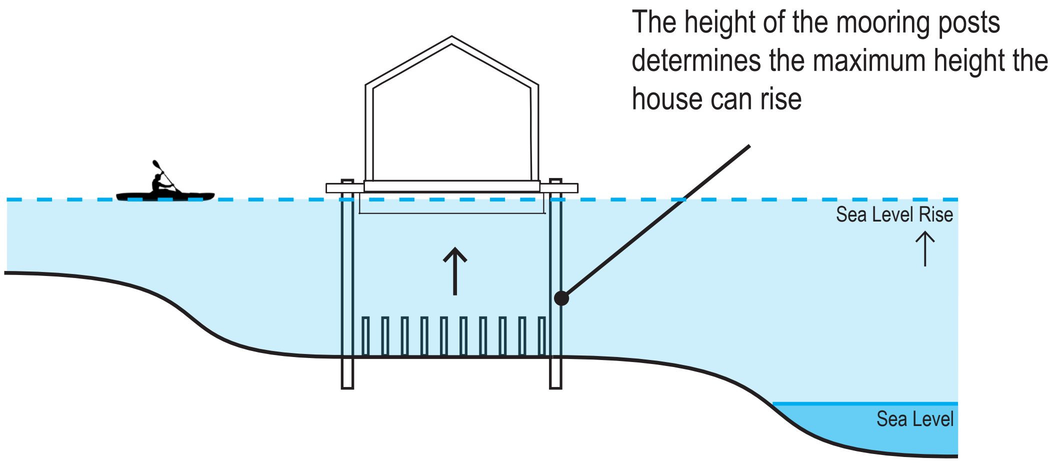


Figure 75.

The second existing amphibious approach is to design the house to rest on pillars, and as the water rises, the house rises with the water and is anchored in place with the use of flexible mooring posts. The house is situated on pillars to ensure the dwelling does not settle into the ground. This approach is an appropriate response for addressing flooding, rising and falling of the tide, and the constant acceleration of sea level rise. Because this approach requires the house to eventually become a completely floating dwelling, this may not be the most stable solution. Because the Wellington context provides for very windy weather conditions a completely floating dwelling may not be best solution.

Strengths:

- Is adaptive and resilient as it addresses sea level rise, flooding and tidal rising and falling very well.
- The technology is visible to the public and could provide for more understanding and awareness of the issues of sea level rise

Weaknesses:

- May not provide for a comfortable living situation due to the building eventually becoming a completely floating dwelling
- The maximum height the dwelling can rise is determined by the height of the mooring posts
- Could potentially be very loud, with the rocking of the waves causing the posts to bang against the guidance sleeves

7.5. Amphibious House Approach Three: House Fixed to Mobile Posts

Innovative, Own Design

House in Normal Position

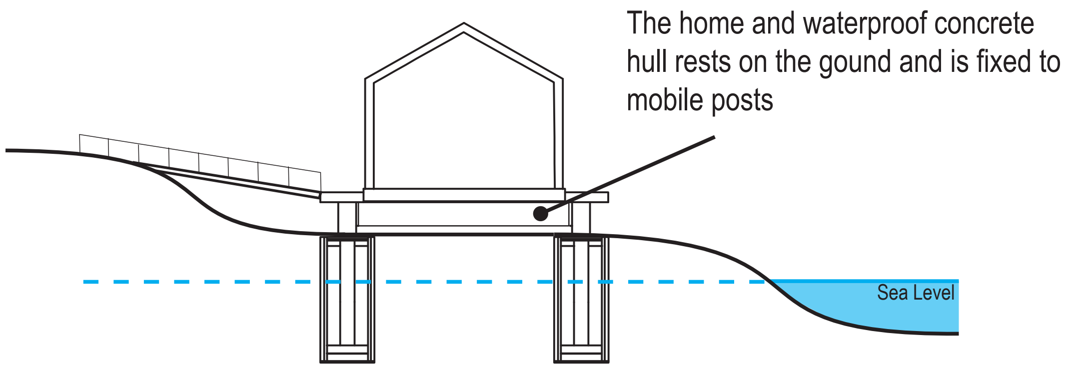


Figure 76.

House During Flood/ Rising Waters

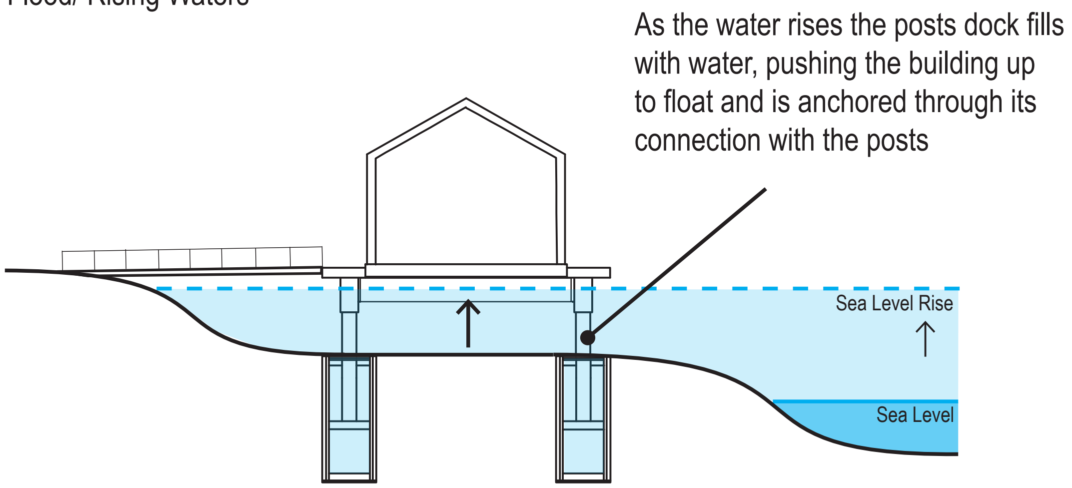


Figure 77.

House at Maximum Rise

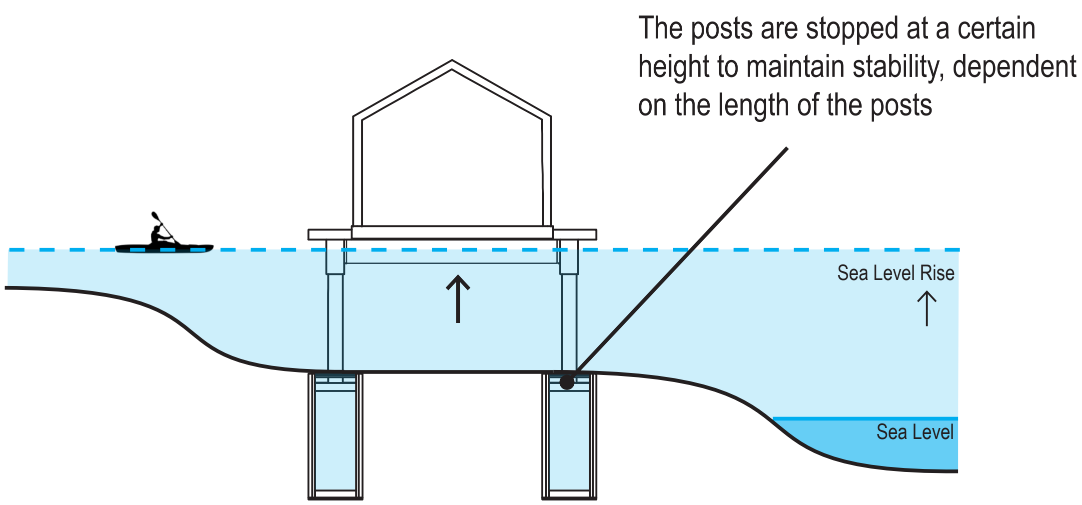


Figure 78.

The third amphibious approach is an innovative design based off the principals that work well in the other two existing designs. As the water begins to rise the dwelling rises on the surface of the rising floodwater. To maintain stability and keep the building anchored, the floating base is fixed to posts that are positioned far into the ground. The posts would hold the weight of the dwelling to ensure it does not settle into the ground. These posts are situated inside of fixed docks below ground level (similar to that of the first approach) to provide vertical guidance and resist lateral movement. Dependent on the posts length, the home rises to a maximum height.

Strengths:

- It is adaptive and resilient as it addresses sea level rise, flooding and tidal rising and falling very well.
- Maintains adequate stability through its connection with the moving posts.

Weaknesses:

- The maximum height the dwelling rises depends on the height of the posts.
- The house could become less and less stable the higher the house rises. This could result in torsion and bending acting on the posts.

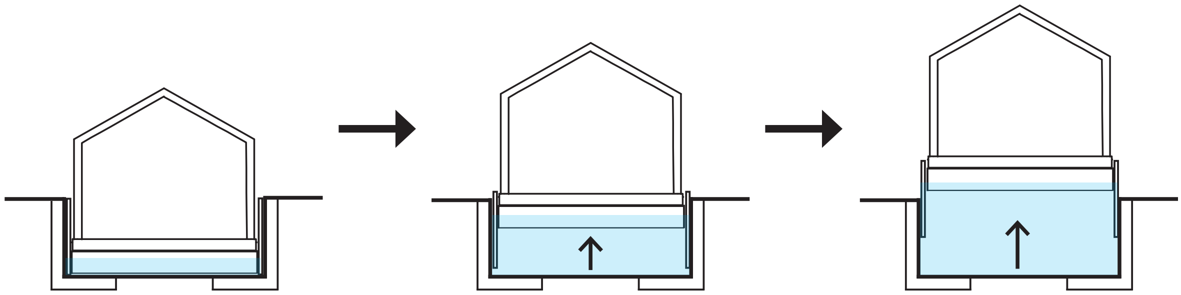
Design Critique One: 3 month progress review - 12 May 2021

Own Critique Based on Review Comments:

At this stage, a clear and interesting research background is evident that deals with a clear real life problem that is often forgotten about. Ultilising this idea of amphibious technologies is the right design choice and should be further explored throughout the design process. Some areas require more consideration and refinement. Considering the Iwi more for the Shelly Bay site could be further investigated, for example, how can amphibious techologies allow the Iwi to reclaim some of the space (water) through this design approach? Other aspects to refine include; what is the impact of water rise on everyday life? How can these dwellings provide adequate means of access? How will the services and plumbing work? How can public/ private spaces be made evident in the design?

7.6. Physical Modelling Amphibious Approaches

Amphibious House Approach One: House In Fixed Dock



House in fixed dock model

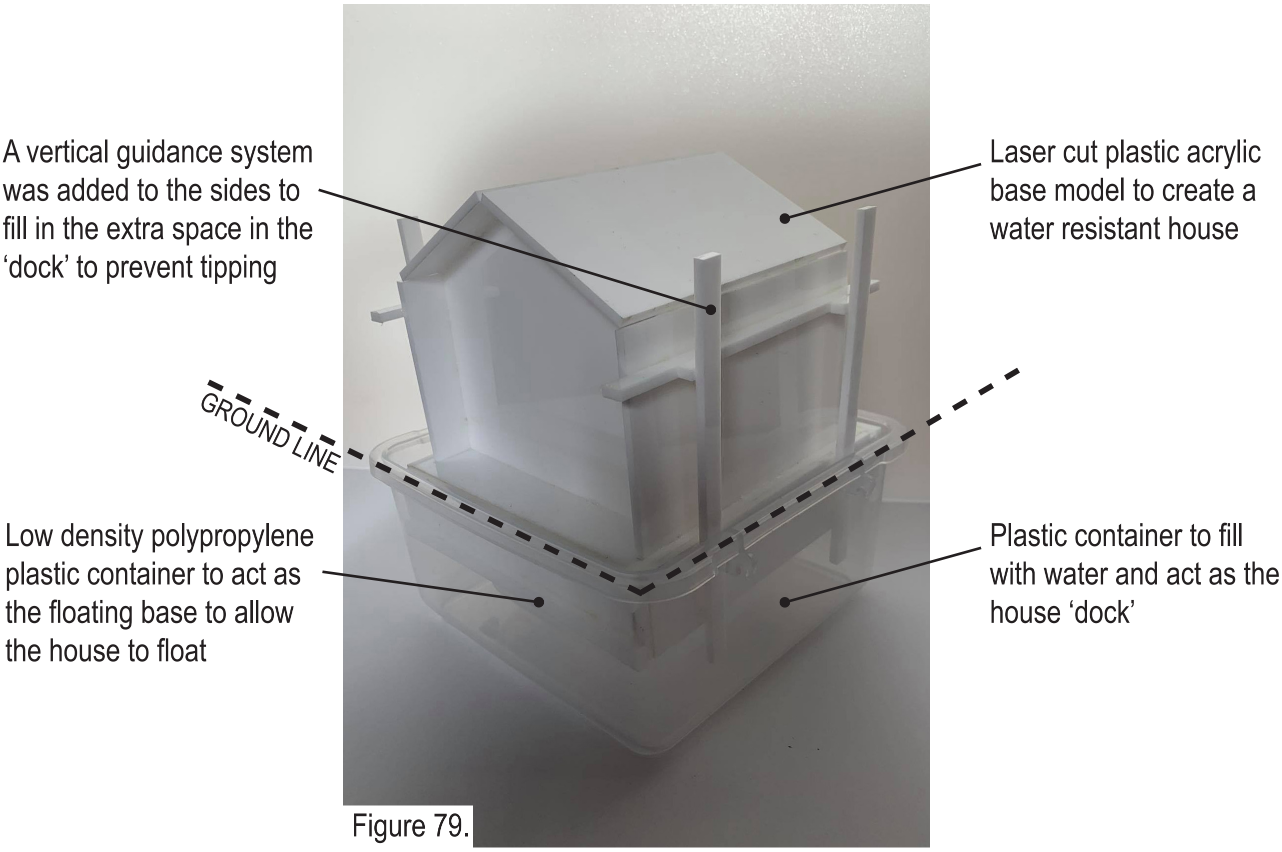


Figure 79.

Testing model with water rise

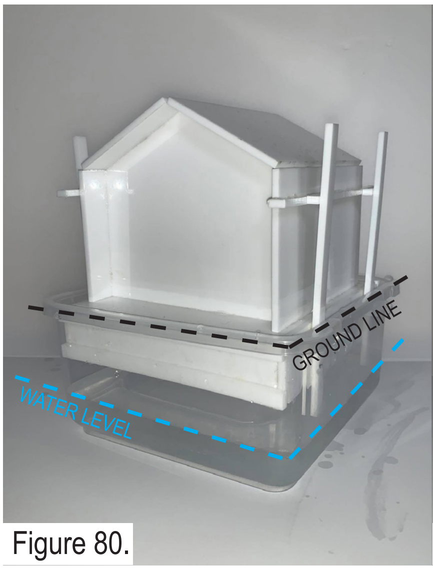


Figure 80.

Figure 81.

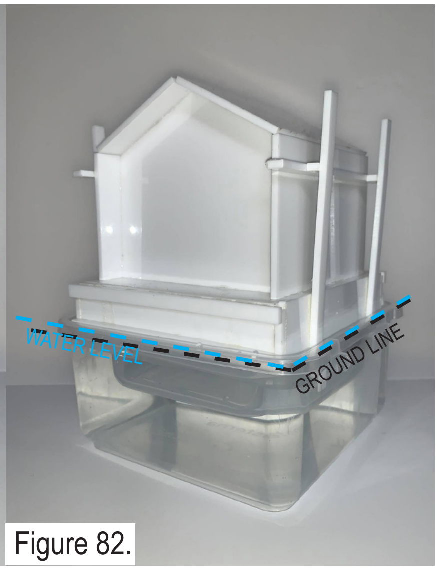


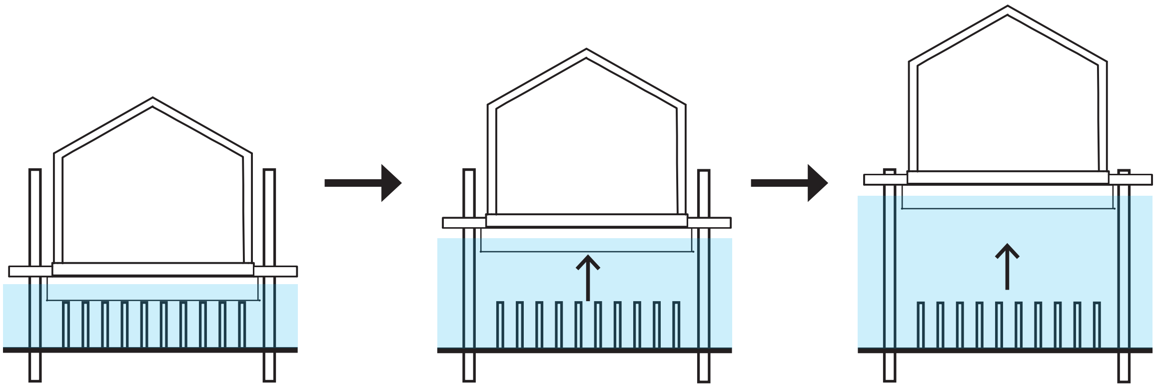
Figure 82.

Summary and Reflection of Testing Model One

Whilst modelling this first amphibious approach, it was discovered that the container that was acting as the ‘dock’ was slightly larger than the widest parts of the floating base and as the model began to float in the water, it would slightly tilt as a result. Therefore, a vertical guidance system was added to the sides to fill in the extra space and prevent the model from tipping, which worked effectively.

Although this design is an effective water rise mitigation strategy, it has limitations that would not work effectively for addressing the constant acceleration of sea level rise. This design addresses rising and falling waters such as floods and tides very well, but because it is only designed to float just out of its dock, it would not be suitable for sea level rise.

Amphibious House Approach Two: House Guided by Mooring Posts



House on pillars with mooring posts model

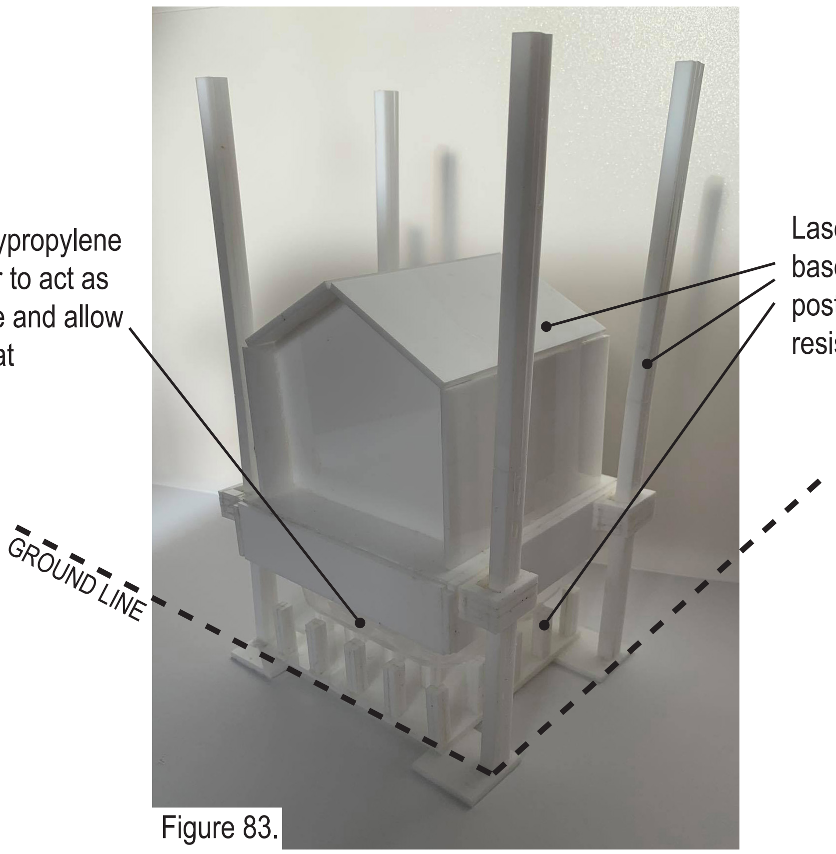


Figure 83.

Testing model with water rise

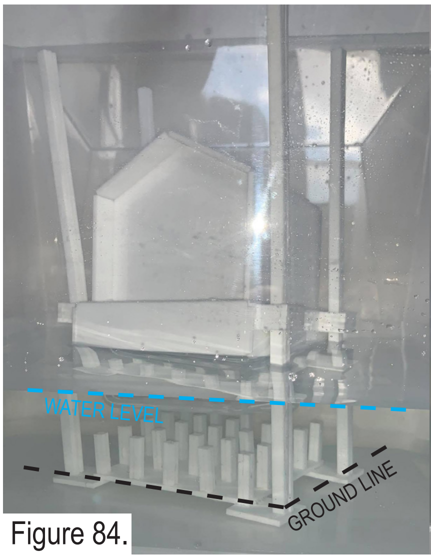


Figure 84.

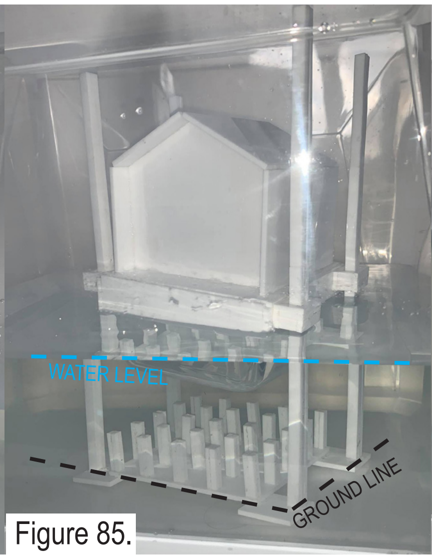


Figure 85.

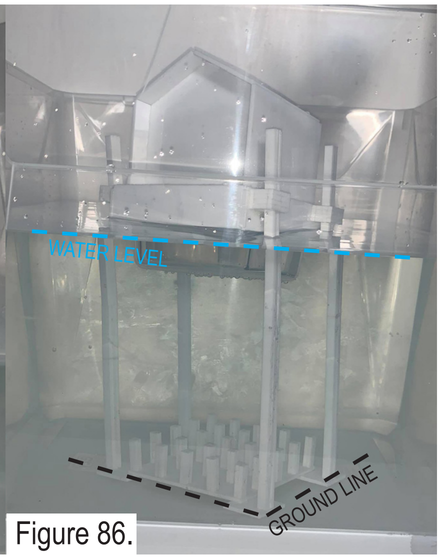
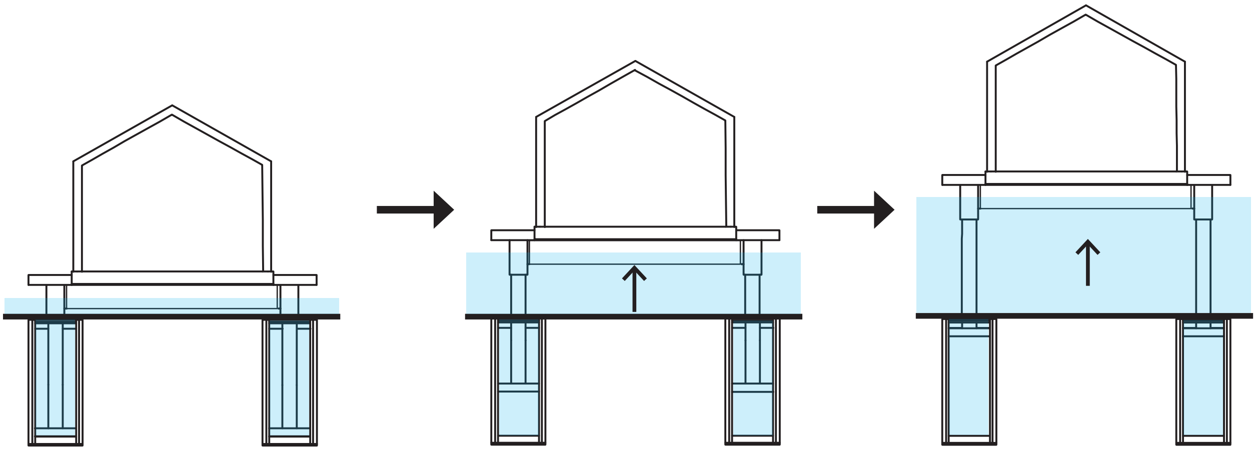


Figure 86.

Summary and Reflection of Testing Model Two

The second design did not provide for a stable ascend in the water as the house began to slightly tilt, as can be seen in figures 84, 85 and 86. The extended guiding system attached to the floating base that guides the house vertically along the mooring posts, was made slightly larger to allow for more room as the posts would previously get stuck upon ascend due to the tight fit. This extra room may have been the result of the house tilting due to the less stability provided from the posts.

Amphibious House Approach Three: House Fixed to Mobile Posts



House fixed to mobile posts model

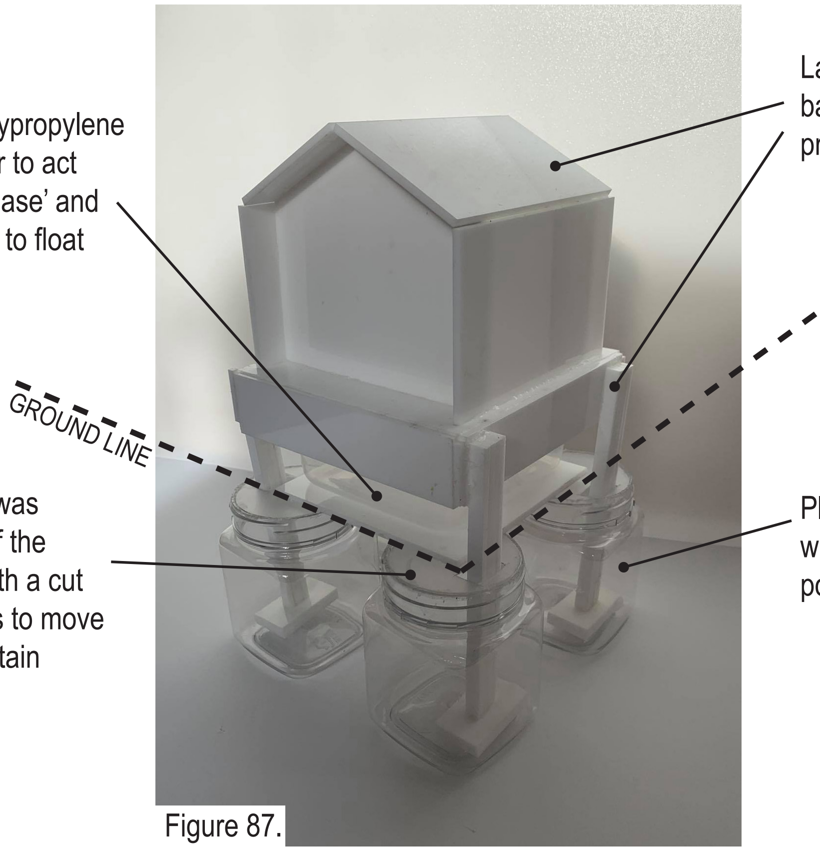


Figure 87.

Testing model with water rise

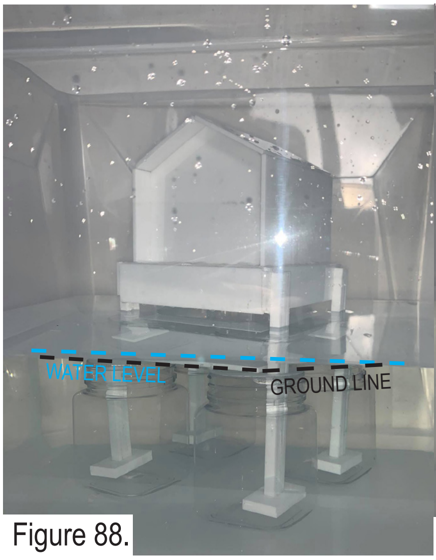


Figure 88.

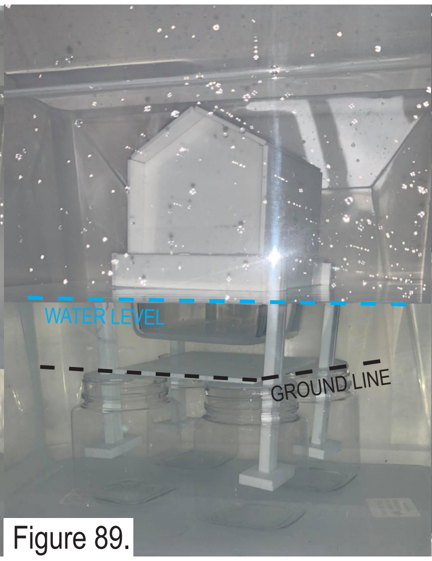


Figure 89.

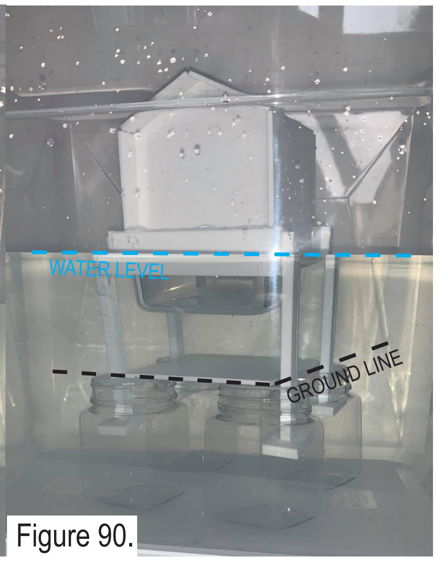


Figure 90.

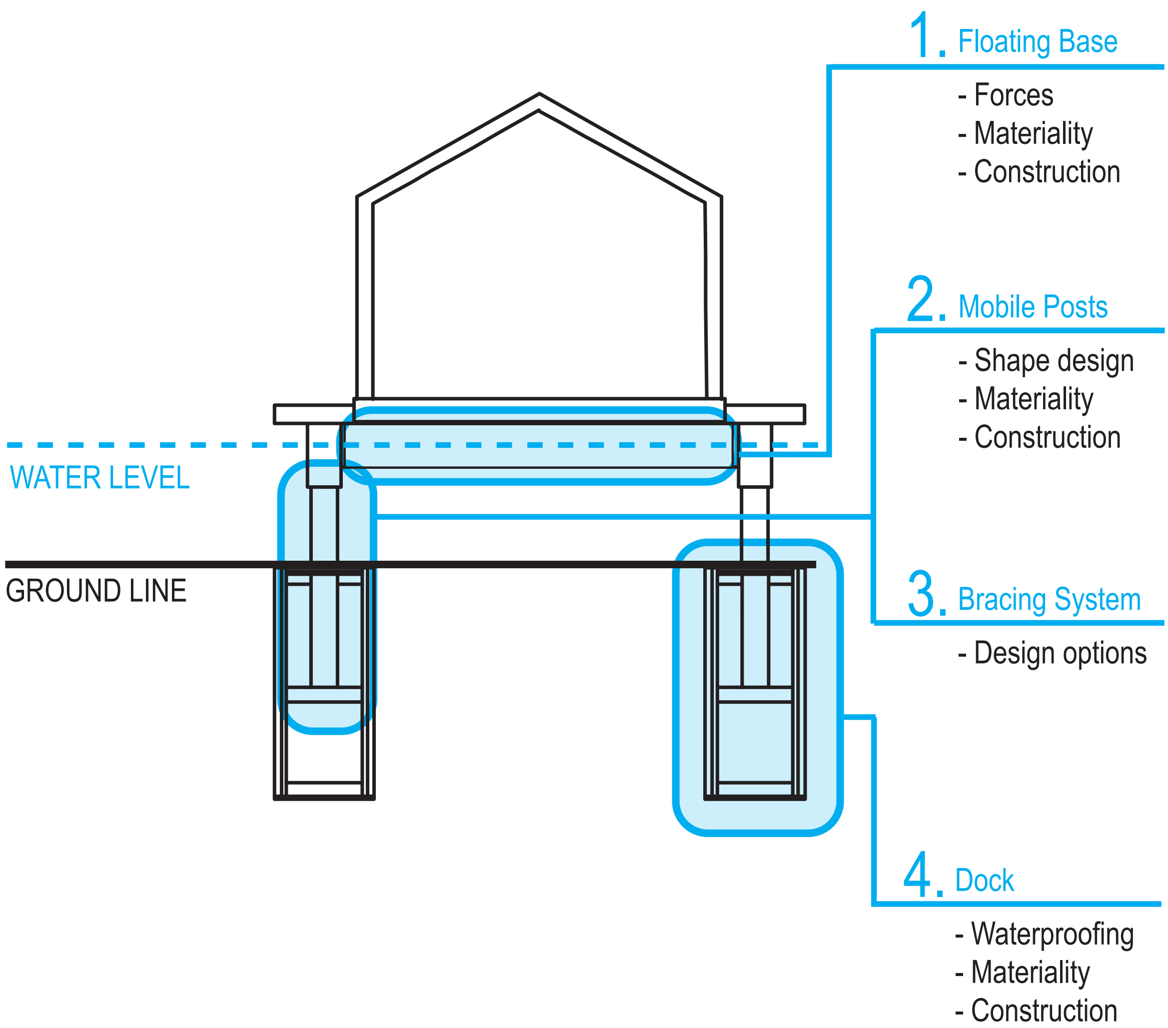
Summary and Reflection of Testing Model Three

With this third design, there were no issues that took place whilst testing the model in rising waters. The model worked exactly the way the diagrams portrayed (figures 88, 89 and 90). As the model began to float, it carried the weight of the house and the posts vertically very well. Due to the fact that the posts are permanently fixed to its anchoring system, this provides for a stable ascend in the water.

This model addresses the issue of rising and falling and waters effectively. This model was the most successful of the three and will be developed further.

7.7. Amphibious House Technology Development

Areas of the amphibious technology to be further developed include the floating base in which carries all of the loads, the construction of the mobile posts that provide the vertical guidance during the rising and falling of the water, a bracing system to resist lateral loads and the docks in which the mobile posts move through.



1. Floating Base Design

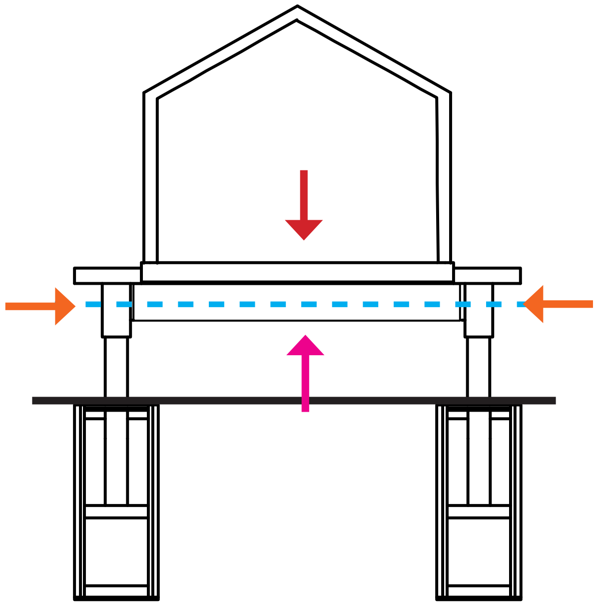
The forces that act on the floating base have been identified. These include the downward forces, upward forces and lateral forces.

Determining the forces acting on the Floating Base Hull

Downward Forces (RED):
The dead and live loads acting on the structure and also the weight of the mobile posts

Upward Forces (PINK):
The buoyant forces created by water pressure beneath the floating base.

Lateral Forces (ORANGE):
The forces from the water surrounding the base, such as currents and wave movement

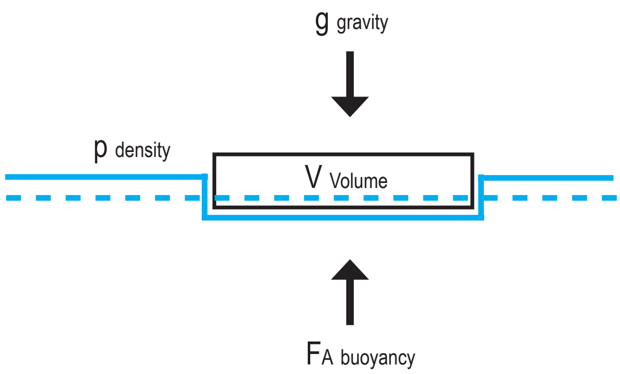


Floating Base follows Archimedes Buoyancy Principle

Archimedes Principle:

$F_A = pVg$

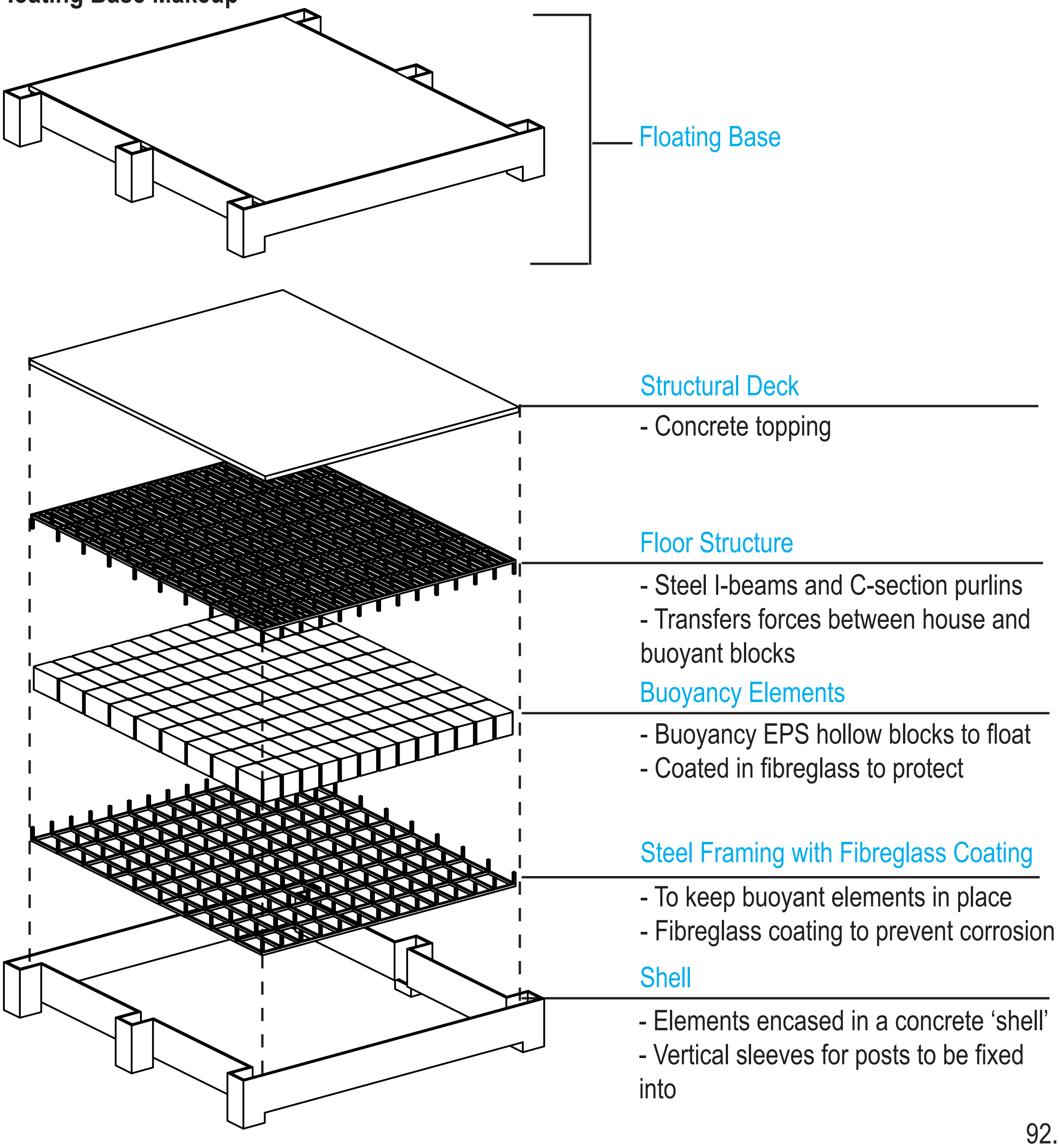
F_A = buoyancy V = volume
p = density g = gravity



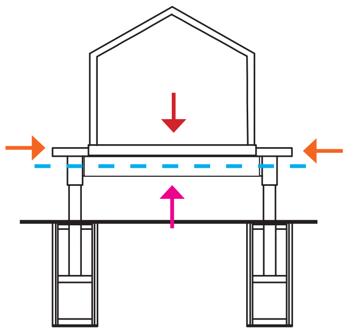
1. Floating Base Design

The floating base design needs to be strong enough to carry all of the downward loads acting on the structure, but also be designed with lightweight materials to remain afloat. The construction makeup and materials are designed to enhance the floatation and also provide a solid, stable foundation base. The general makeup of existing floating foundations consist of buoyant EPS blocks that cause it to float. These are encased in steel structures. These steel structures allow the forces acting on the base to be evenly distributed and transferred along the buoyancy blocks to ensure equilibrium is met. These steel structures would need fibreglass coating to prevent corrosion.

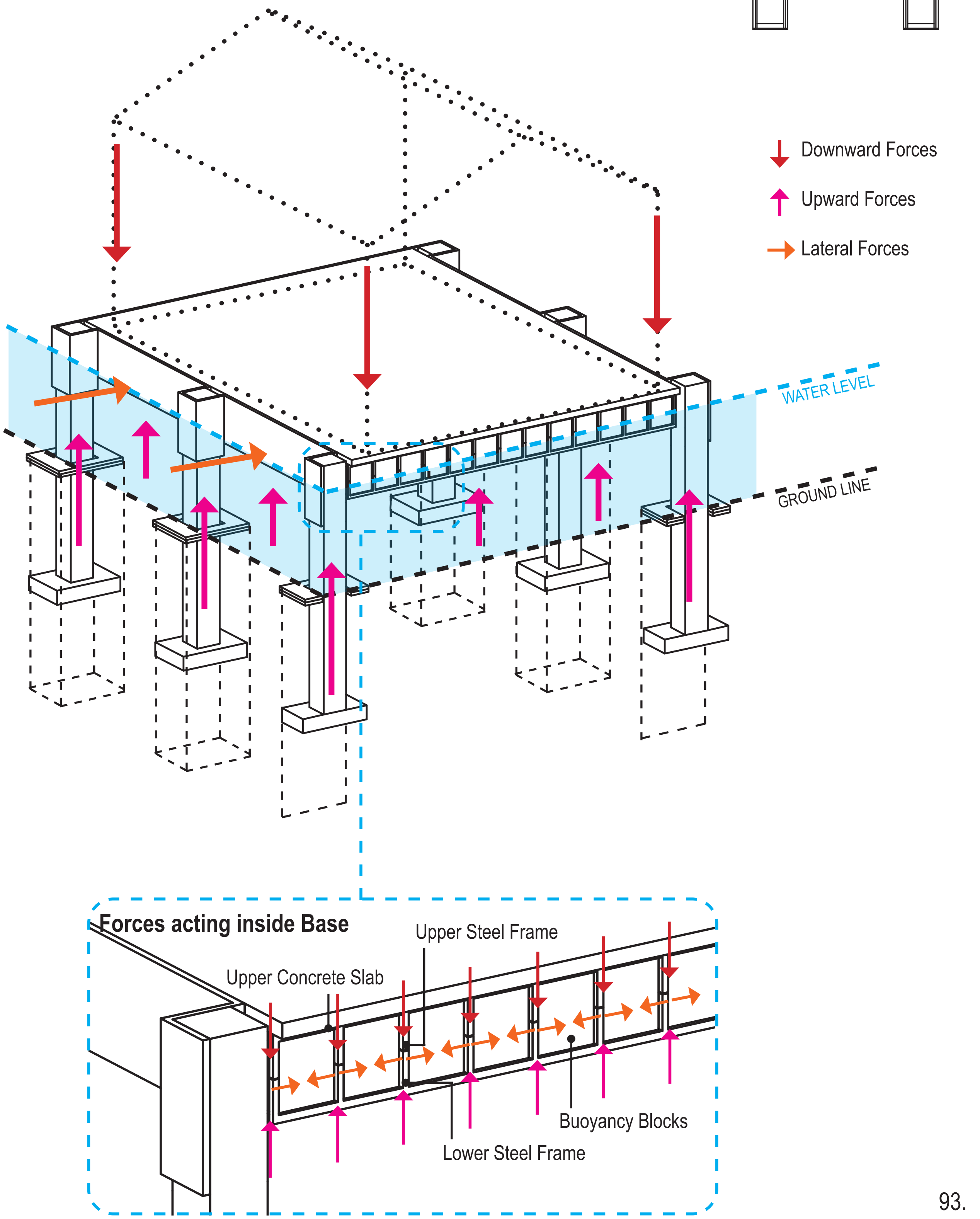
Floating Base Makeup



1. Floating Base Design

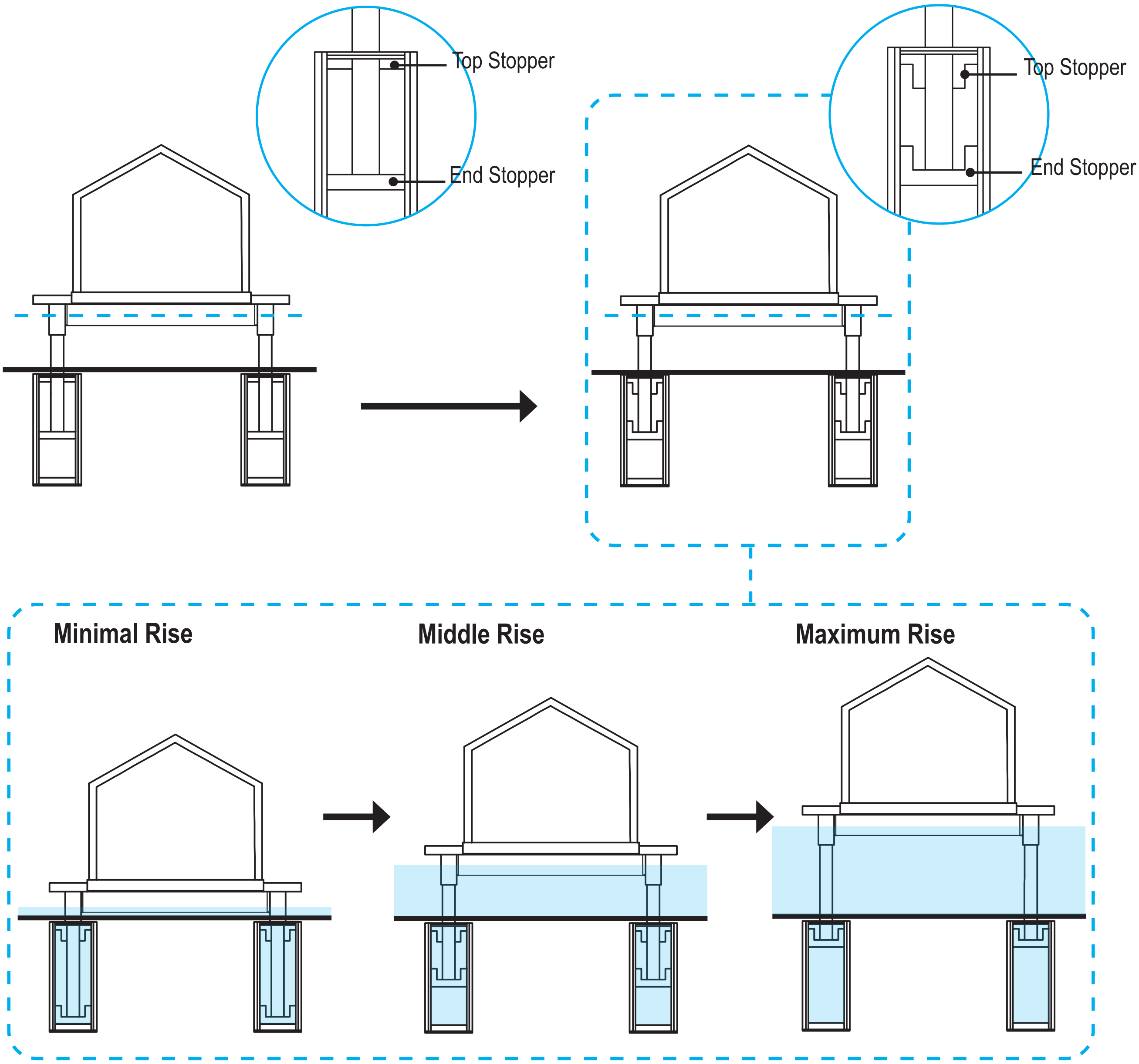


Forces acting on Floating Base



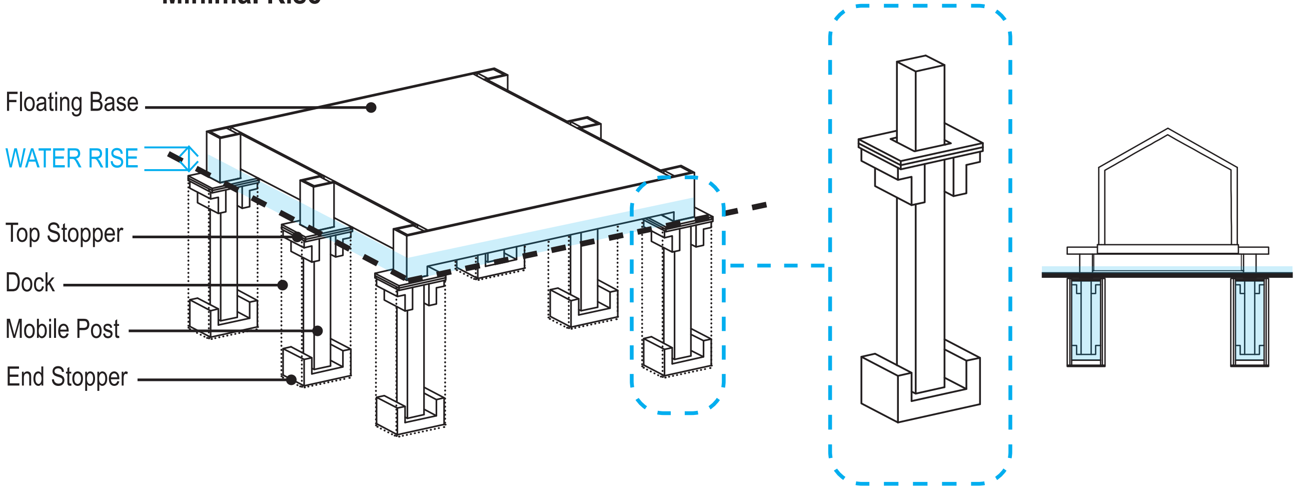
2. Mobile Posts Design

The mobile posts are designed to allow the structure to move vertically with the rise and fall with the water, but also acts as an anchoring system to ensure any lateral movements are resisted. The posts are made of lightweight timber to provide rigidness. The ‘end stopper’ located at the bottom of the post was altered to have two extruded ends to provide more stability when moving through the dock. The ‘top stoppers’ shape was also modified to fit with this new shape and allow the ‘end stopper’ to fit perfectly once the maximum height is reached. The posts hold the weight of the entire strucutre to ensure the dwelling does not settle into the ground whilst in its resting position. Therefore the posts transition from being structurally load bearing to a structural post that resists lateral forces.

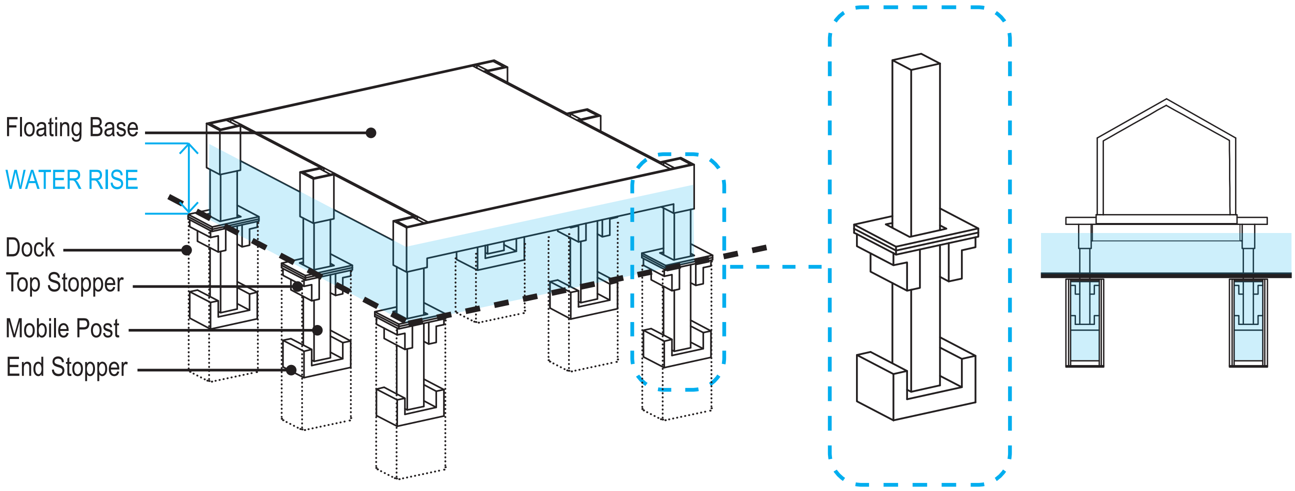


2. Mobile Posts Design

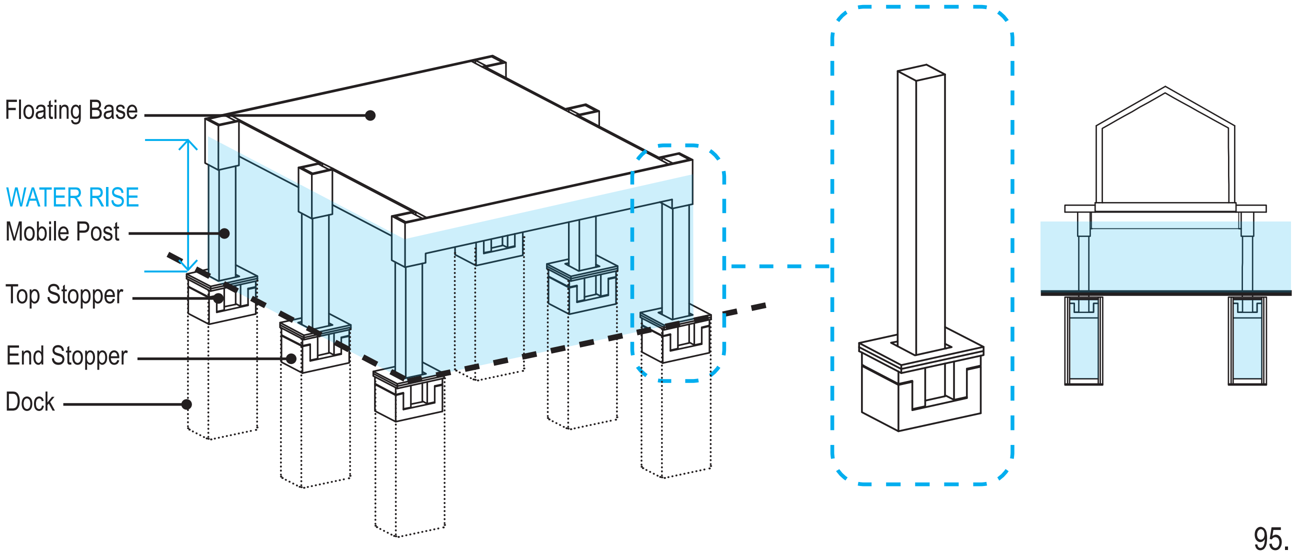
Minimal Rise



Middle Rise



Maximum Rise

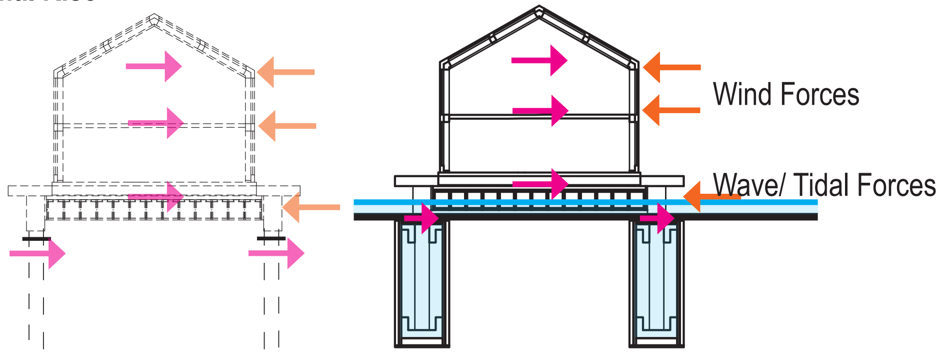


3. Bracing System

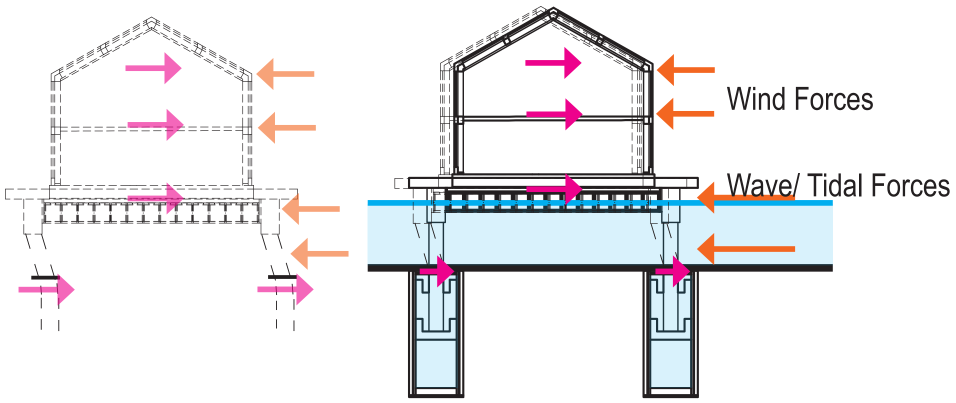
The higher the structure rises with the water, the more force is acting on the posts, therefore the more bending and torsion would occur on the posts. A bracing solution would need to be designed in order to apply rigidness between the elements to reduce this.

Lateral Forces Acting on Entire Structure

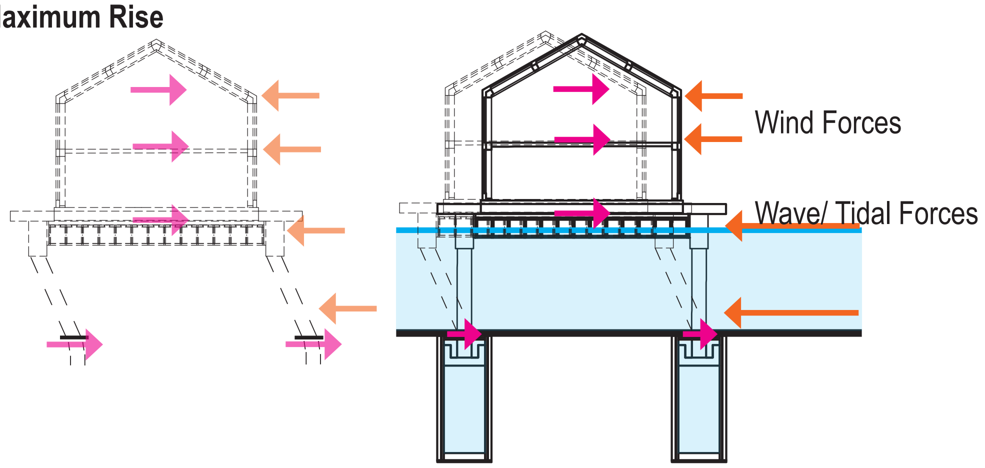
Minimal Rise



Middle Rise



Maximum Rise

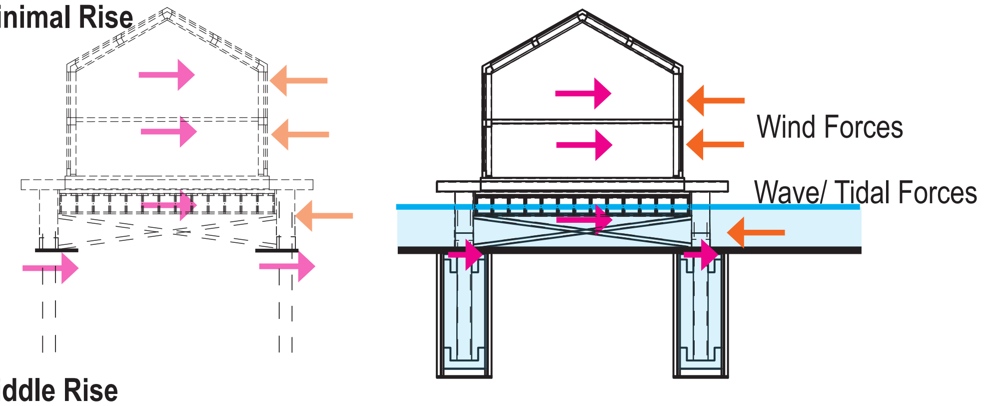


3. Bracing System

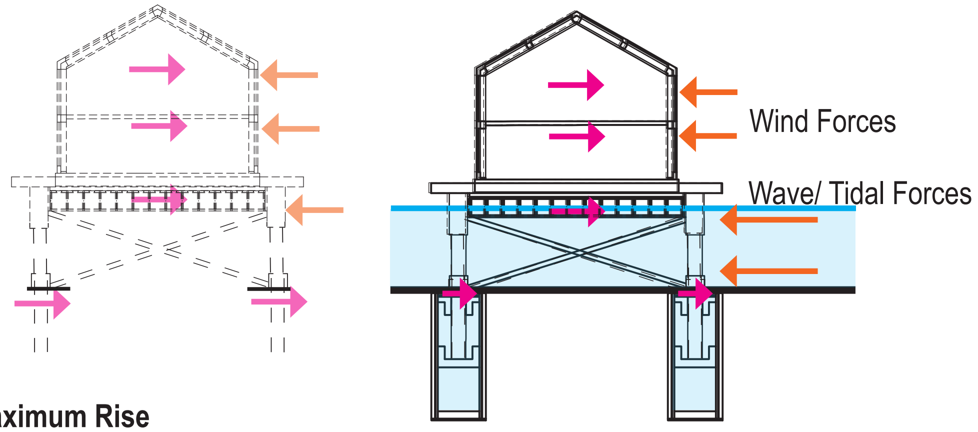
A cross bracing system would be the most efficient to solve this issue. Working with how the structure rises and falls with the water, a cross bracing system would need to be designed using pin joint connections to allow the bracing to extend, through a scissoring effect, with the structure. The bracing would need to be fixed to the bottom of the floating base and to sleeves that the posts move through. The bracing system would need to be situated around the perimeter of the base to reduce torsion.

Lateral Forces Bracing Solution

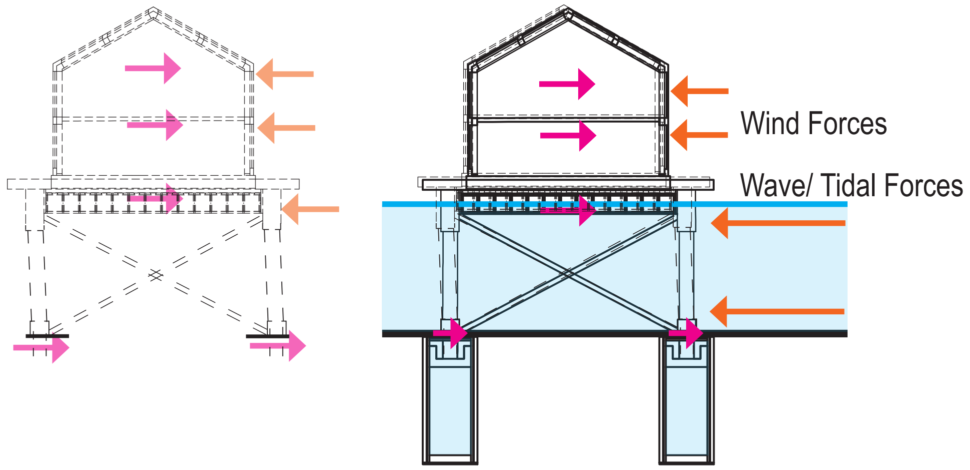
Minimal Rise



Middle Rise



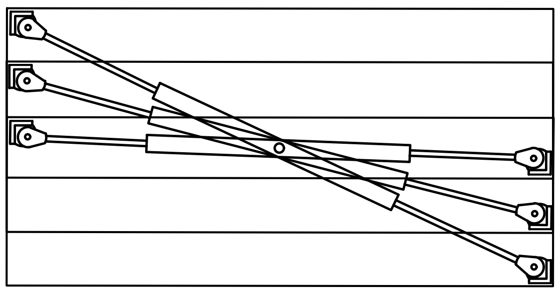
Maximum Rise



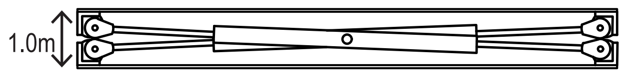
3. Bracing System

Two bracing systems were explored; the first being a more engineered solution that would require pin joint connections in all four corners and in order to work with the changing length between the ends as the structure rises, the bracing elements would need to extend using either an internal spring system or a mechanical fixing system to lock the structure in place as it extends and retracts. The second option was to look at more of an architectural solution that includes these arc guiding systems situated in the four corners. These would allow the bracing ends to move along the arcs as the structure rises and falls and therefore accommodates for that changing length difference. The bracing system is placed around the perimeter of the structure to minimise torsion and bending on all the posts. The architectural response is more appropriate to use as it requires less maintenance and is not as complex as the engineered response.

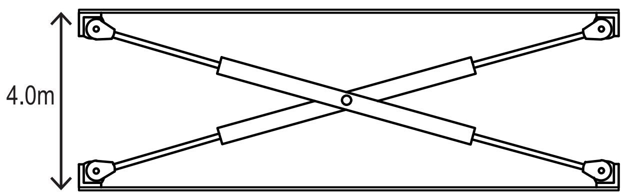
Engineering/ mechanical system



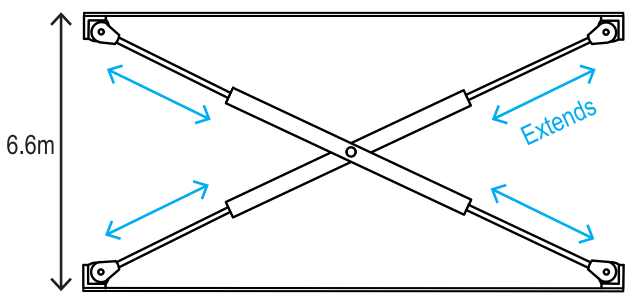
Minimal Rise



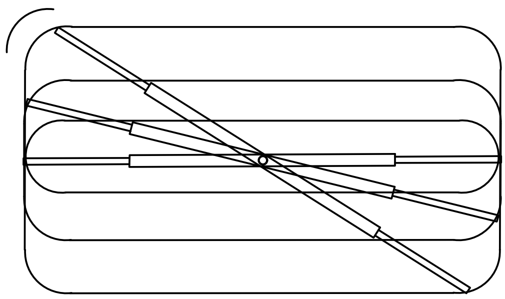
Middle Rise



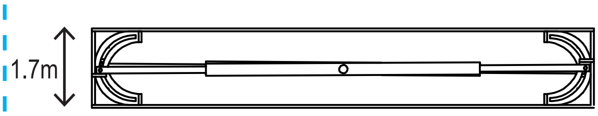
Maximum Rise



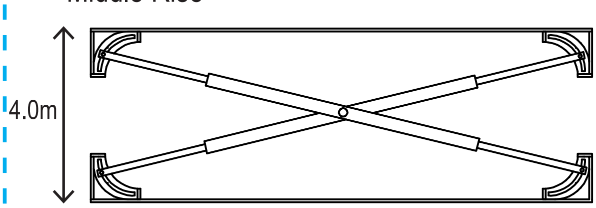
Architectural system



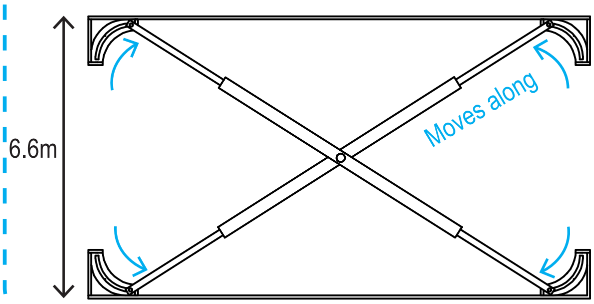
Minimal Rise



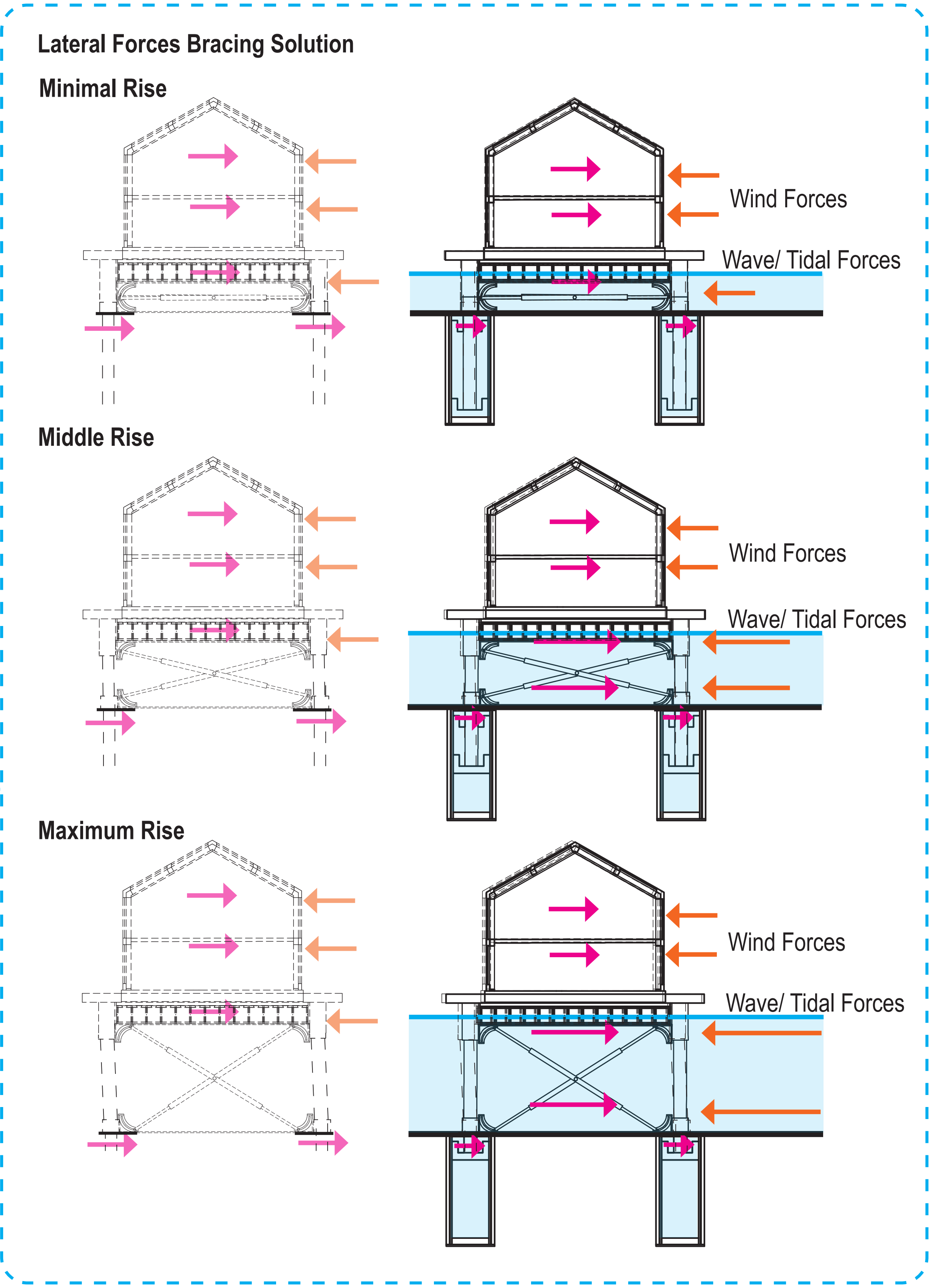
Middle Rise



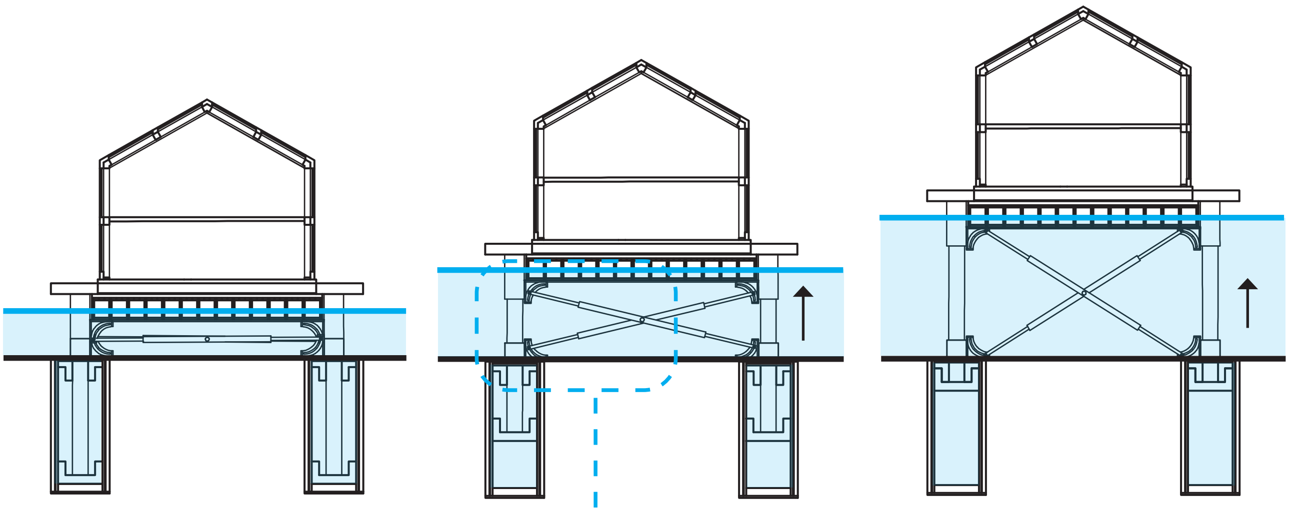
Maximum Rise

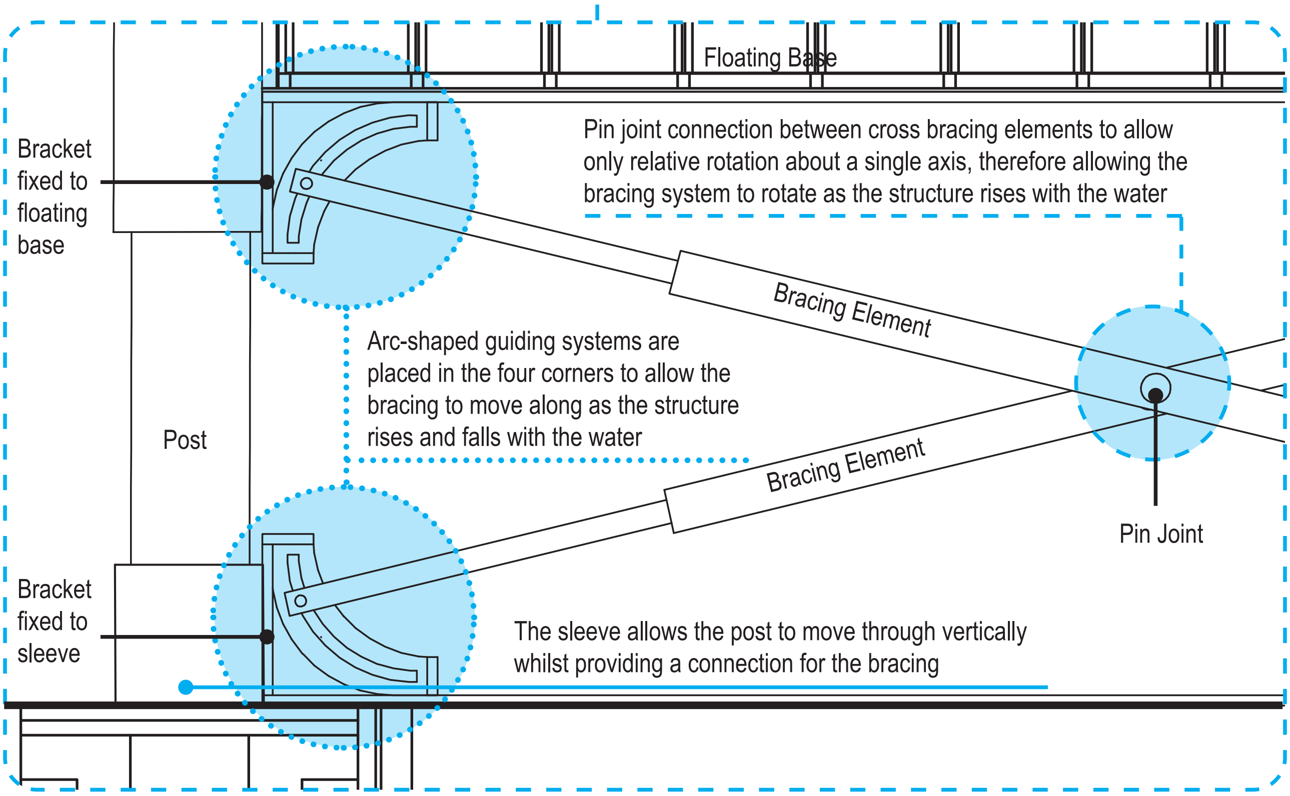


3. Bracing System

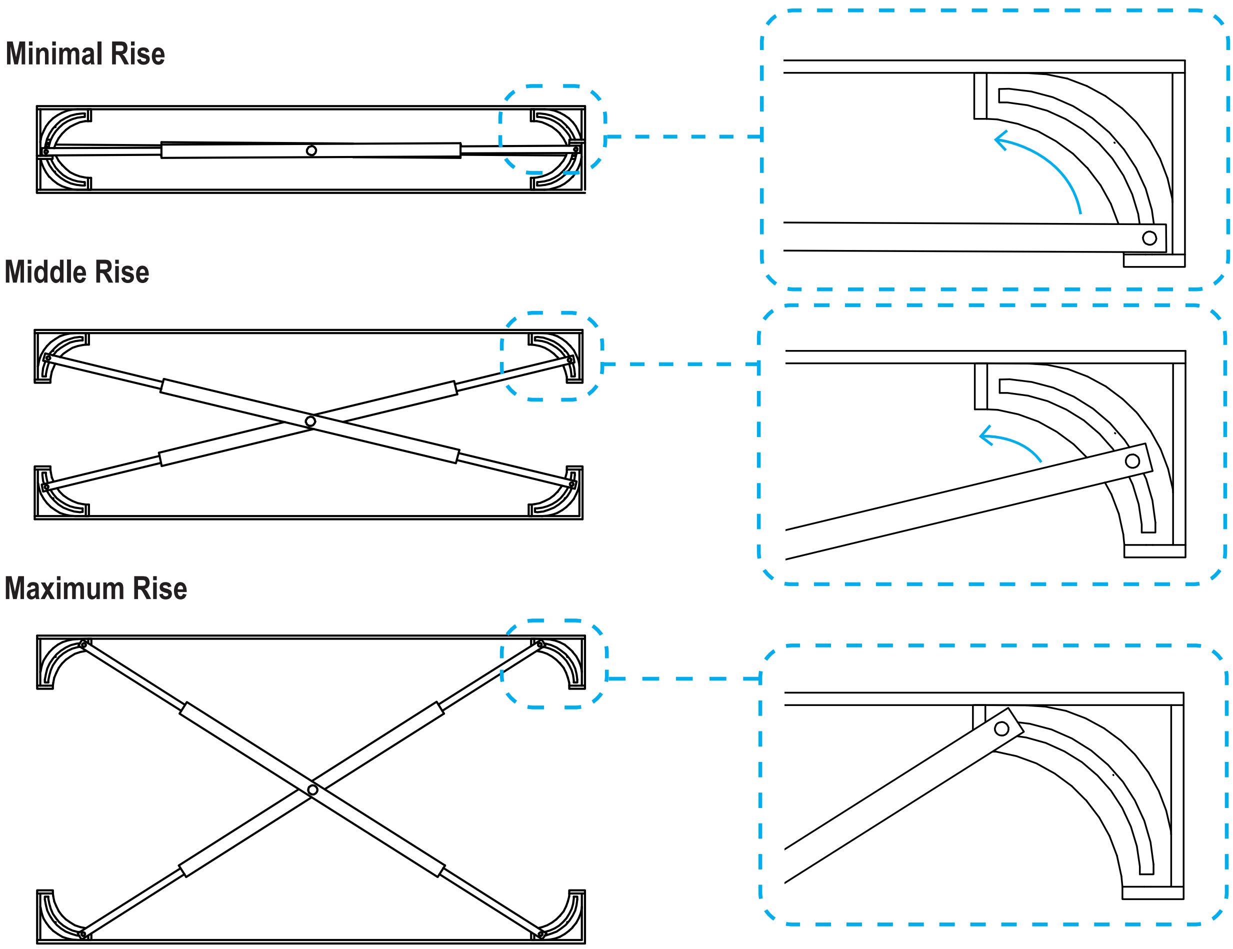


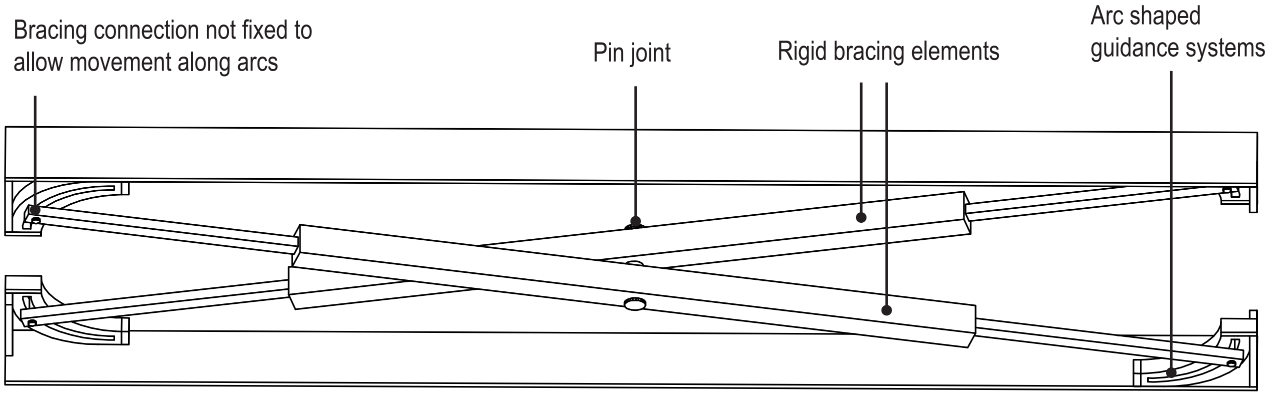
3. Bracing System





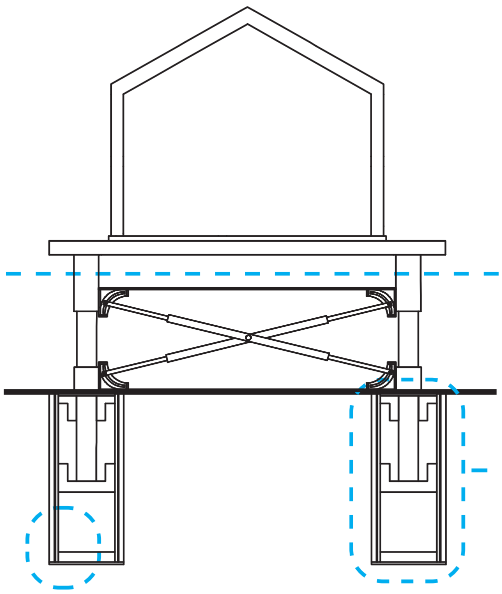
3. Bracing System



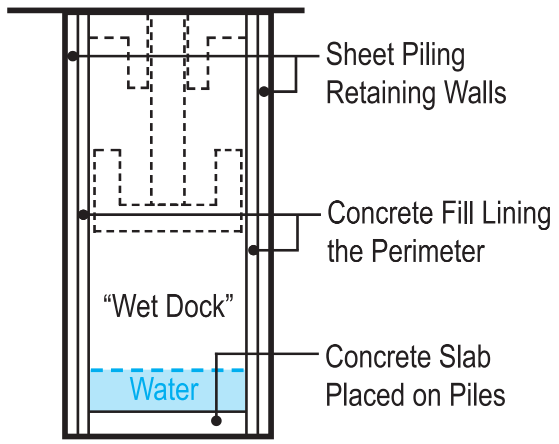


4. Dock Design

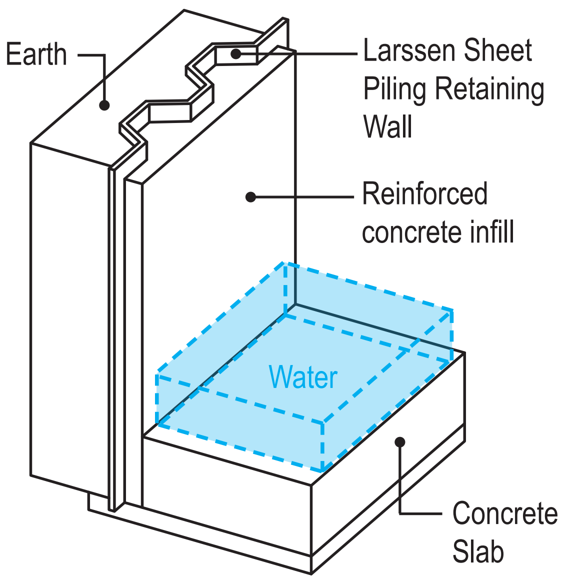
The docks provide the stability and vertical guidance for the mobile posts to be situated in and move through as the water rises. The docks fill with water. During normal conditions the posts rest on the bottom of the dock holding the weight of the entire structure. This is to ensure the structure above ground level does not settle into the land whilst in resting position.



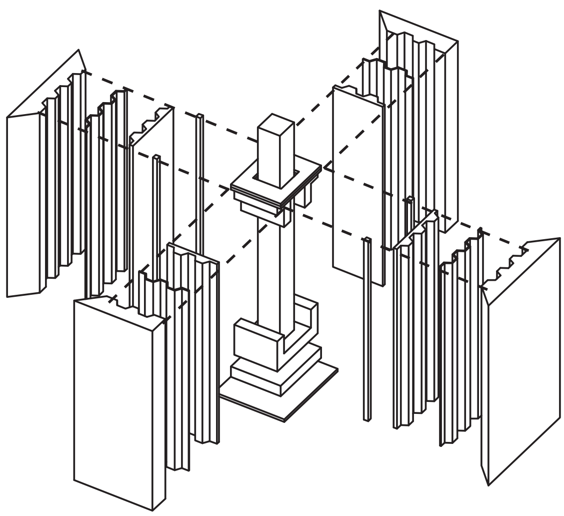
Dock Section



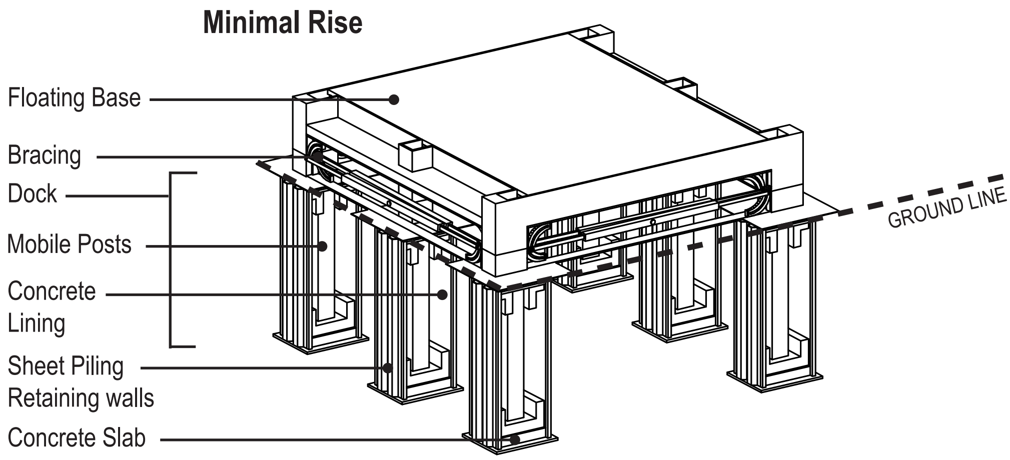
Dock 3D Cutaway Section

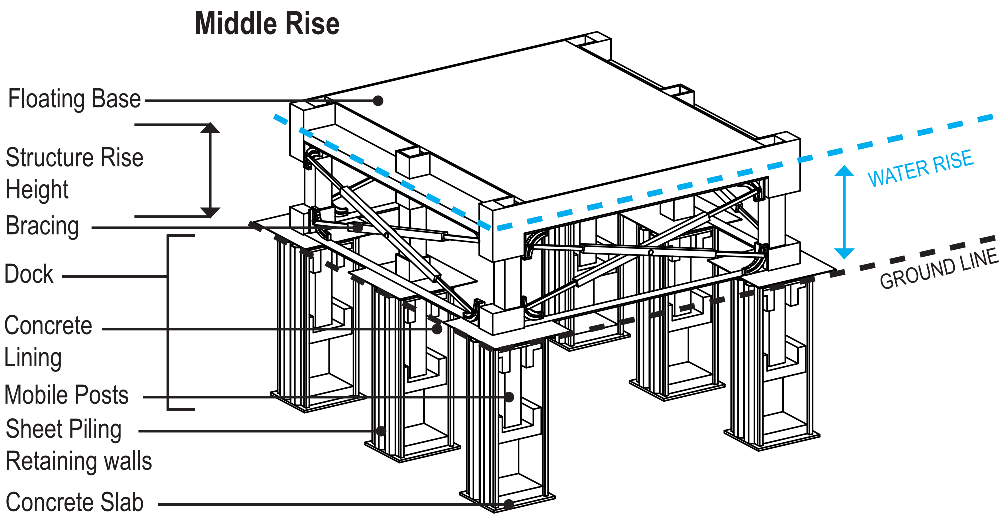


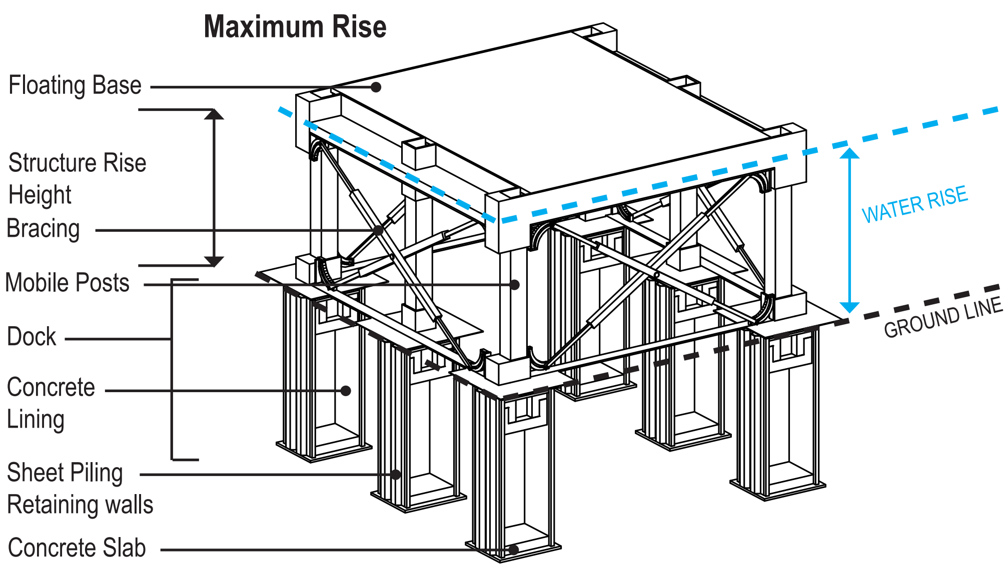
Dock Exploded View



4. Dock Design







Chapter Eight: Design Phase Two

8.1. Architectural Design Development

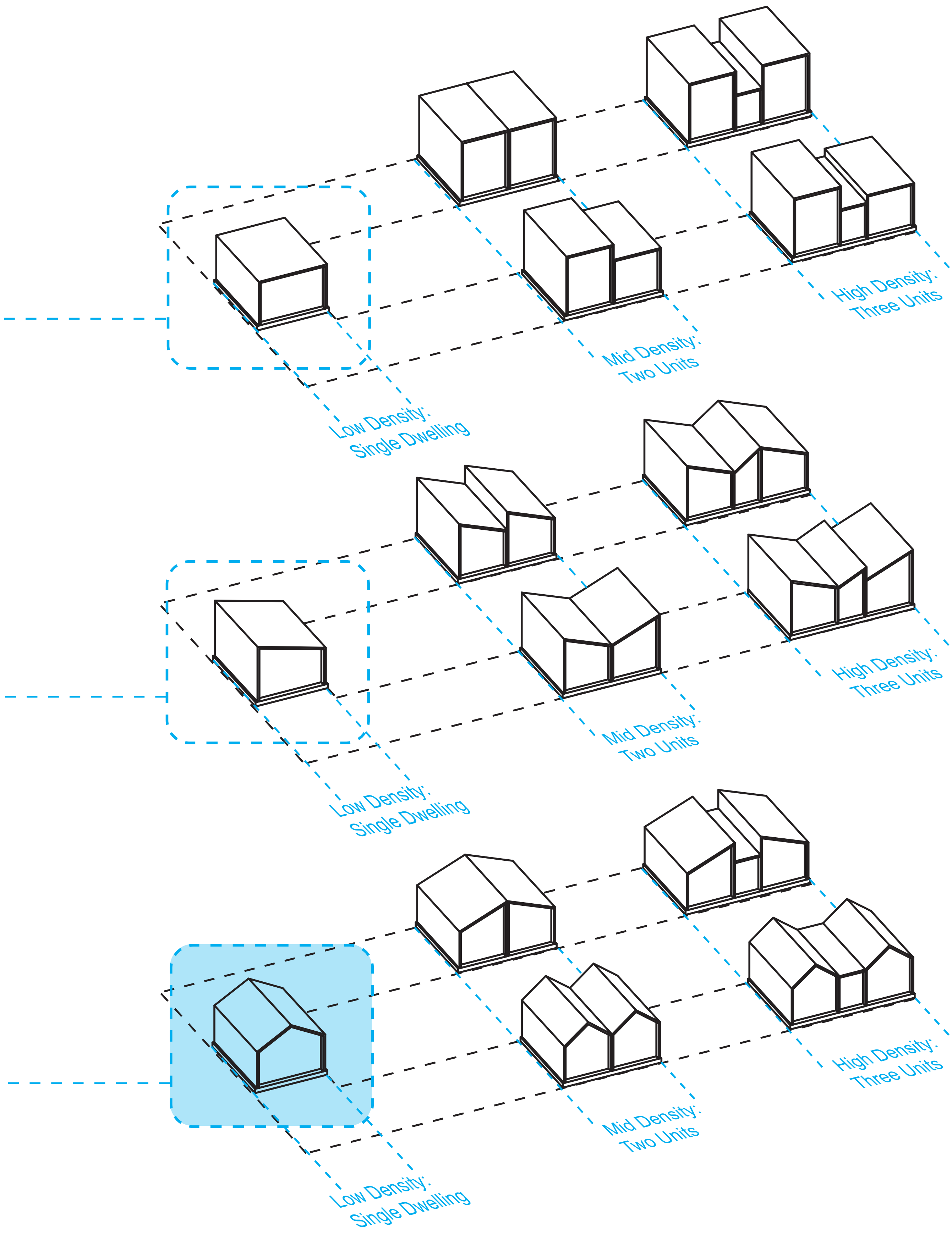
Housing Typology and Density Exploration

Housing typologies that currently exist on Shelly Bay have been identified and used as a design framework to develop the architectural construct of the housing system, situated on top of the amphibious technology. The three building typologies that are currently present on the site consist of a flat roof building to resemble that of the Blackmore and Best Gallery (Figure 91.), a slanted roof building to resemble that of the Shed 8 Propellar Studios Buildings (Figure 92.) and a the traditional pitched roof building that most of the buildings on Shelly Bay obtain (Figure 93.). These three typologies were developed through iterations consisting of different housing densities; low medium density (a single dwelling), medium density (two units to a dwelling), and high medium density (three units to a dwelling). After this exploration, the decision was made to move forward with the single dwelling pitched roof design due to the fact that this design option not only closely resembles the existing character buildings on Shelly Bay the most, the fundamentals of a floating building needs to be considered. The architecture will eventually float, and therefore needs to be as lightweight as possible. The architecture also needs to obtain a simple and symmetrical composition to ensure the equilibrium is balanced. Separate stand-alone dwellings also acquire a sense of freedom, privacy and independence.

Figure 91.

Figure 92.

Figure 93.



Low Density:
Single Dwelling
Mid Density:
Two Units
High Density:
Three Units
Low Density:
Single Dwelling
Mid Density:
Two Units
High Density:
Three Units
Low Density:
Single Dwelling
Mid Density:
Two Units
High Density:
Three Units

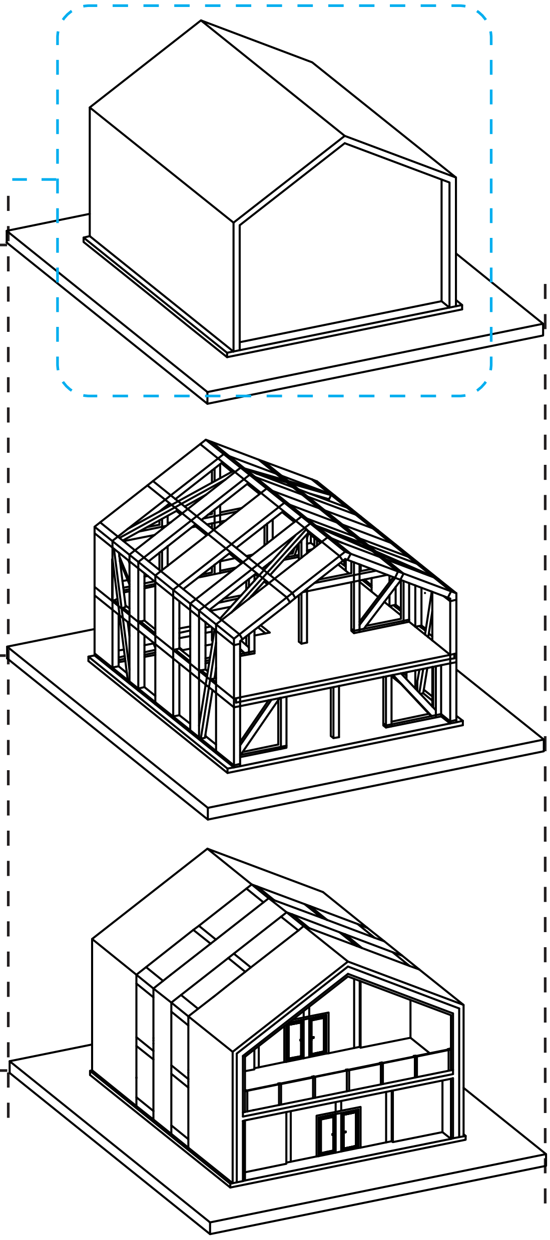
Designing for Three Dwelling Sizes

The house structure consists of a very simple, symmetrical form to maintain stability and minimise any torsion that may occur whilst afloat. To minimise the risk of torsion, the center of mass needs to be at the center of the structure and the center of resistance needs to be as close as possible to the center of mass. Keeping in mind the volume needs to be large enough to make it buoyant with a low enough center of gravity to keep it upright to reduce any unnecessary tilting. To achieve this, the dwelling will be only two storeys high. This simple shape was formed to ensure these factors are met. Three dwelling sizes were created within the same framework and makeup. A two bedroom (75m²), a three bedroom (110m²) and a four bedroom (165m²) dwelling. The larger the building gets, the more posts are required to maintain that stability whilst afloat.

Existing buildings on Shelly Bay


Figure 94.

Figure 95.



House Shape

- Traditional pitched roof to resemble that of Shelly Bay character buildings
- Symmetrical
- Simple rectangular floorplan

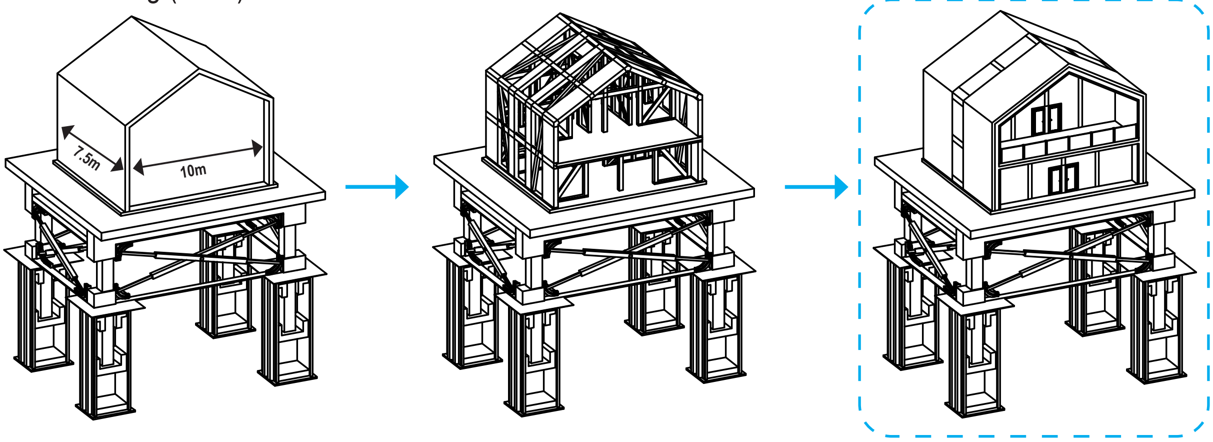
Structure

- Triangulated frame
- Bracing for lateral forces
- Timber for lightweight construction

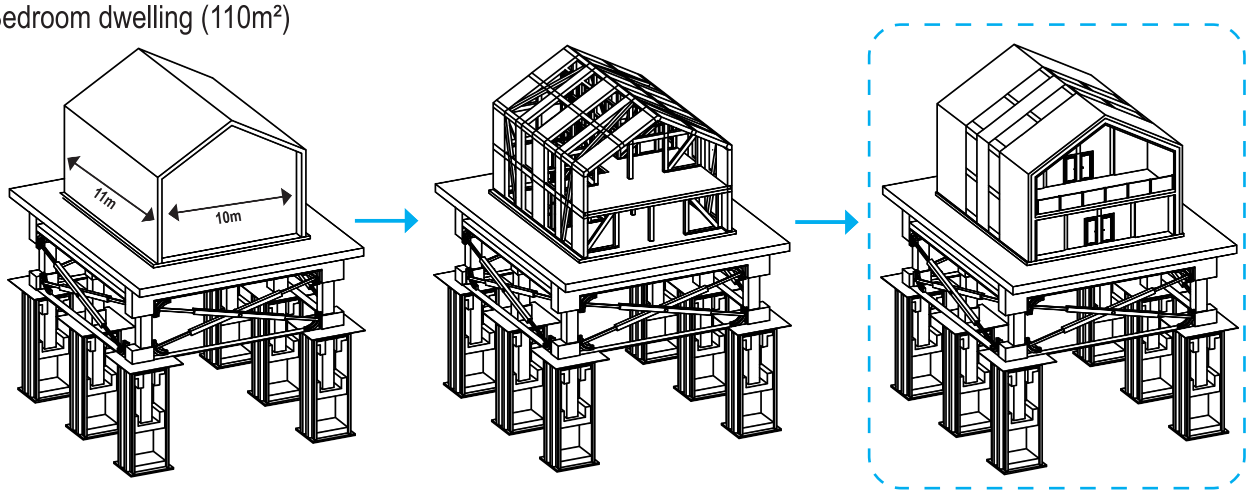
Window Placement and Finishes

- Large floor to ceiling height west facing windows overlooking the ocean
- Skylights for passive natural lighting
- Waterproof external finishes

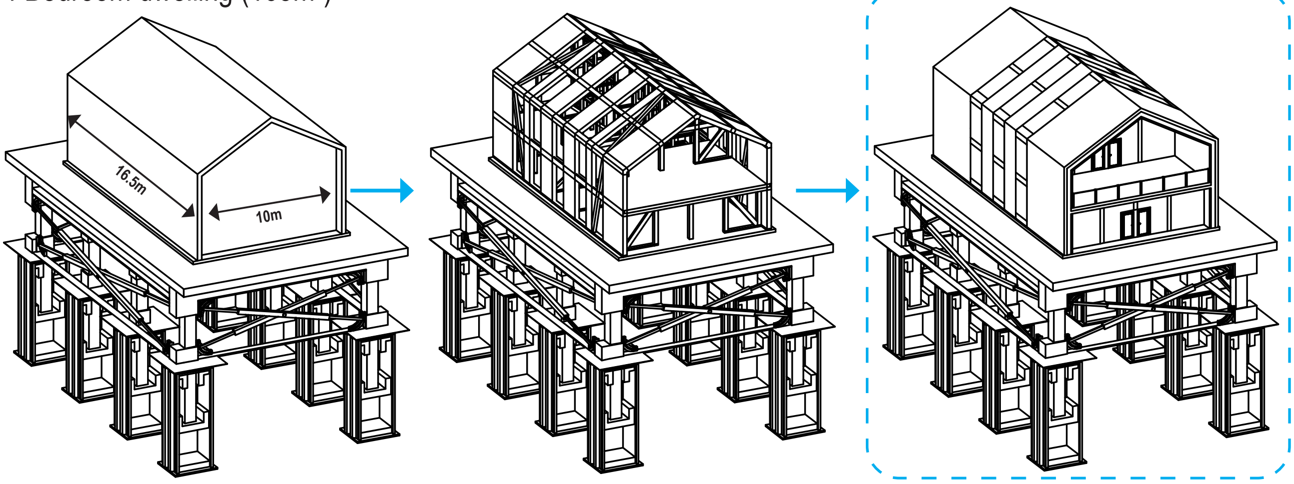
2 Bedroom dwelling (75m²)



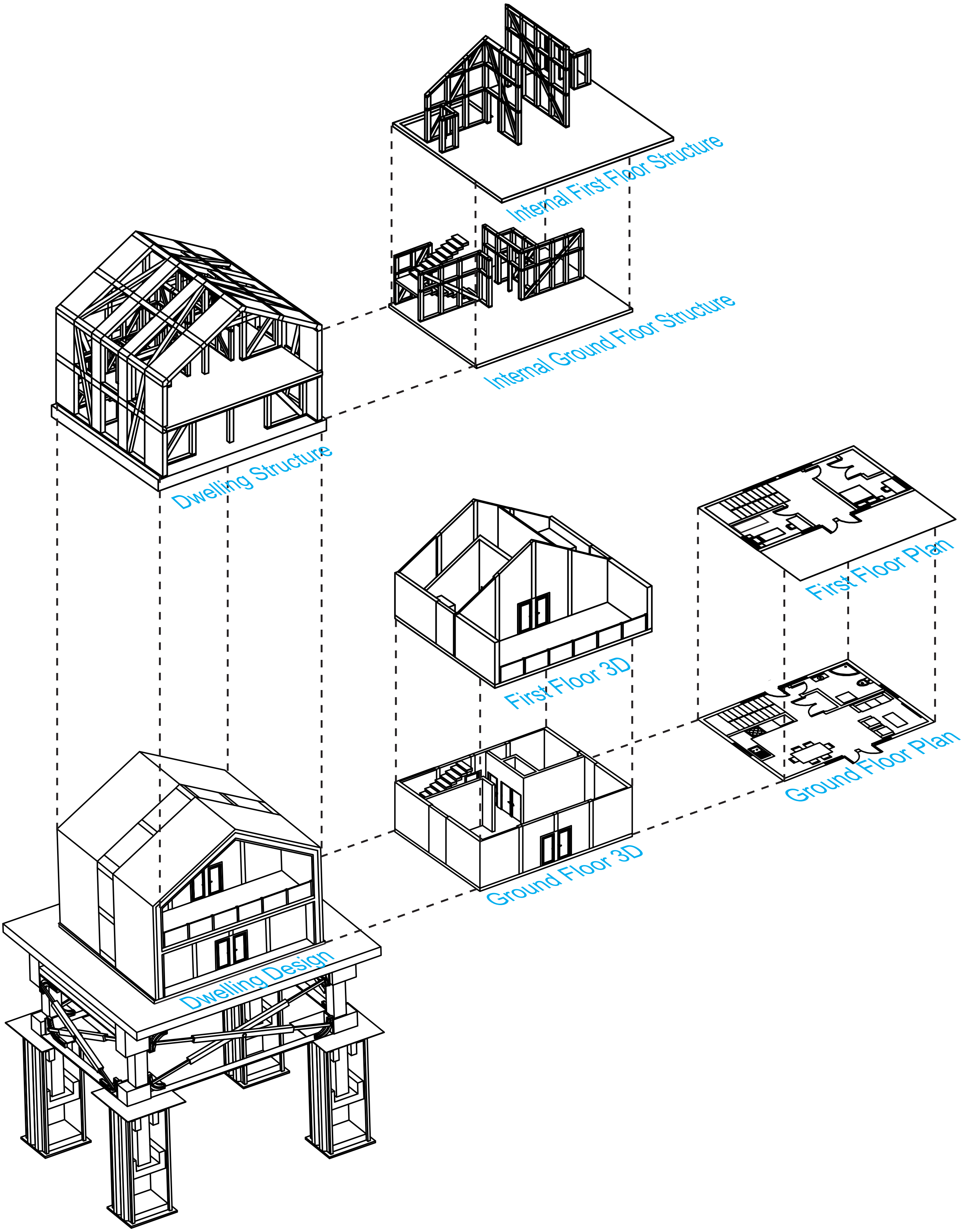
3 Bedroom dwelling (110m²)



4 Bedroom dwelling (165m²)

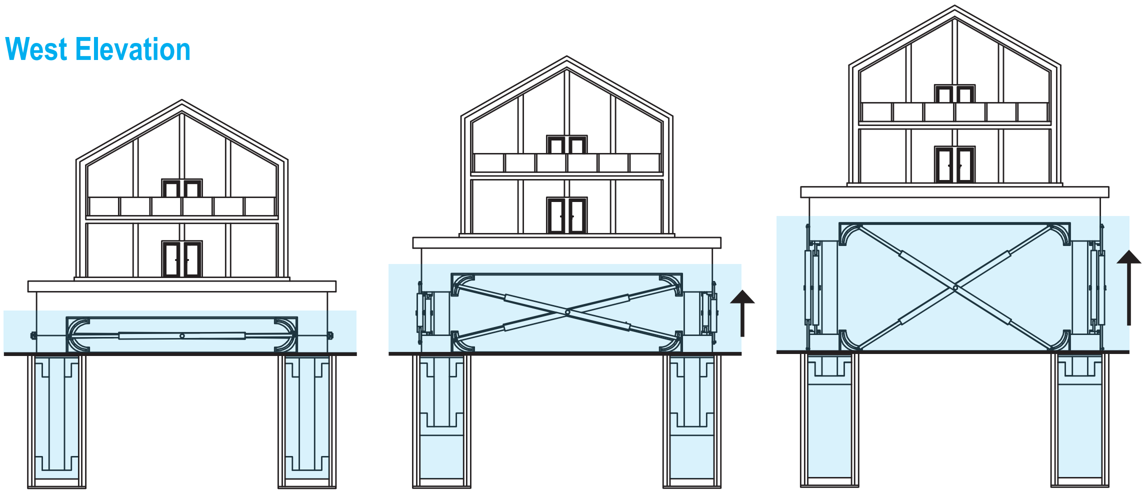


2 Bedroom Dwelling

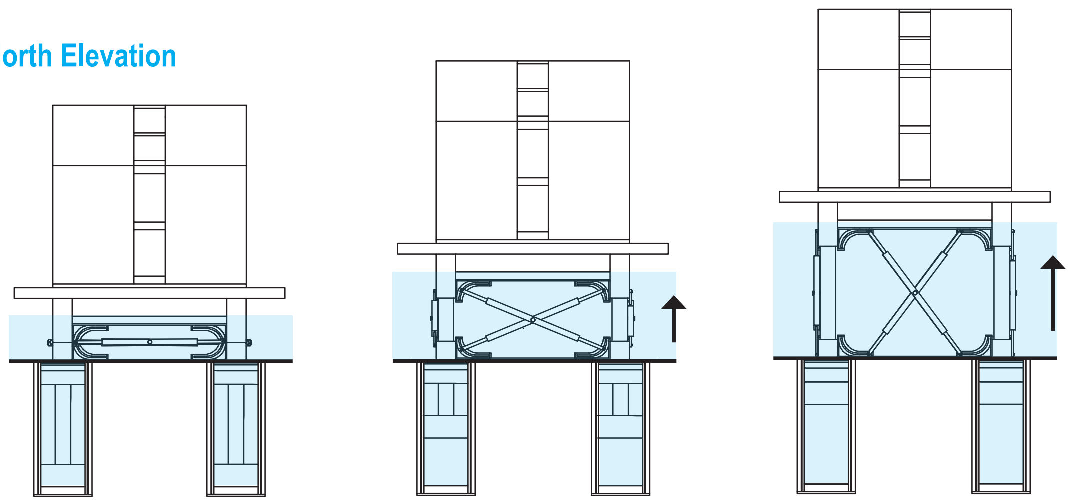

Internal First Floor Structure
Internal Ground Floor Structure
Dwelling Structure
First Floor Plan
First Floor 3D
Ground Floor Plan
Ground Floor 3D
Dwelling Design

Elevations

West Elevation



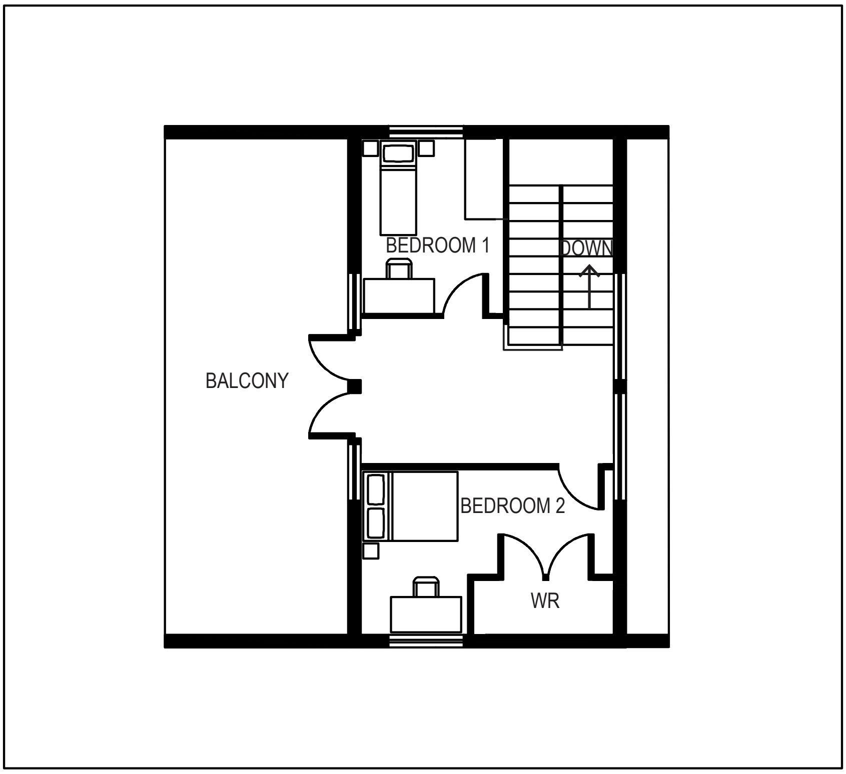
North Elevation



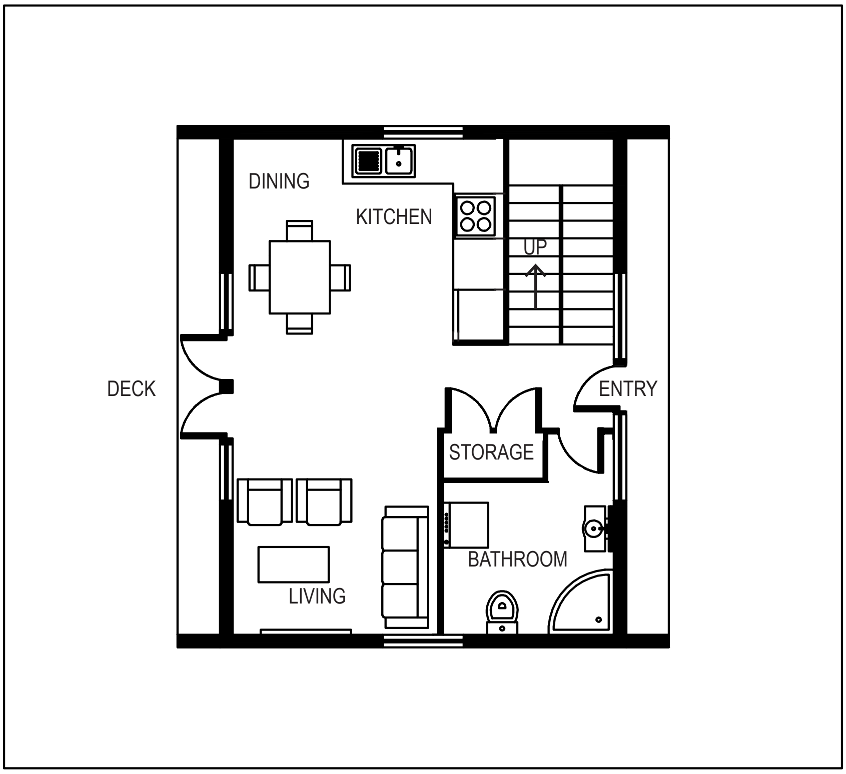
Floorplans

First Floor Plan

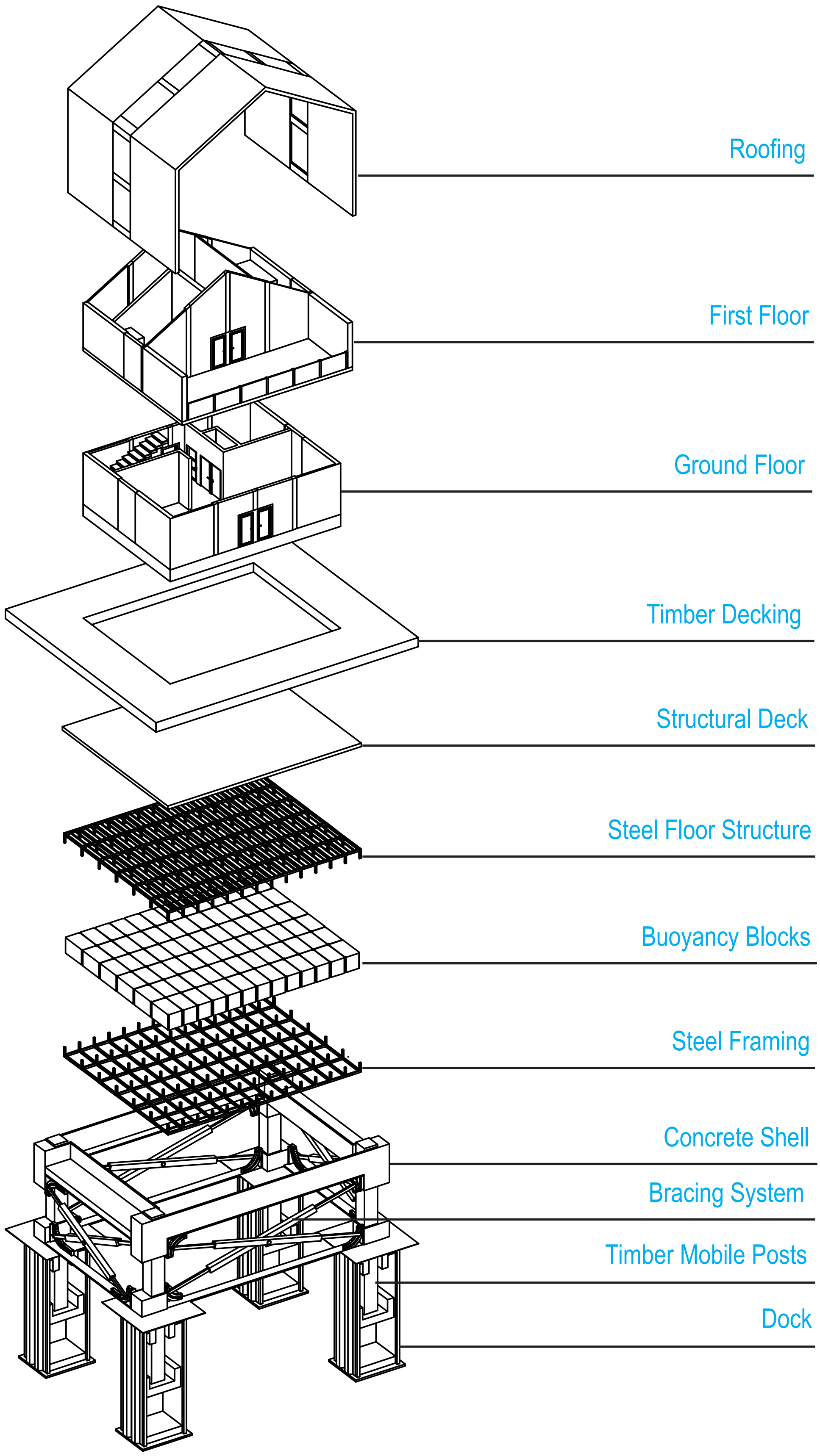
N



Ground Floor Plan

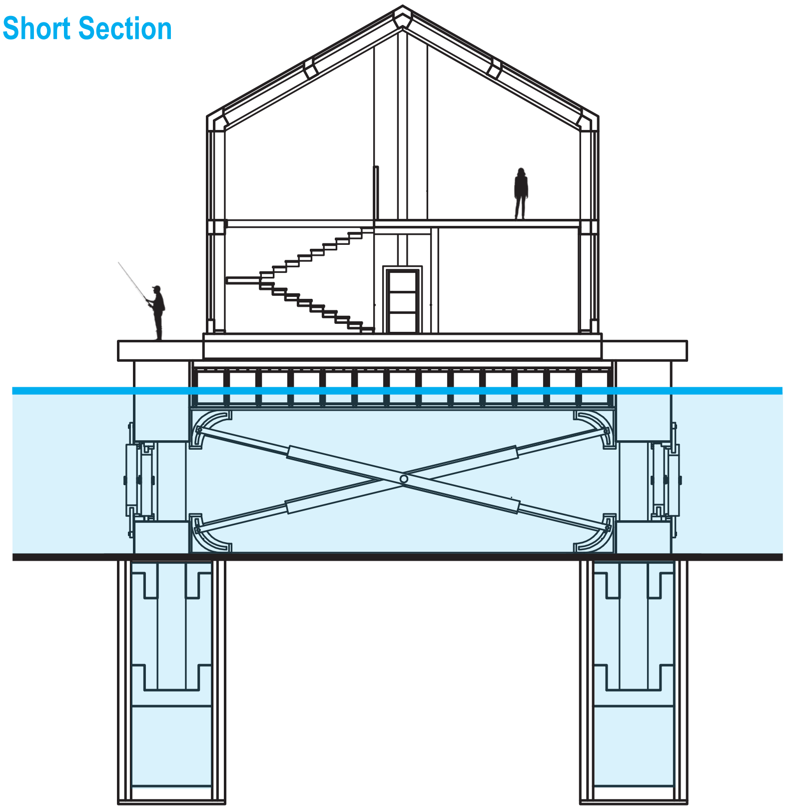


Entire Makeup

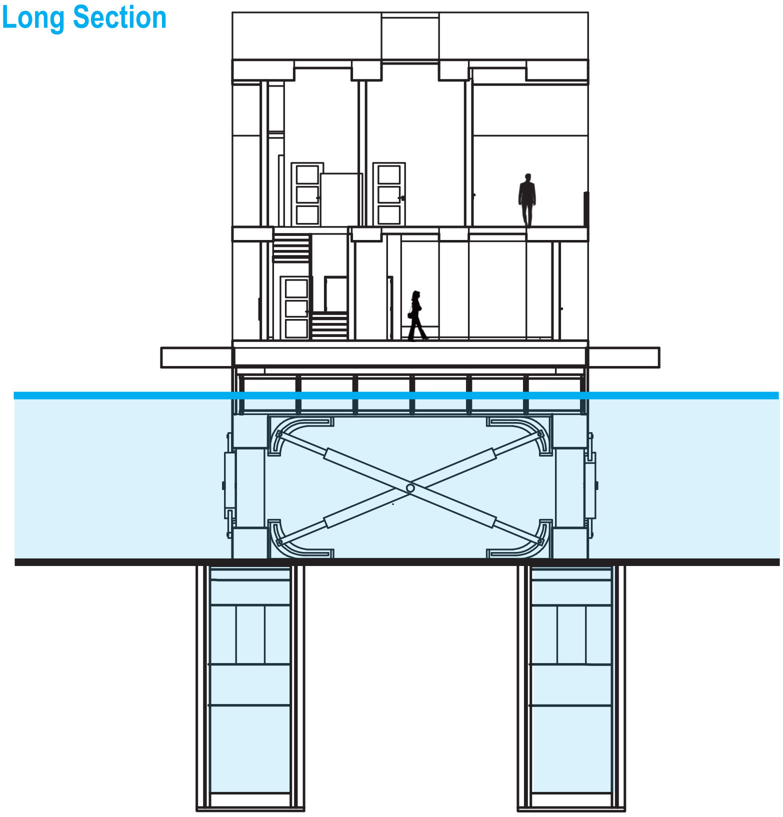


Sections

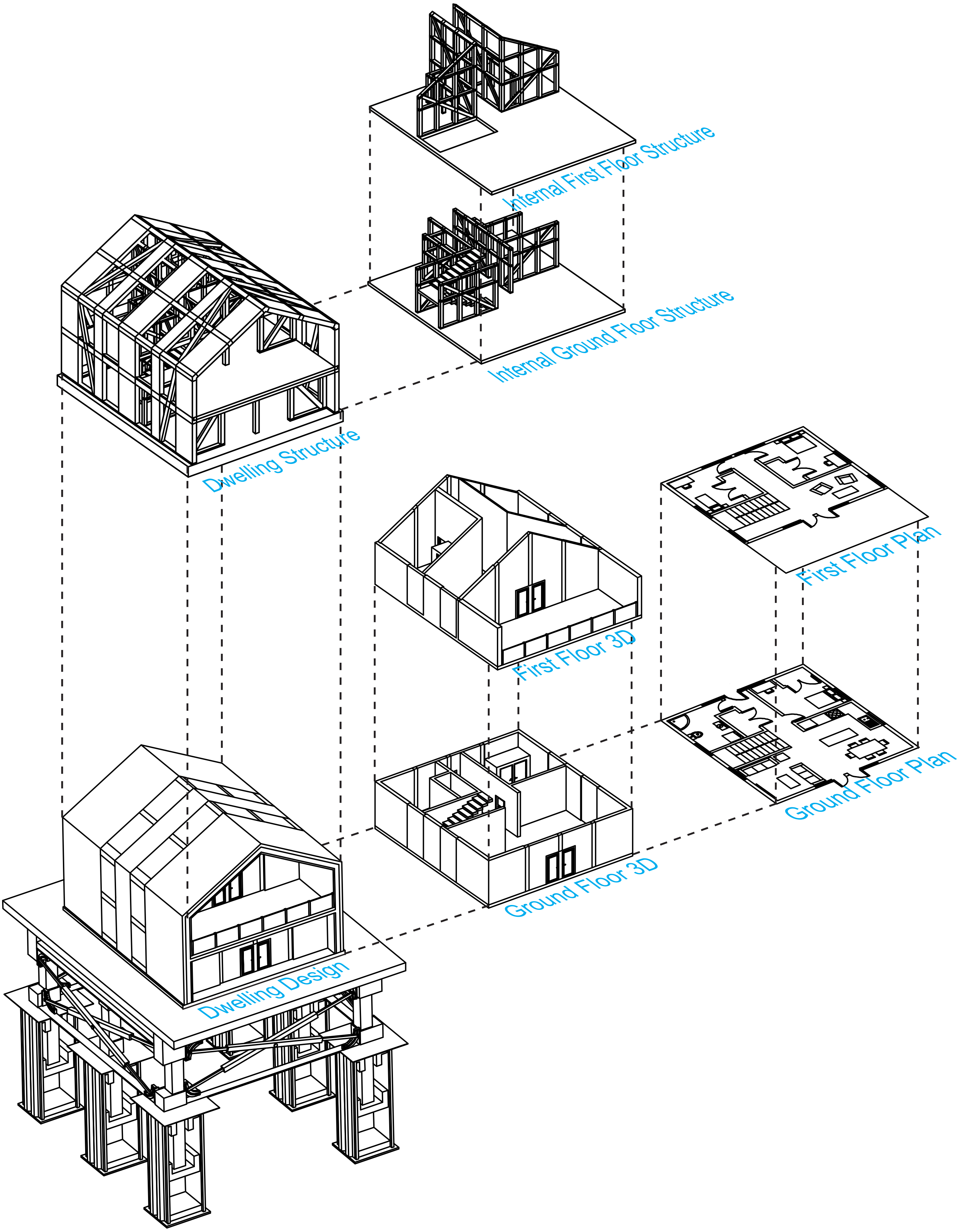
Short Section



Long Section

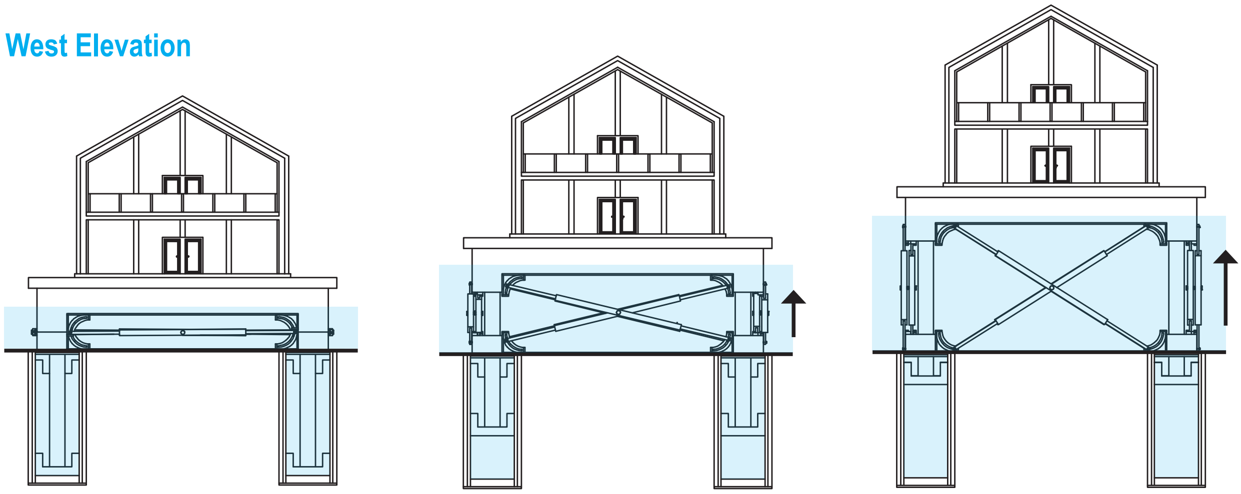


3 Bedroom Dwelling

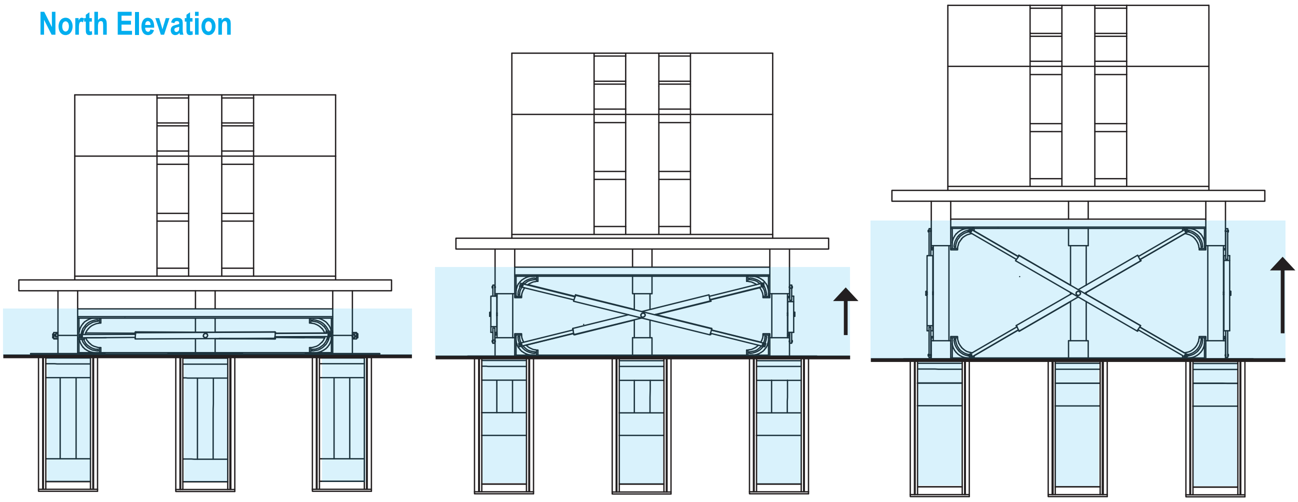

Internal First Floor Structure
Internal Ground Floor Structure
Dwelling Structure
First Floor Plan
First Floor 3D
Ground Floor Plan
Ground Floor 3D
Dwelling Design

Elevations

West Elevation

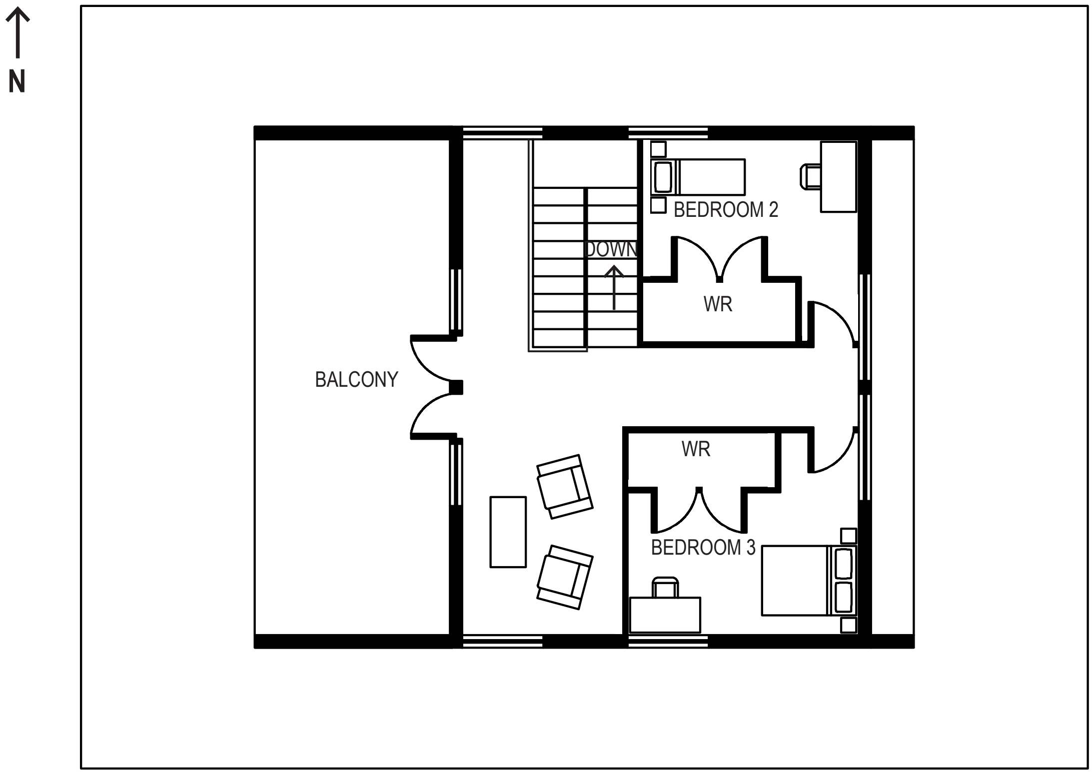


North Elevation

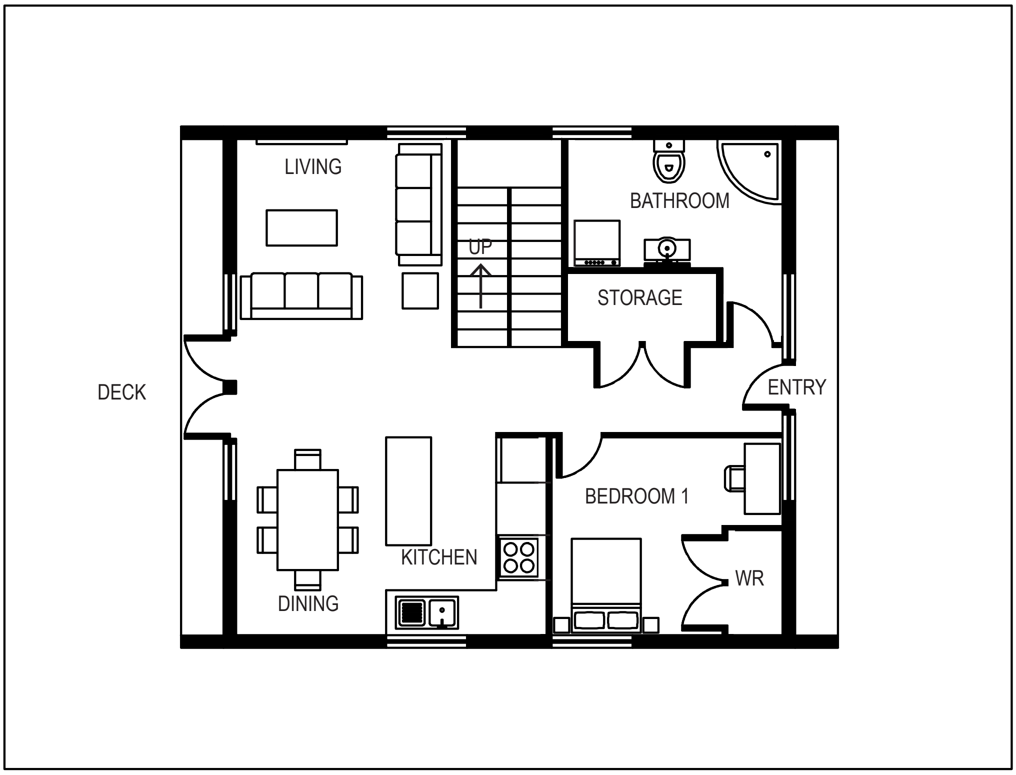


Floorplans

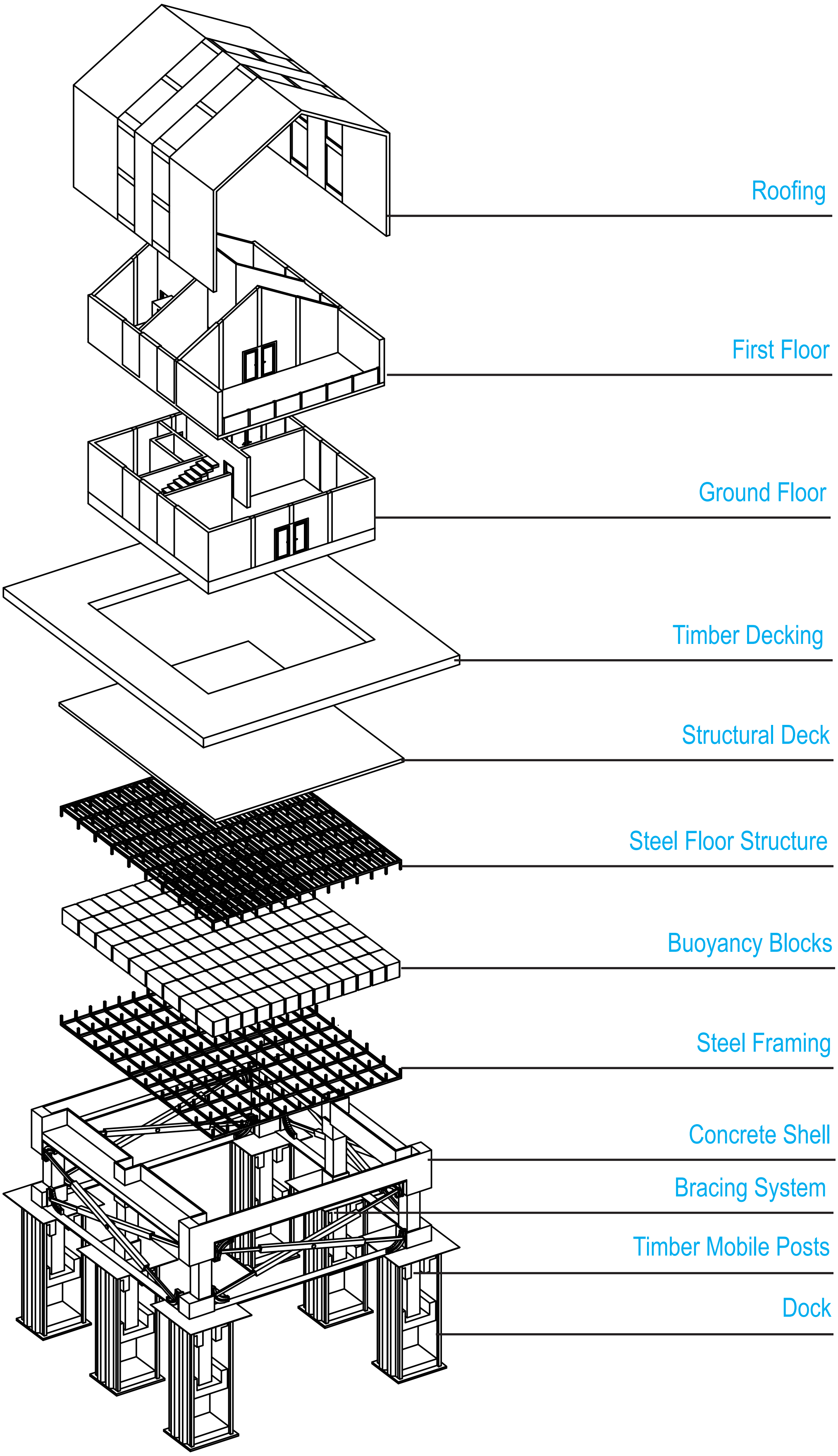
First Floor Plan



Ground Floor Plan

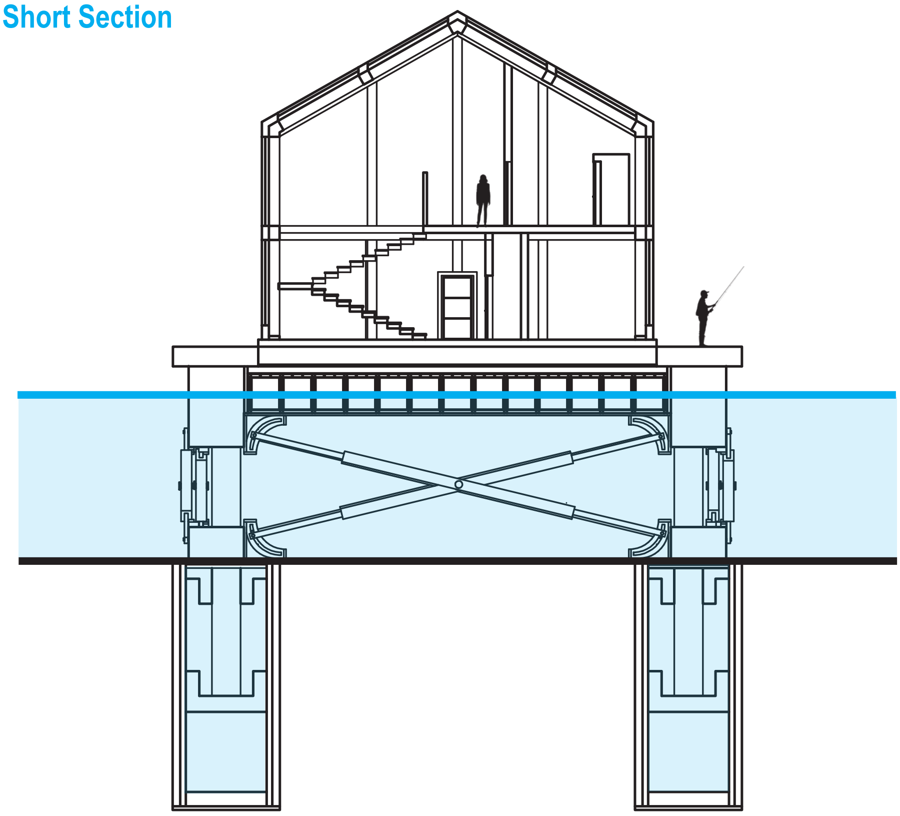


Entire Makeup

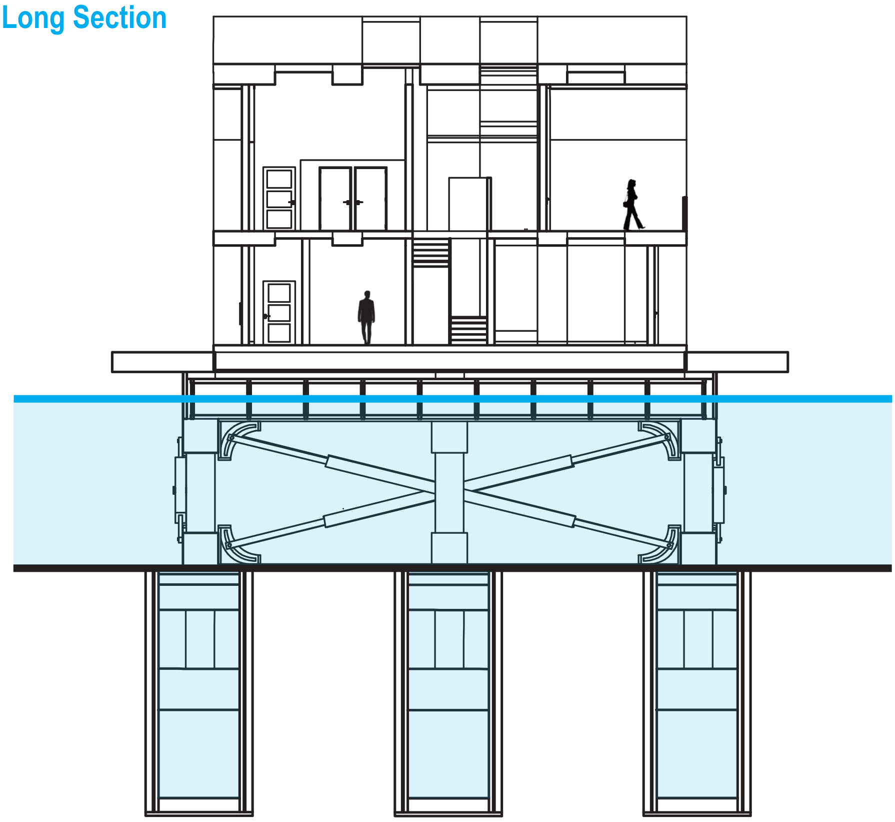


Sections

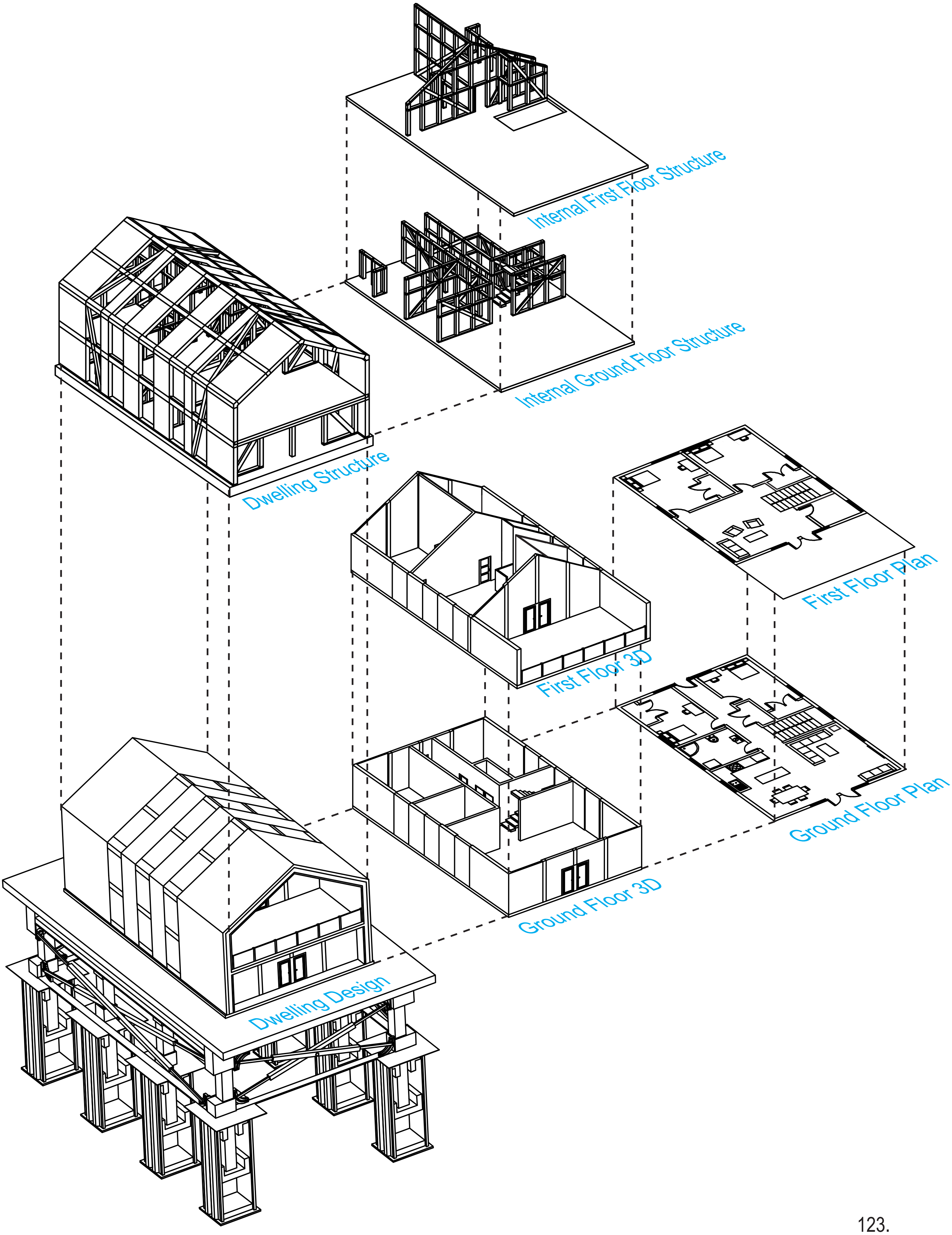
Short Section



Long Section

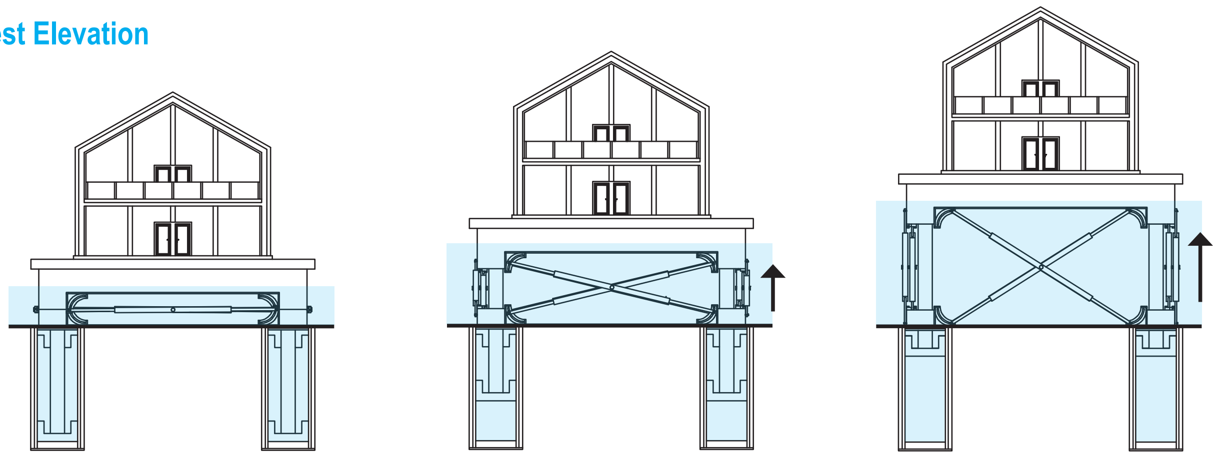


4 Bedroom Dwelling

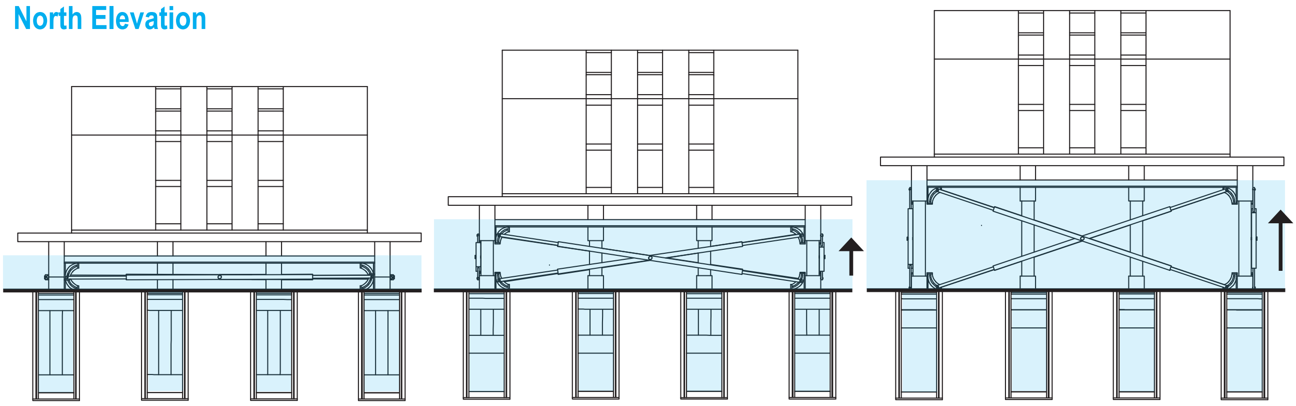

Internal First Floor Structure
Internal Ground Floor Structure
Dwelling Structure
First Floor Plan
First Floor 3D
Ground Floor Plan
Ground Floor 3D
Dwelling Design

Elevations

West Elevation

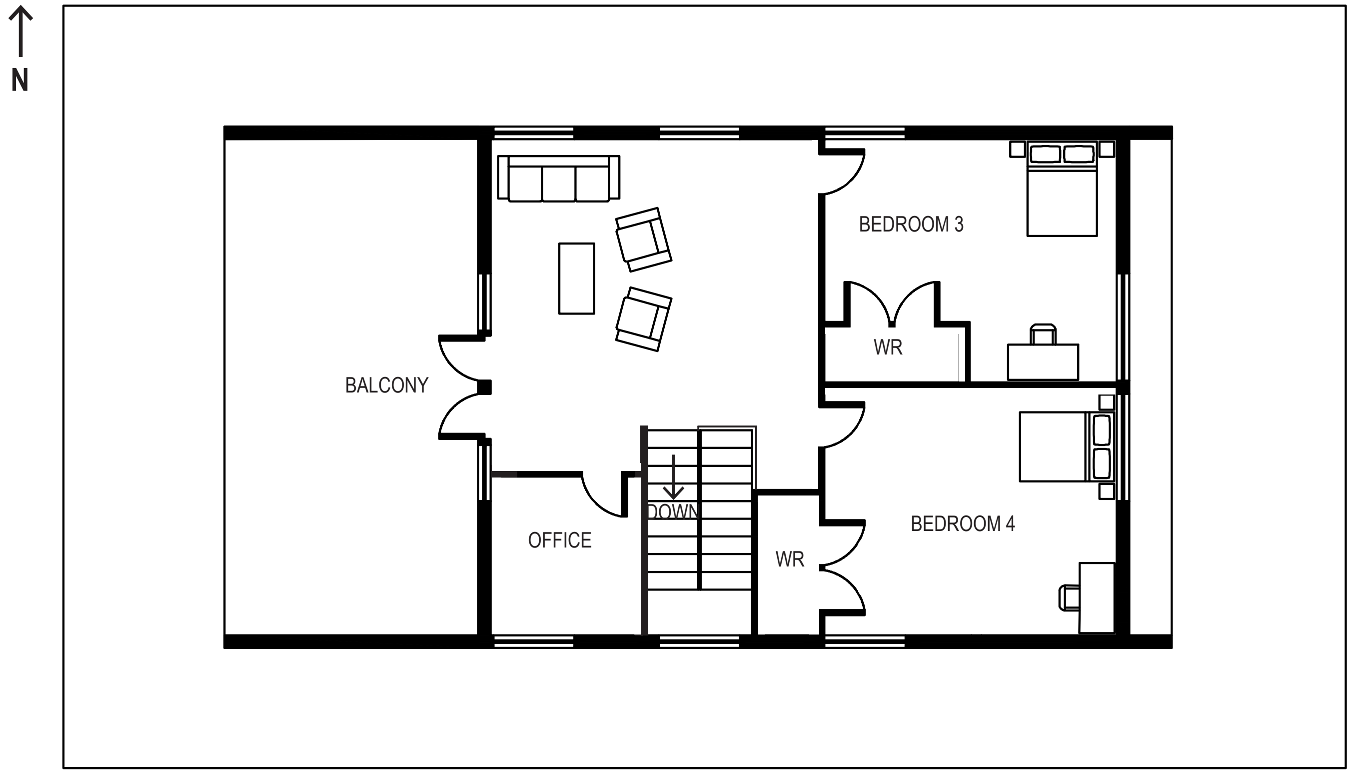


North Elevation

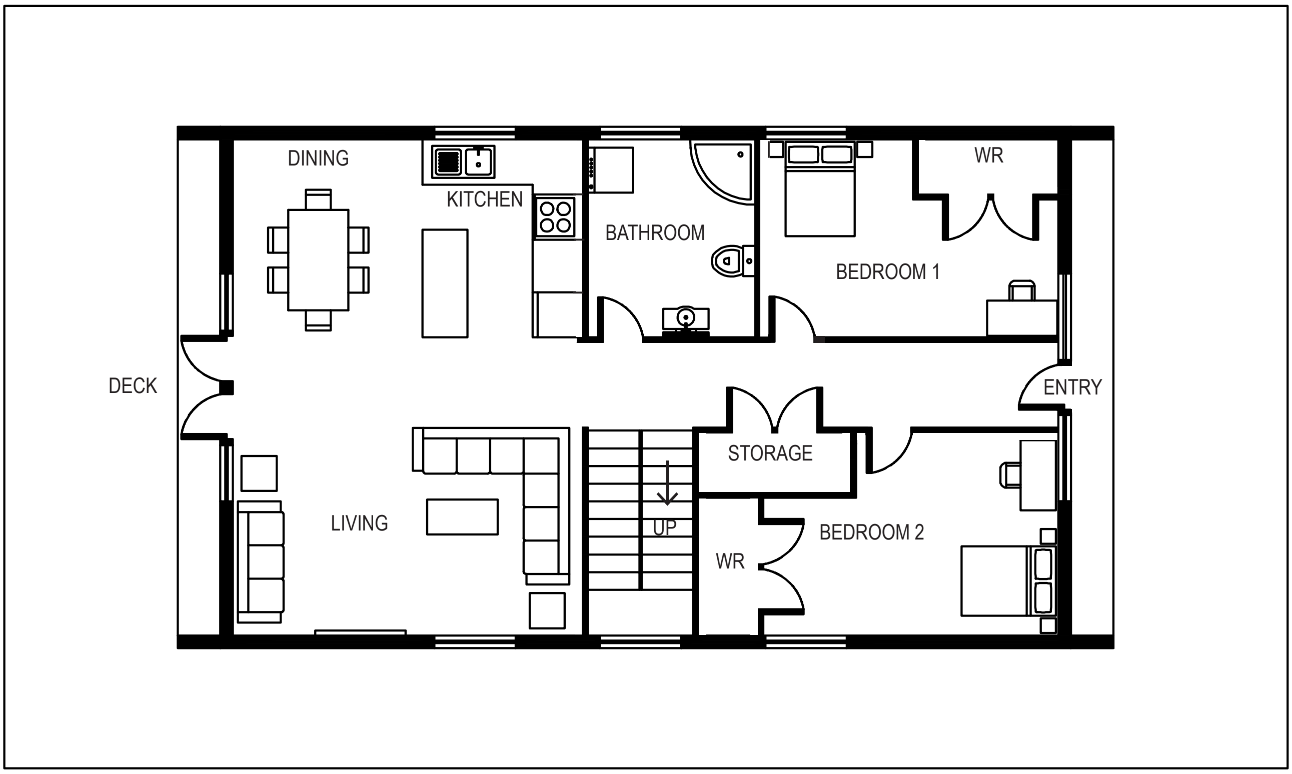


Floorplans

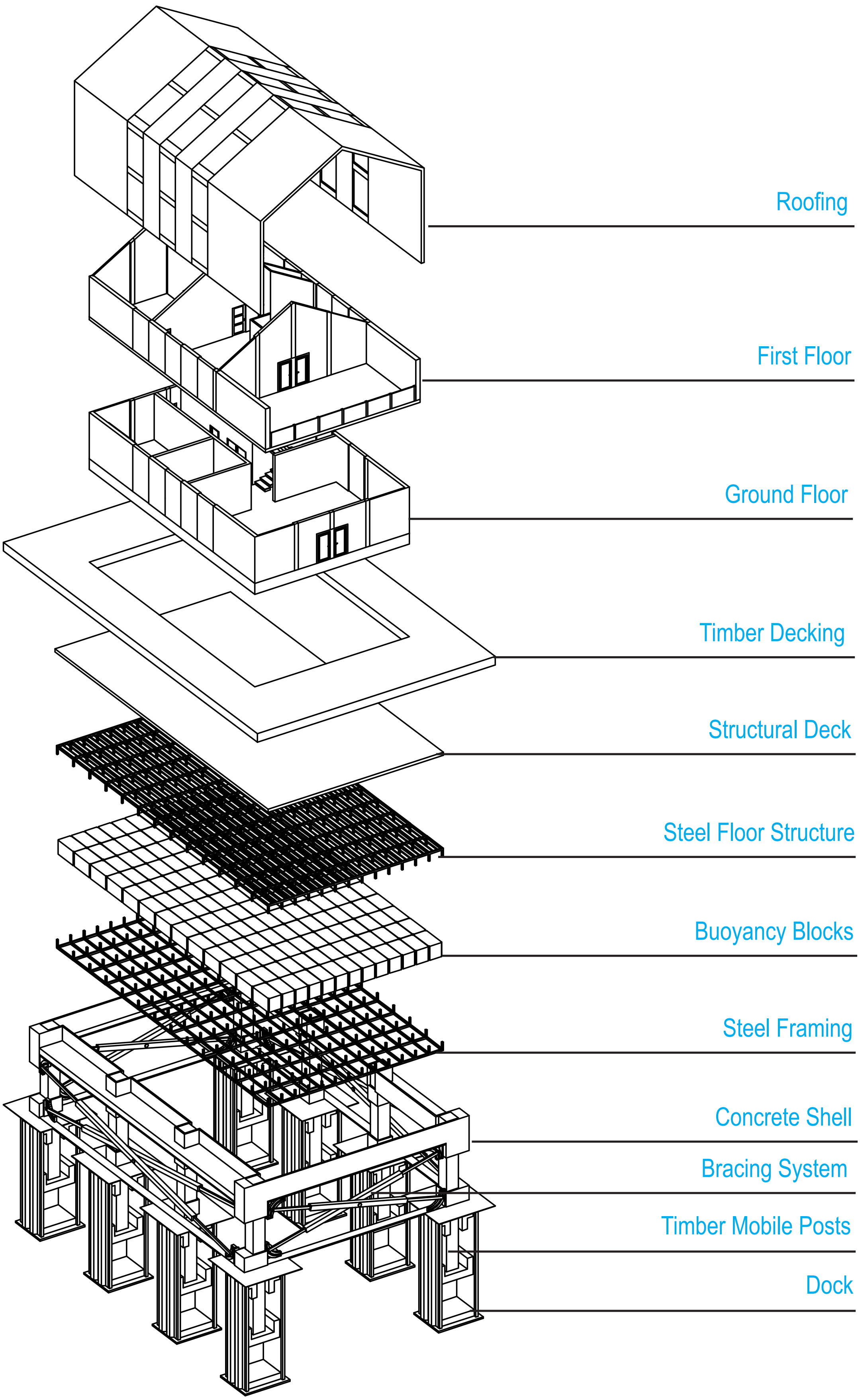
First Floor Plan



Ground Floor Plan

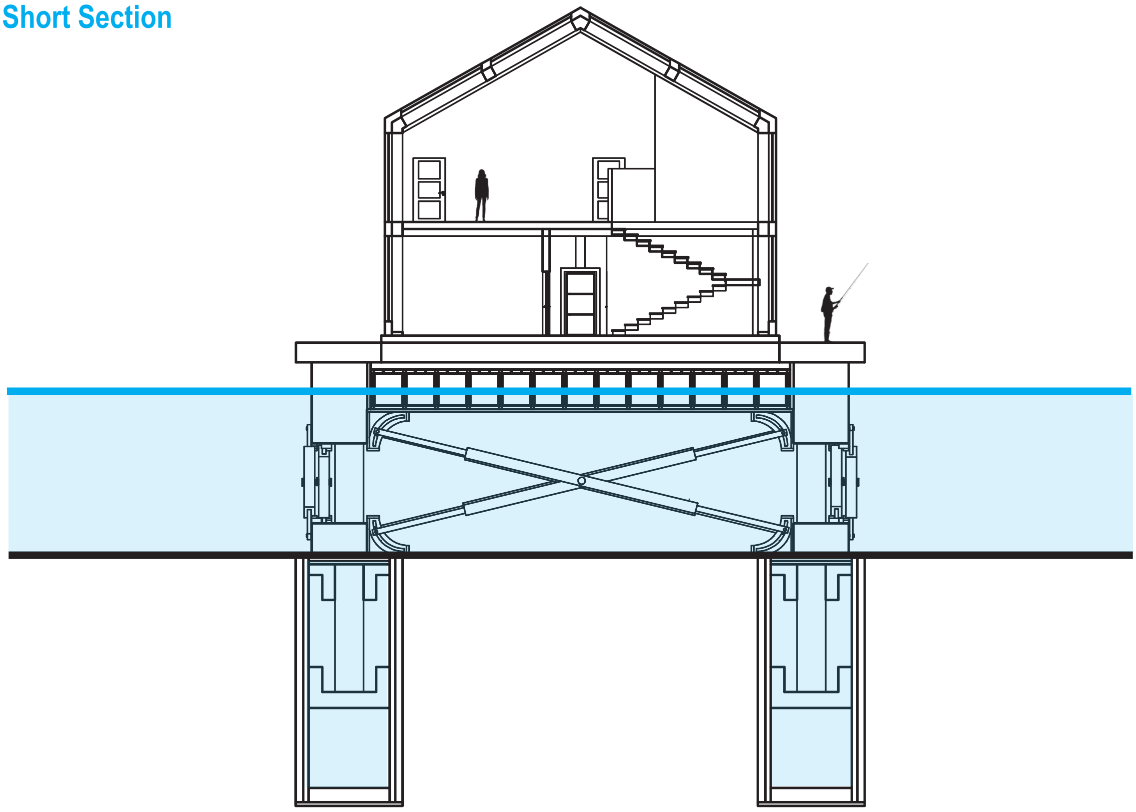


Entire Makeup

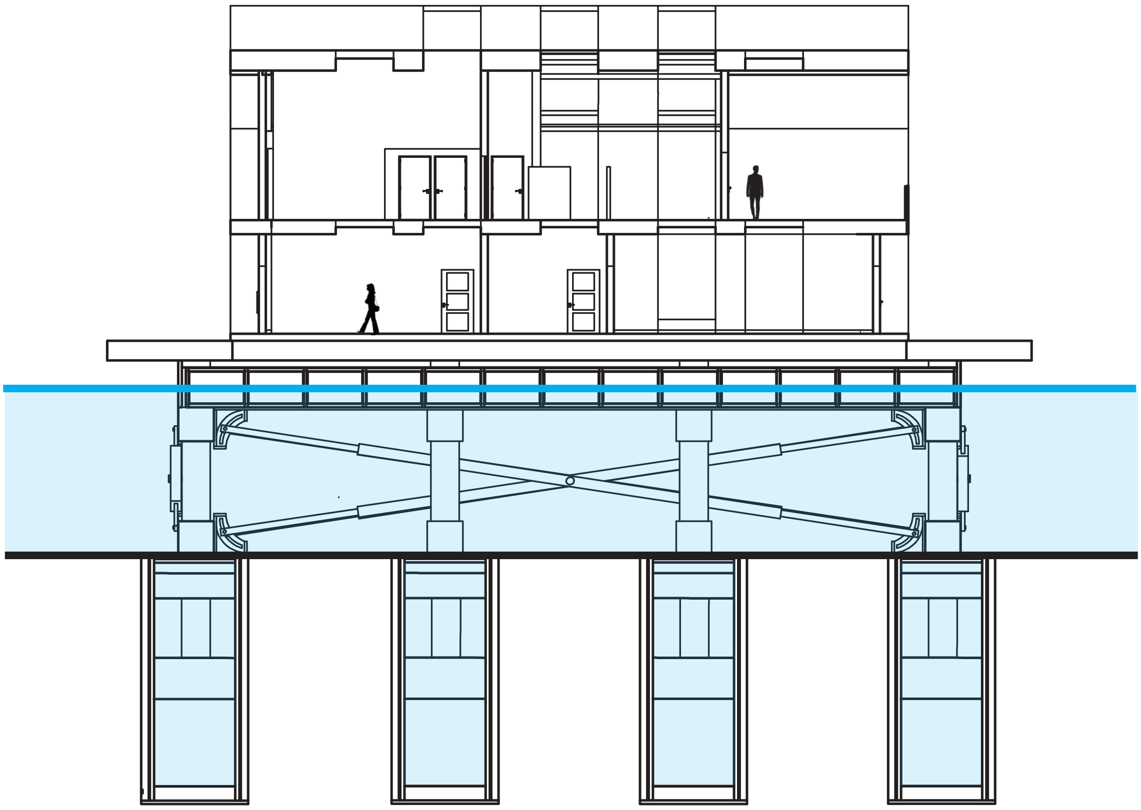


Sections

Short Section



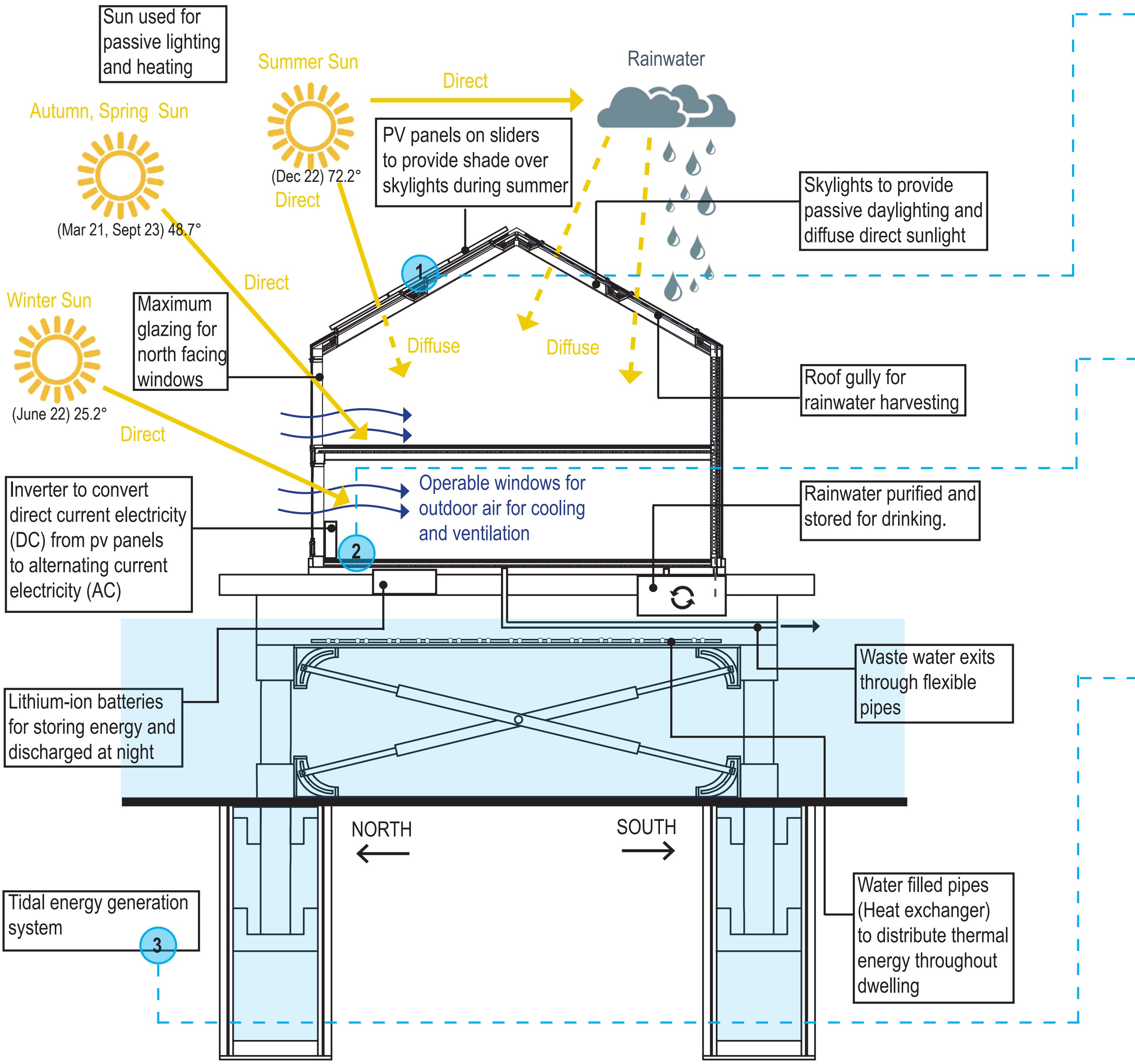
Long Section



8.2. Energy Generation (Self-Sufficiency) and Passive Design

Energy generation from renewable sources to compensate for architectures own energy demand

Designing on the water provides an opportunity to create a self sufficient dwelling that generates energy from renewable sources, such as solar and tidal, to compensate for the architectures own energy demand. Different passive design considerations were explored to ensure a sustainable way of living.



Energy Generation Aspects in More Detail

1

PV Panels on Sliders

The pv panels on the north facing side of the dwelling will be placed on 'sliders'. The purpose of this is to utilise the pv panels as a shading system over the skylights during the summer time. During the winter months, they can slide out and allow the skylights to receive sunlight to provide passive heating and natural daylighting. More information of how this works is presented on page 130.

2

Conversion of Solar Power Energy

During the daytime the energy from the pv panels is stored in lithium-ion batteries. During the night when the sun is no longer available, the stored energy can be released into the building. More information of how this works is presented on page 131.

3

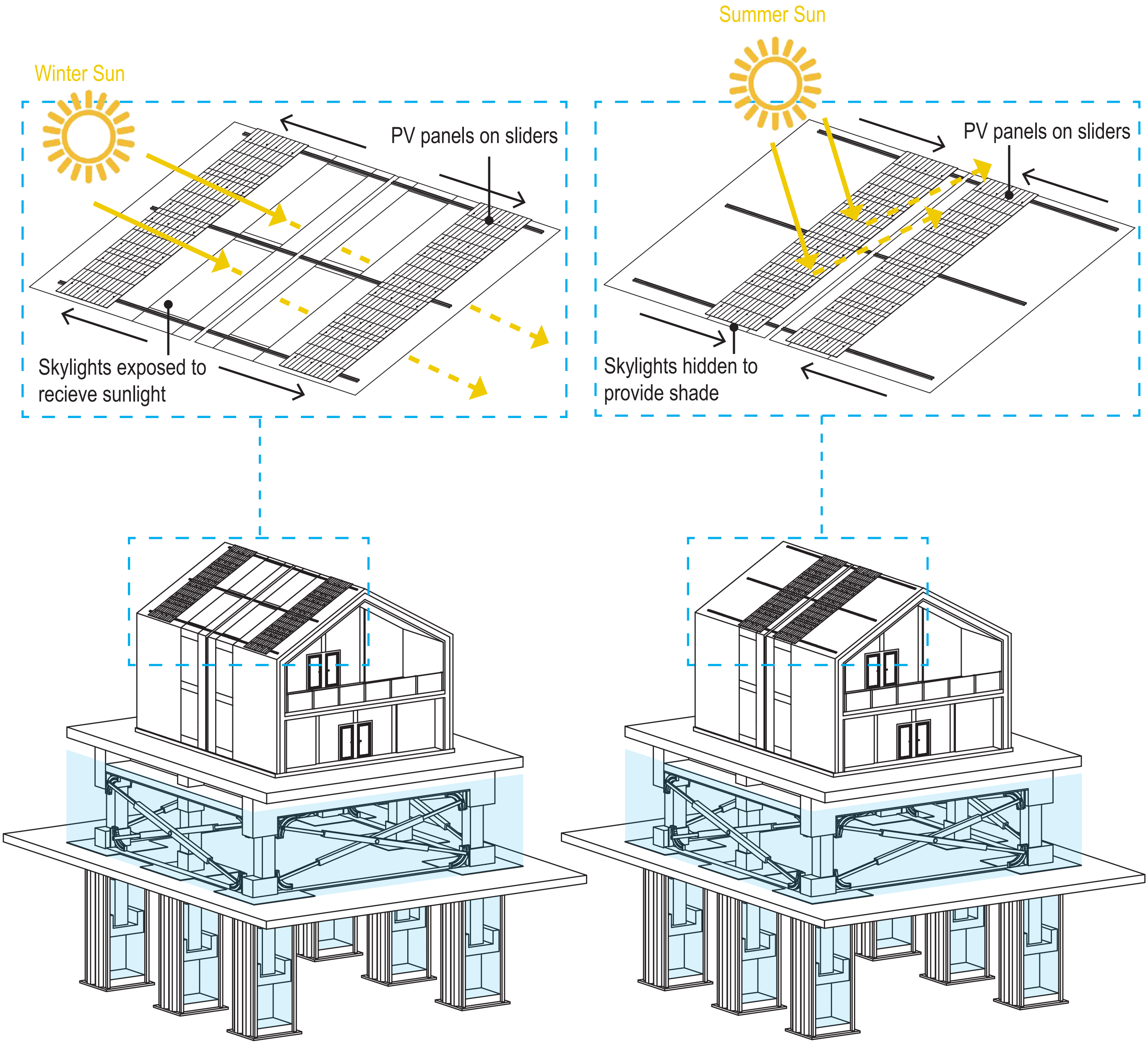
Tidal Energy System

Tidal energy is a renewable source that could be utilised within the design to provide a natural source of energy. Two options are explored; The first is looking into how the posts connected to the floating base could compress air through the natural rising and falling of the tide as a way to generate energy. The second is to look into tidal turbines that could be situated underneath the floating jetty access ways as a second option for generating tidal energy through the waves and rising and falling of the tides. More information of how this works is presented on pages 132, 133, 134 and 135.

PV Panels on Sliders

1

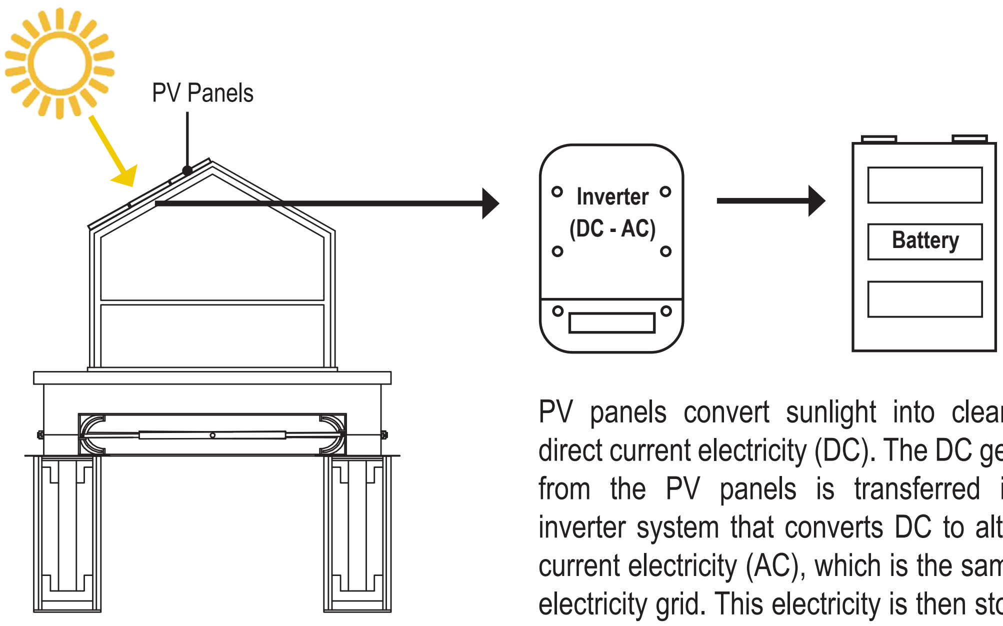
The pv panels move along ‘sliders’. This allows the skylights to receive maximum sun during winter and provide shade over the skylights during summer. They can be adjusted any time during the year to suit the occupants preferences.



Conversion of Solar Power Energy

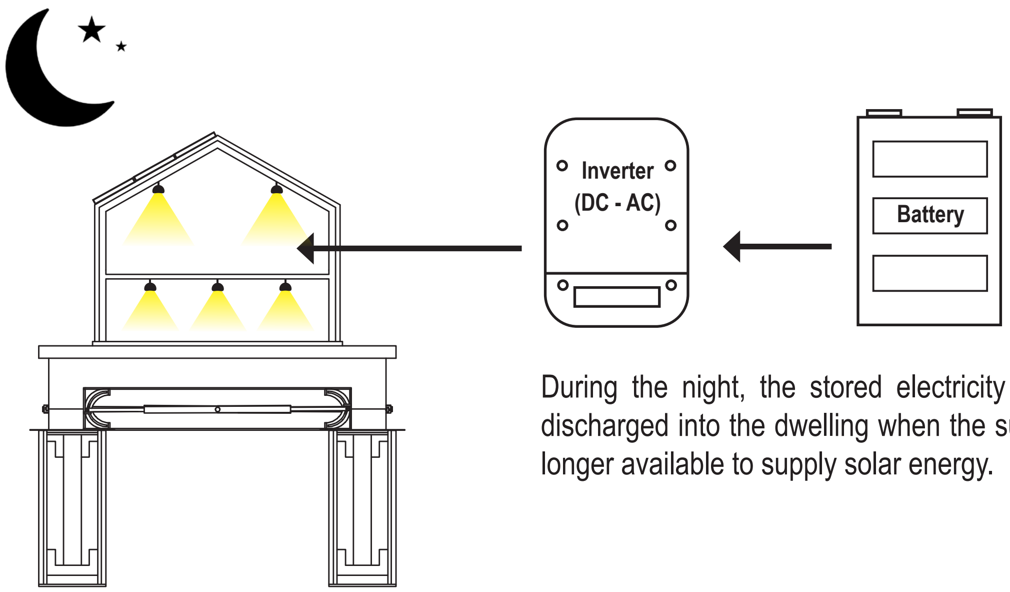
2

During the day:



PV panels convert sunlight into clean green direct current electricity (DC). The DC generated from the PV panels is transferred into the inverter system that converts DC to alternating current electricity (AC), which is the same as an electricity grid. This electricity is then stored into lithium-ion batteries.

During the night:



During the night, the stored electricity is then discharged into the dwelling when the sun is no longer available to supply solar energy.

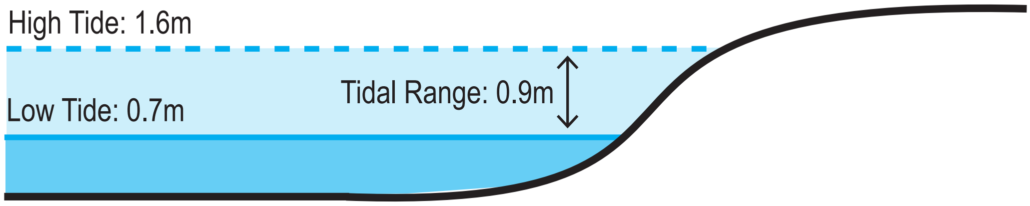
Tidal Energy System

3

Tidal energy is a type of renewable source that generates power through the natural motions of the water and the rising and falling of the tides caused by the moons gravitational pull. Tidal energy is very reliable and highly predictable, as opposed to wind, which is unpredictable with varying intensities.

Shelly Bay tides

Tide Difference: Rises and falls 0.9m with each tidal cycle (2x a day)



Two tidal energy options will be explored:

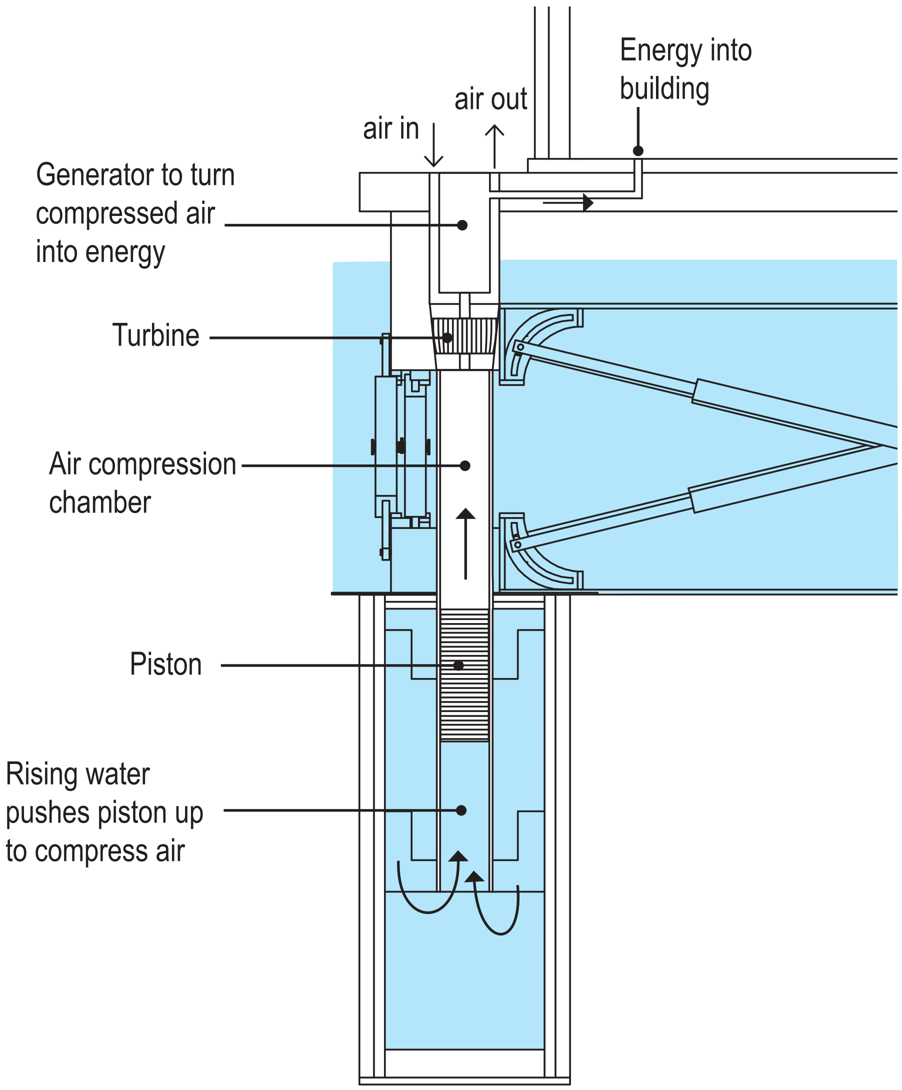
Option One: The energy can be generated through the vertical motions of the rising and falling of the tide by compressing air through air chambers that then turns a turbine to generate energy.

Option Two: The energy can be generated by using tidal turbines (similar to wind turbines) in which the natural motions of the water cause the blades to turn and are connected to a generator to generate power. Because water is a lot denser than air, the blades will turn more slowly and is safer for marine life.

Tidal Energy System: Option 1

Tidal pneumatic pistons would be located in the posts that anchor the dwelling. These pistons are used to generate energy from the vertical movements of the tide. When the dwelling rises and falls with each tidal cycle, air is compressed within the piston chambers and converted into energy.

Oscillating water column using piston to generate tidal energy

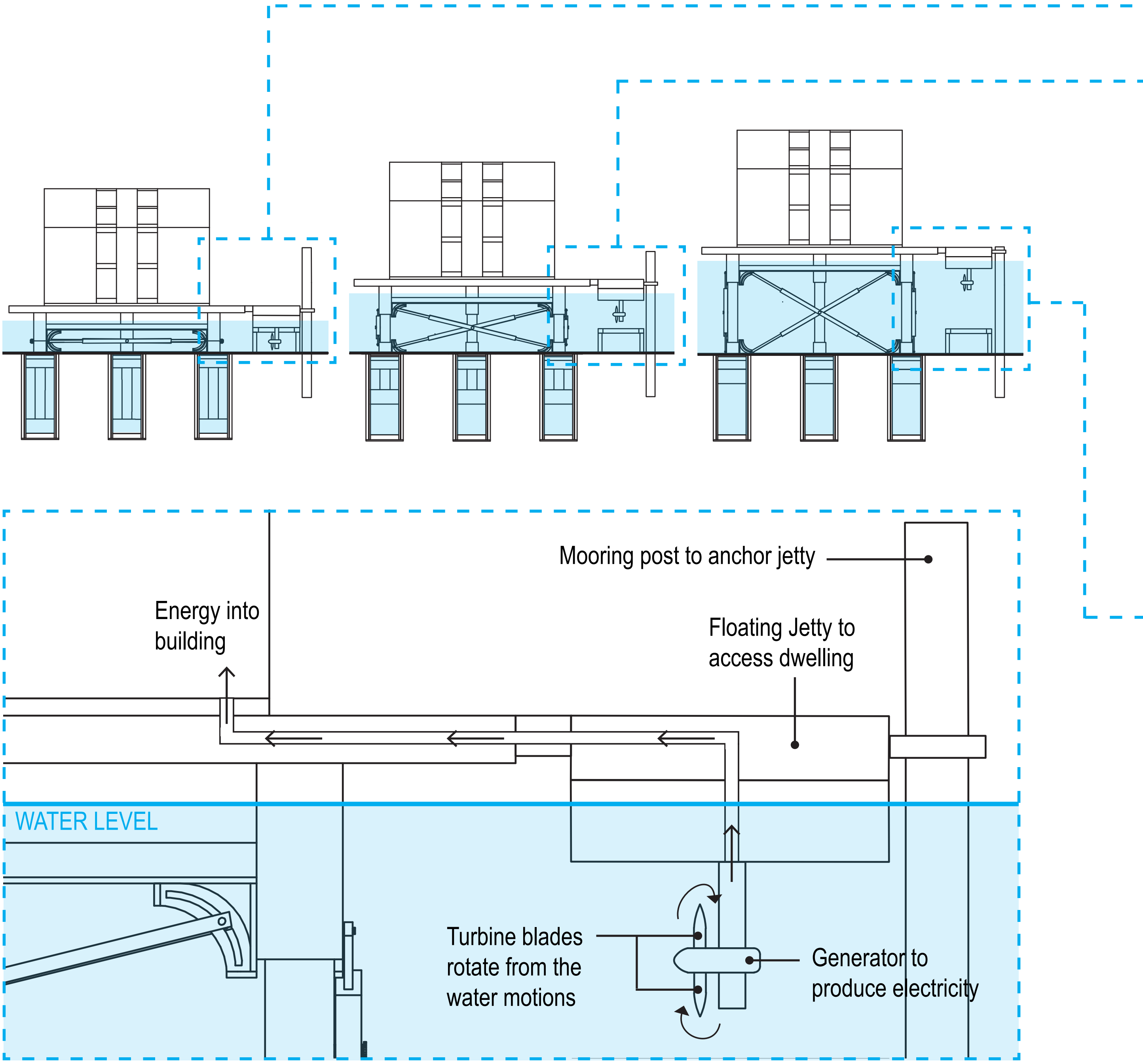


Because the rising and falling of the tide is a slow process, this movement may not be enough to compress as much air that would be required to spin the turbine and generate energy. This option is also very complex and could possibly be overcomplicating the design. A more simple approach could be undertaken instead.

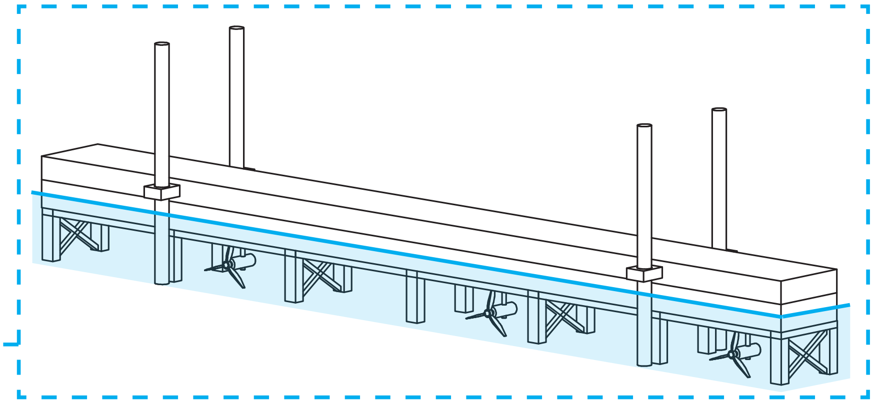
Tidal Energy System: Option 2

Tidal turbines could be situated below the floating jetty access way and remain underwater. The waves cause the turbines blades to turn to generate energy. That energy is then released into the dwellings.

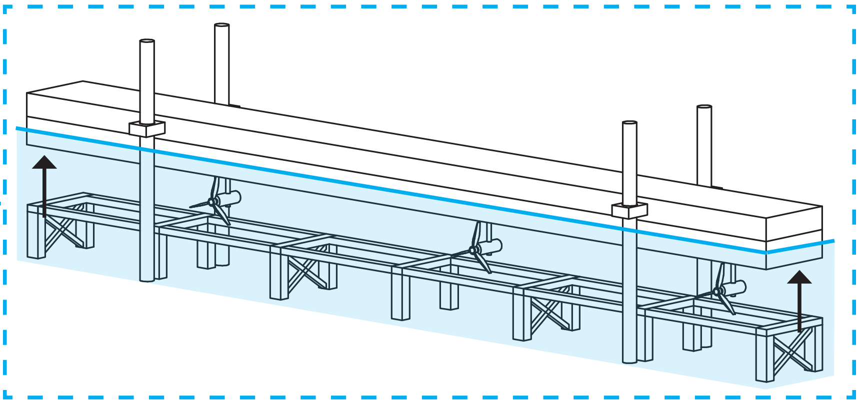
Tidal turbines to generate tidal energy



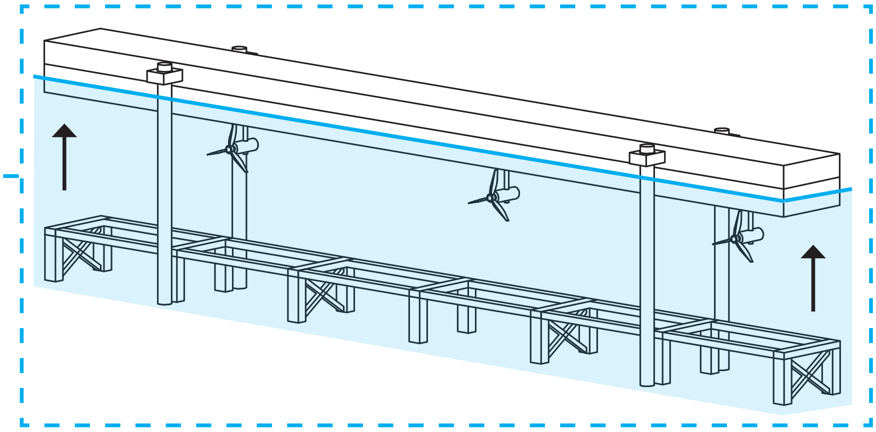
Minimal Rise



Middle Rise



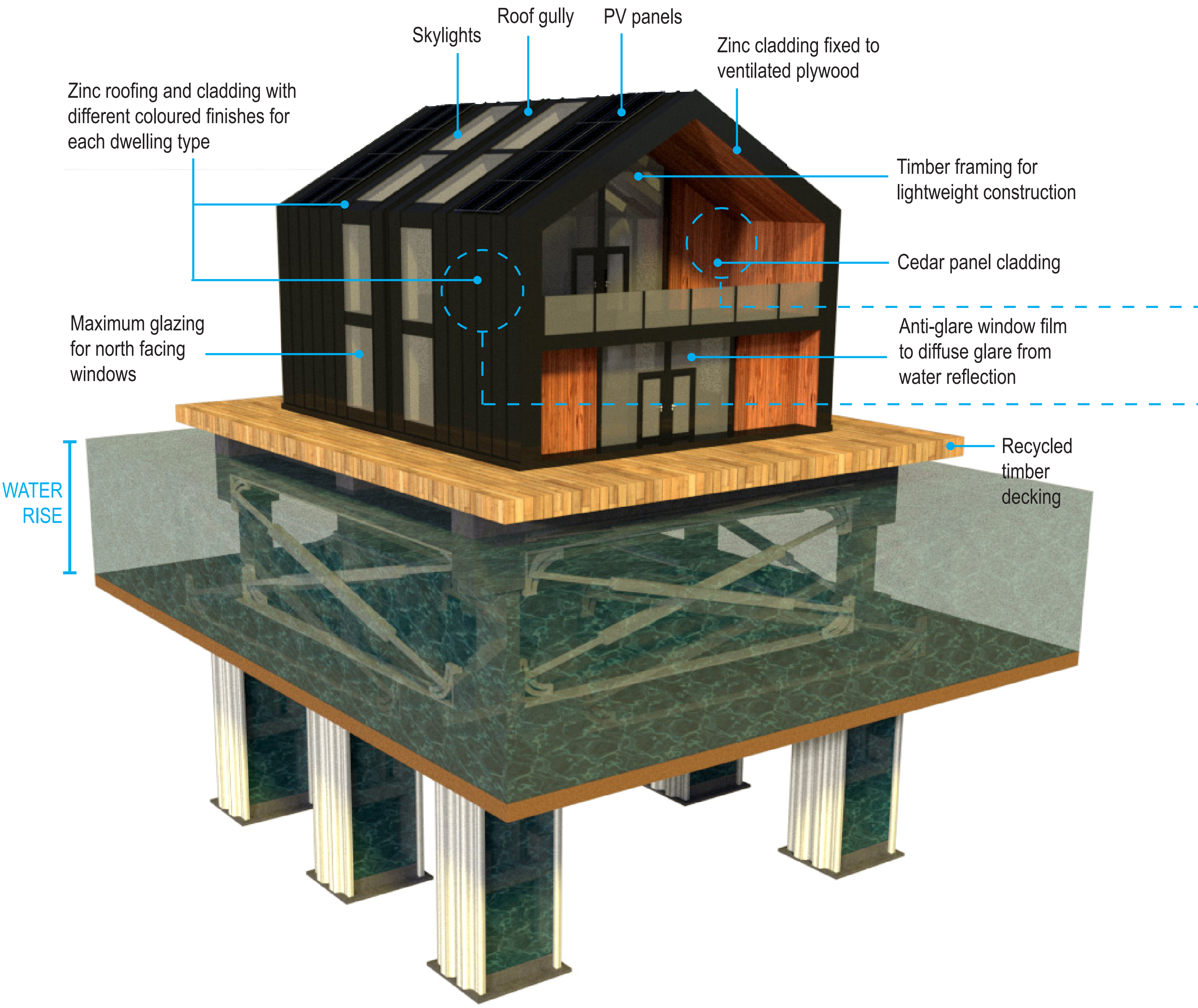
Maximum Rise



Due to the site being very exposed and open, tidal turbines may also not be the most appropriate way of generating tidal energy for this particular site. In order for these to work effectively, the water would need to be funneled in such a way, to provide a larger force on the turbines. The normal wave movements may not be enough to generate an adequate amount of energy and therefore would not add any value to the energy generation aspect of the design. Tidal energy generation design needs to be very site specific in order to work effectively. The chosen site, however, does not provide for adequate conditions to supply tidal energy and therefore this idea will be dismissed.

8.3. Sustainable Building Material Selection

Eco-Friendly Materiality Selection to Work with Site Conditions



The external material selection needs to be suitable for the conditions in which they are exposed to. This includes (and is not limited to) salt water resistance, weather resistance, lightweight, eco-friendly and sustainable. The two main external materials used within the design construct include zinc roofing and cladding, with different coloured finishes for each dwelling type and cedar panel cladding on the east and west facing sides. Utilising sustainable materials will help aid in the mitigation against climate change.

Cedar Cladding Advantages:

- Most weather-resistant timber
- Durable (used in boat making)
- Lightweight
- Sustainable
- Acts as insulation
- Resistant to moisture
- Aesthetically appealing
- Like all timber, is not affected by salt water (provided it is well maintained)

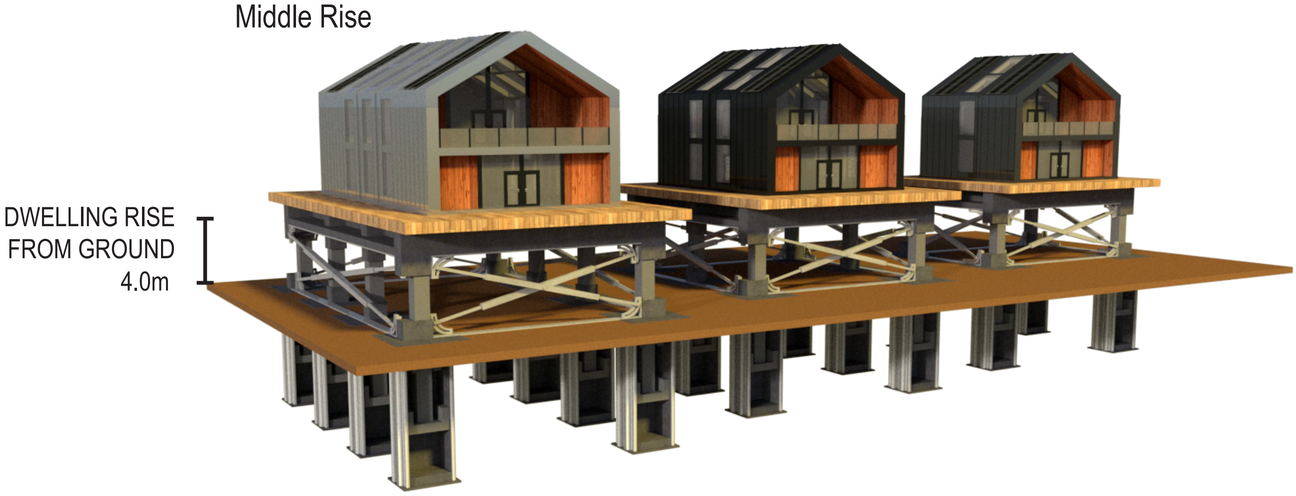
Zinc Cladding and Roofing Advantages:

- Natural resistance to salt water corrosion
- Excellent long-life durability
- Minimal maintenance
- Flexible and malleable
- Aesthetically appealing
- At least 95% recyclable (does not lose any of its properties)
- Eco-friendly
- Integrates well with solar panels

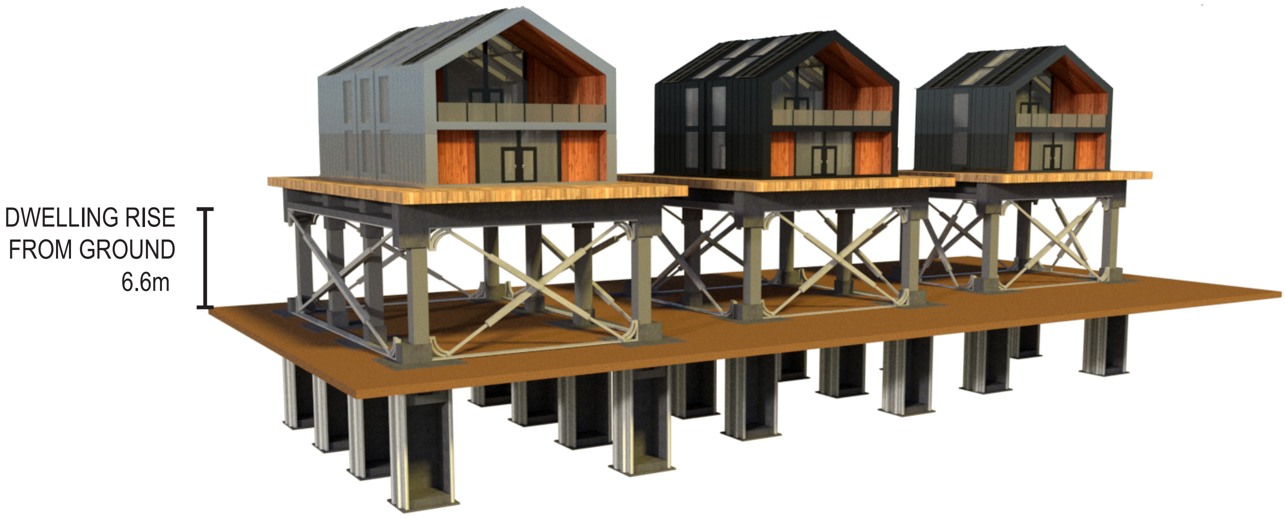
3 Dwelling Typologies

No Rise/ Minimal Rise

Middle Rise

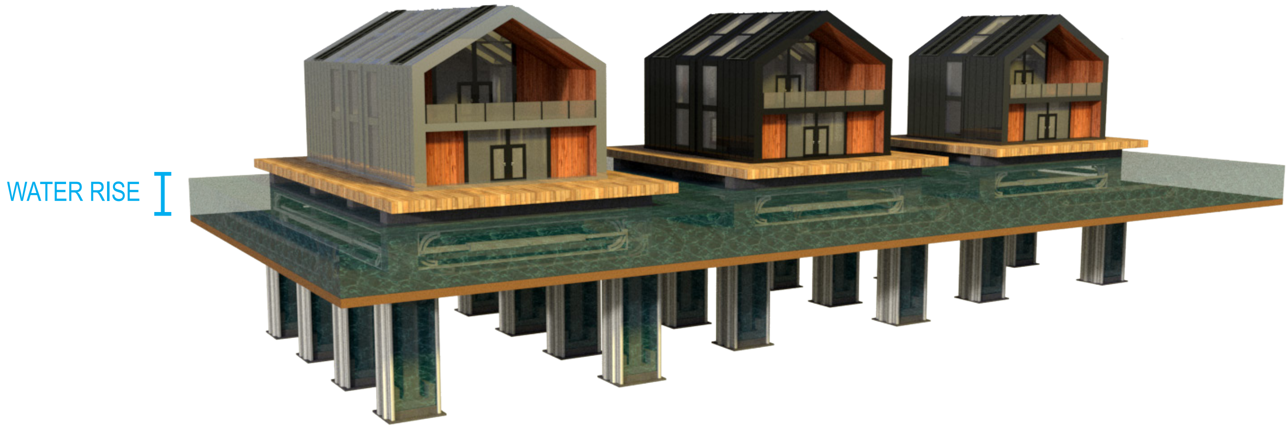


Maximum Rise

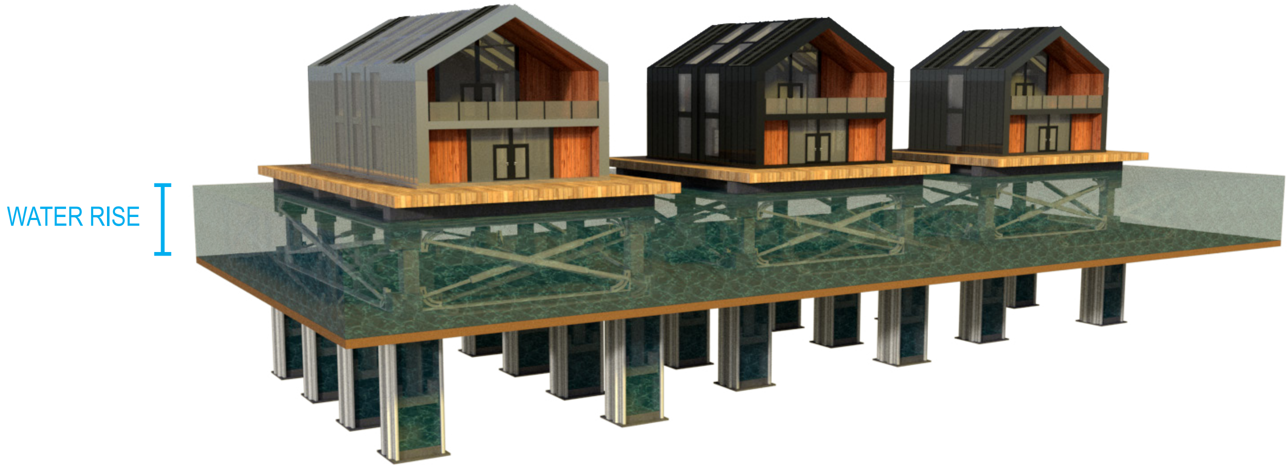


3 Dwelling Typologies

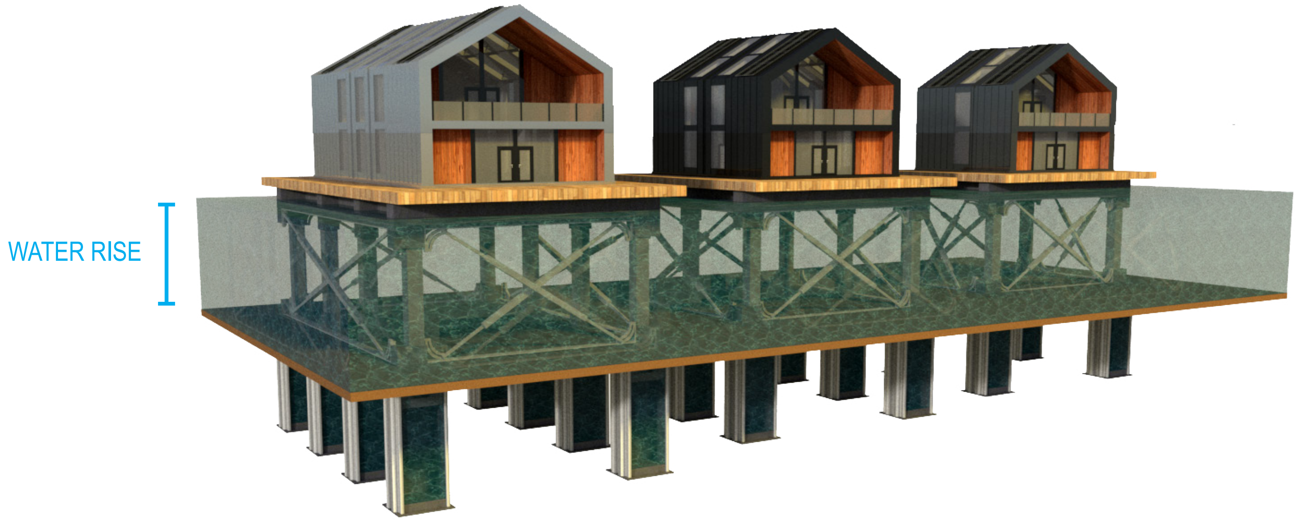
No Rise/ Minimal Rise



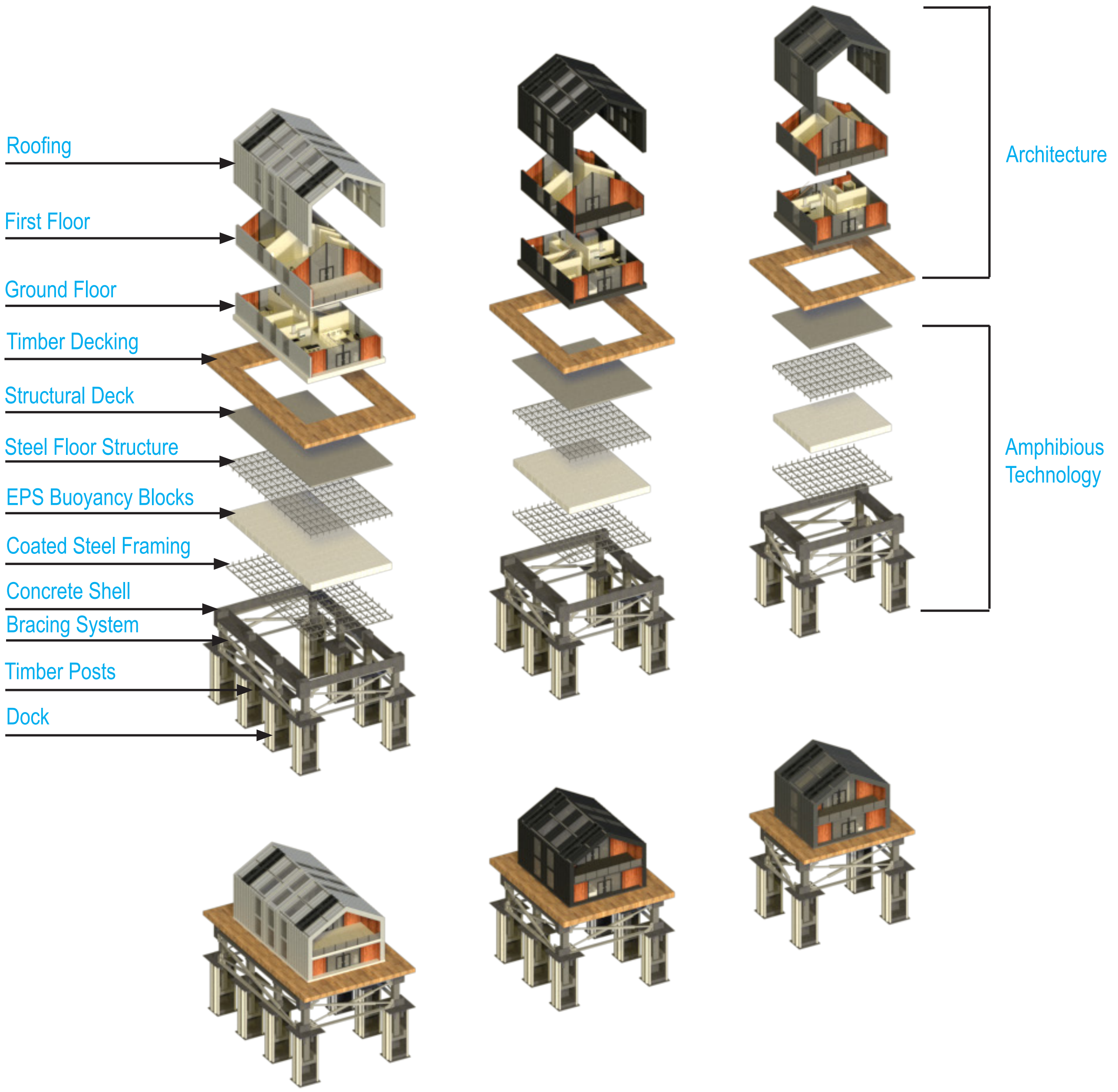
Middle Rise



Maximum Rise



3 Dwelling Typologies



8.4. Physical Modelling Final Design

Laser Cut Physical Model

A physical model of the two bedroom dwelling was created to test the ascend of the structure in water. The model was created with 3mm thick acrylic plastic and each piece was laser cut to the correct size to ensure the proportions are the same as what has been designed in theory. The windows, skylights and balcony were made from a frosted plastic material ensure these areas were also water resistant. The bracing connections were created with pins at the connections to provide the relative rotation in order for the structure to extend through a scissoring effect, as the water rises.

Front View

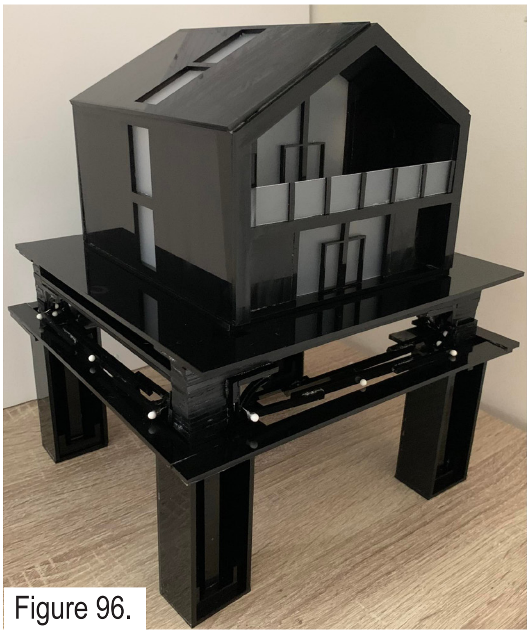


Figure 96.

Back View

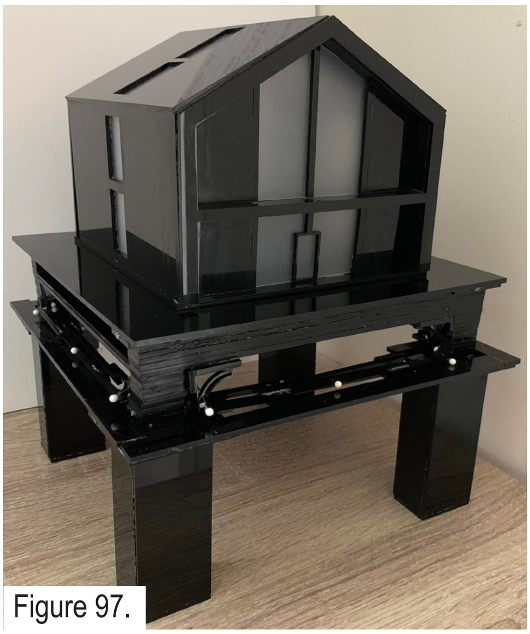


Figure 97.

Physical Model

The model was tested in water at three different sea level rise scenarios. The first is at minimal rise. This is the maximum height the water can rise to before the dwelling begins to float. The second is middle rise. This is the midpoint that the dwellings can rise to. The last is Maximum rise. This is the maximum that the dwelling can rise to. When testing the model in the water, The bracing system worked very effectively underwater and had no issues when extending with the structure as it arose in the water. Th ascend of the entire structure was very stable and balanced and therefore the design considerations in the design were successful.

Minimal Rise

Figure 98.

Middle Rise

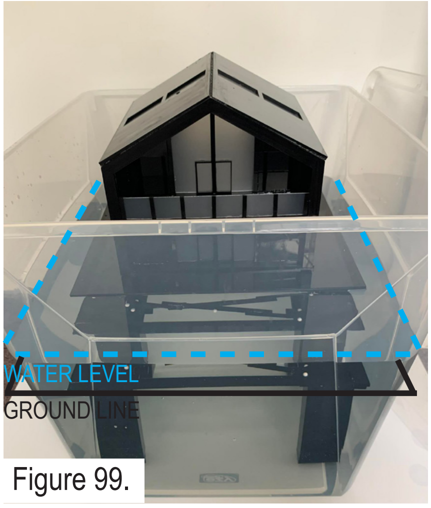


Figure 99.

Maximum Rise

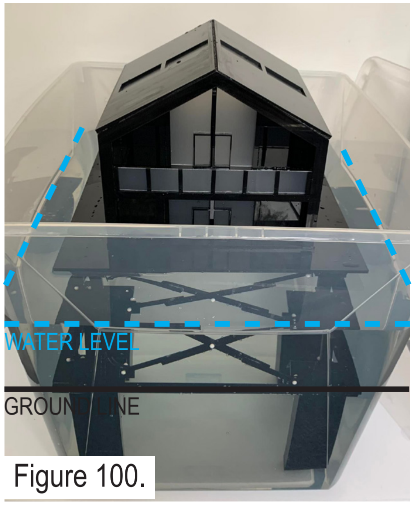
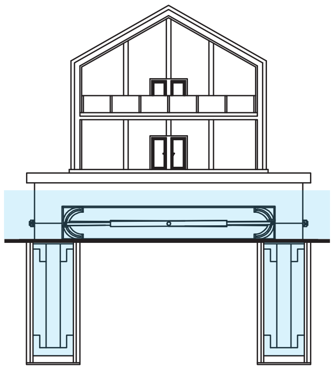


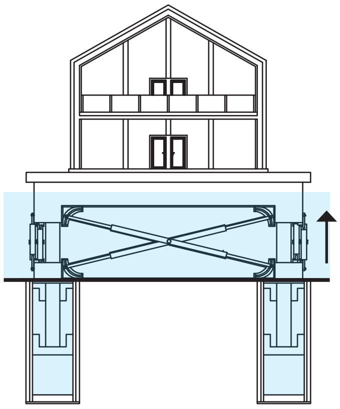
Figure 100.

Testing Model with Water Rise

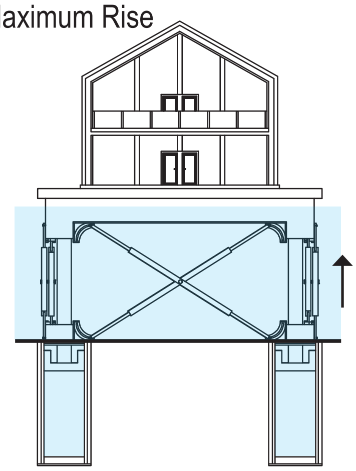
Minimal Rise



Middle Rise



Maximum Rise



Minimal Rise

Figure 101.

Middle Rise

Figure 102.

Maximum Rise

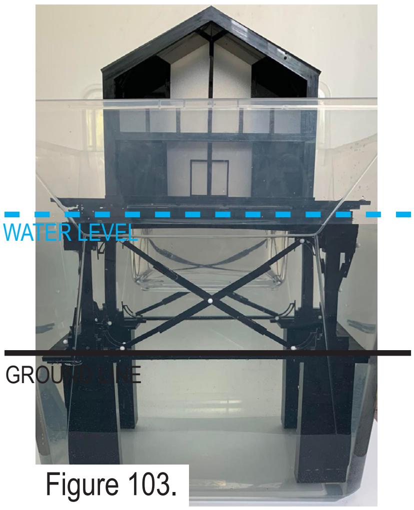
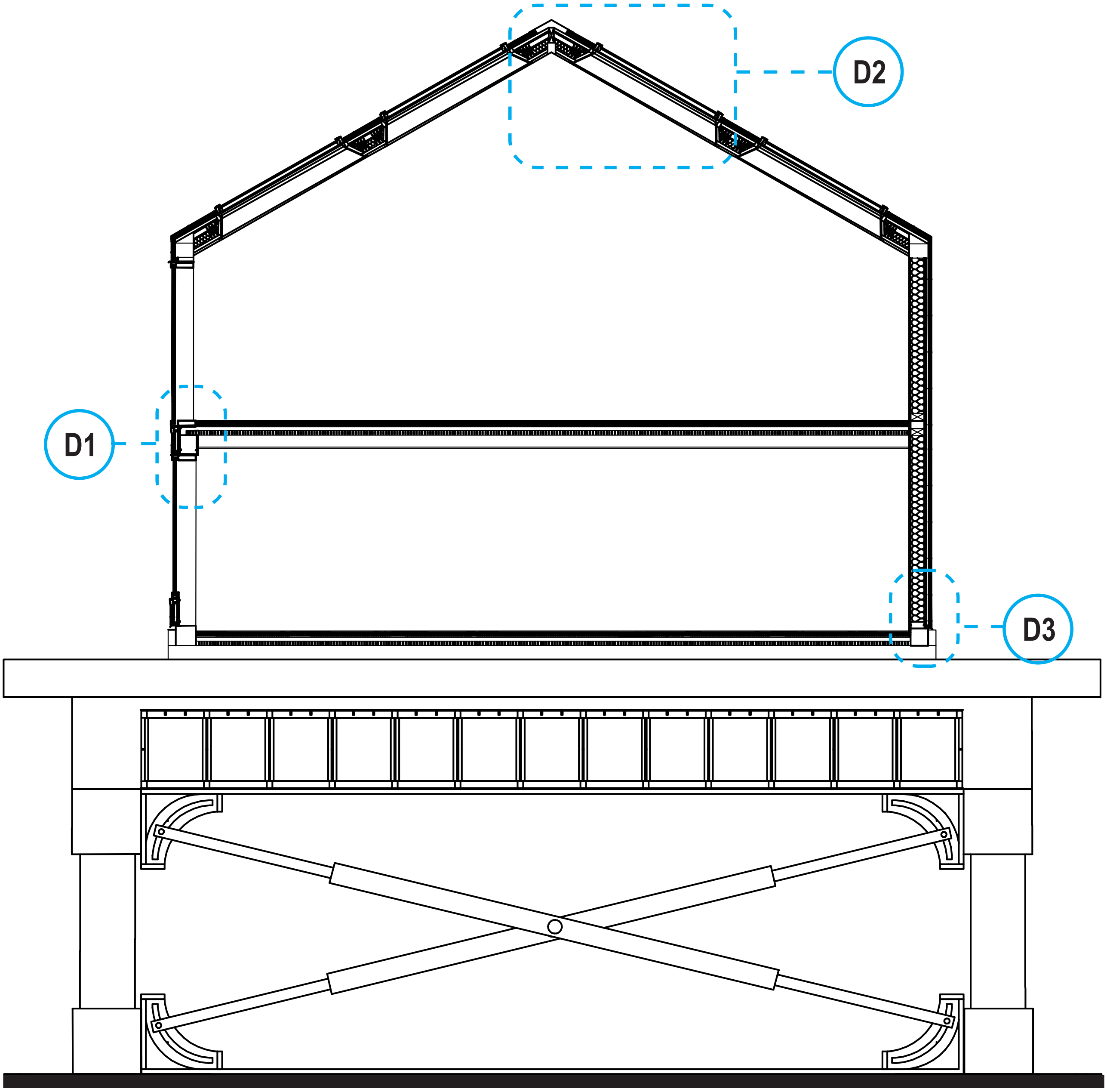


Figure 103.

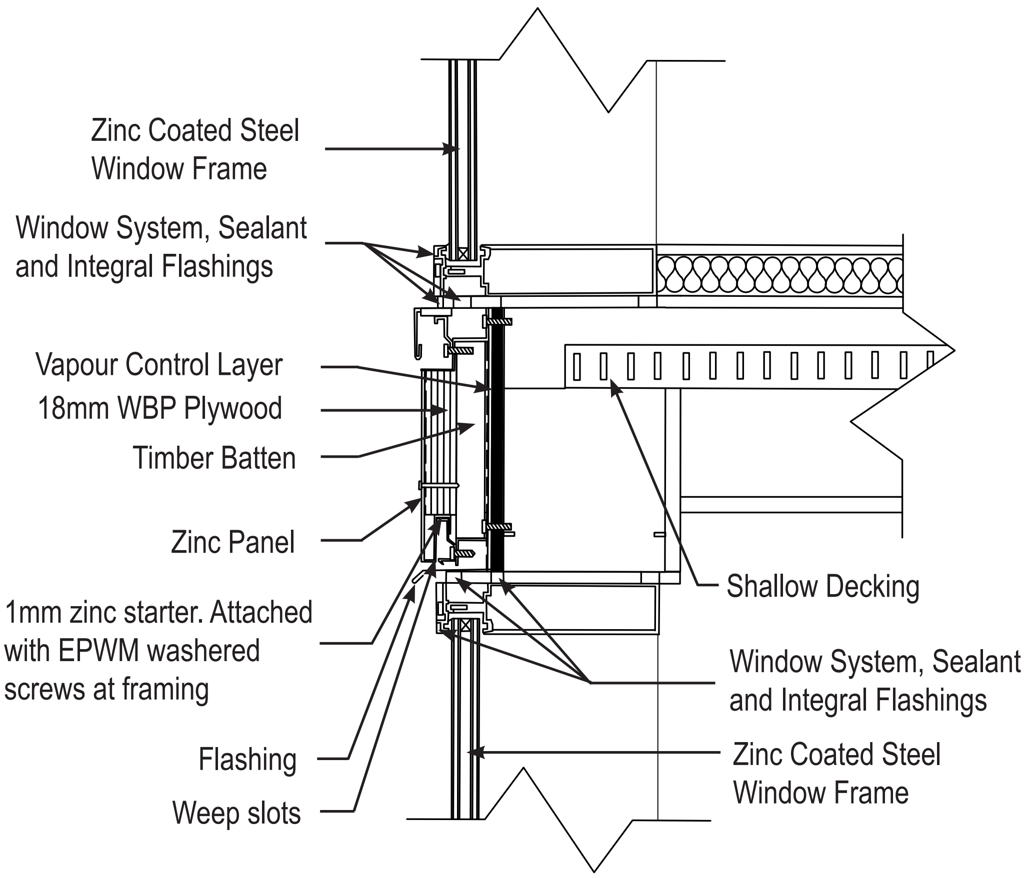
8.5. Section with Details



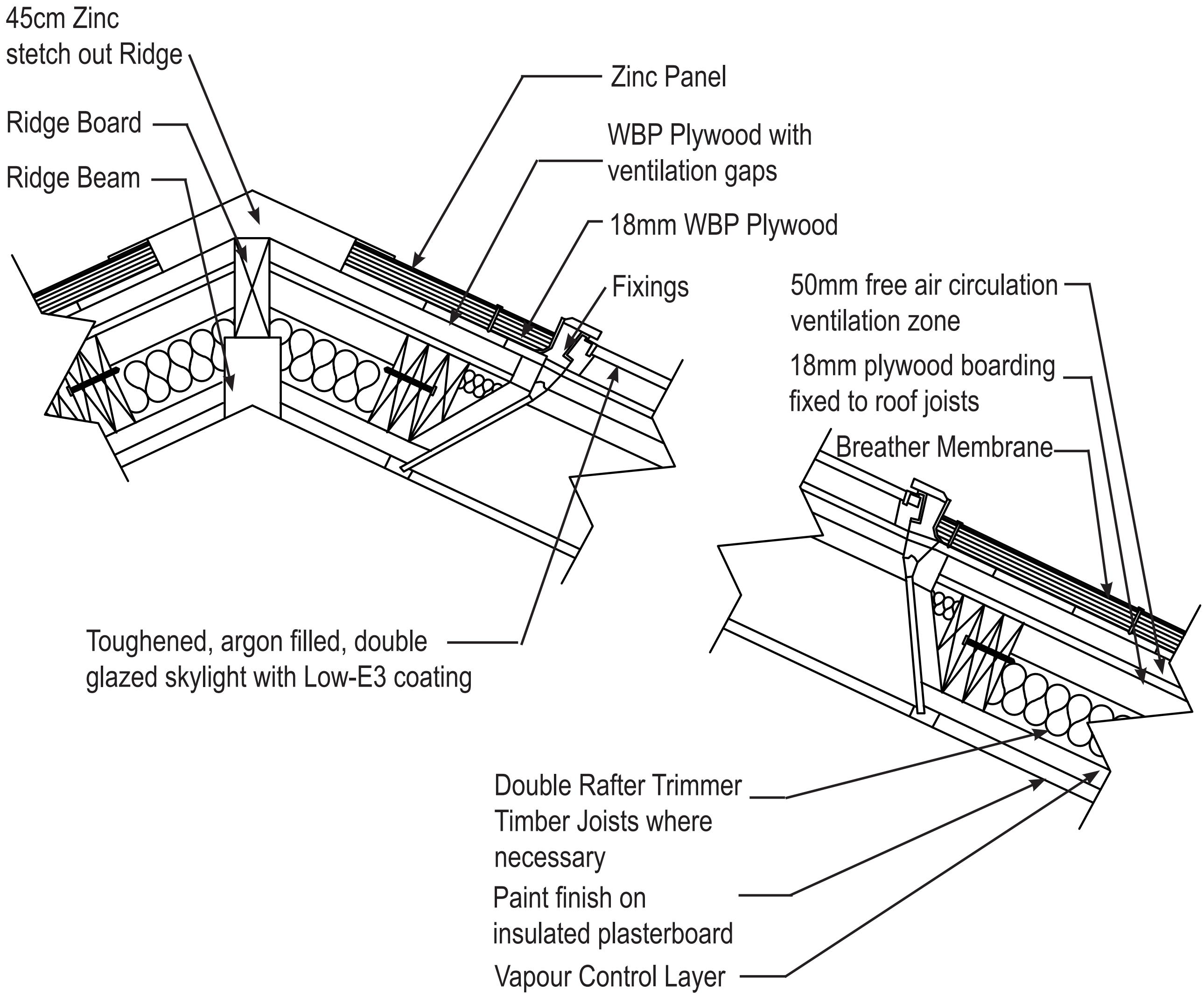
D1

Wall/ Window/ First Floor Junction Detail, 1:5

Window Sill, Window Head, Wall and First Floor Connections

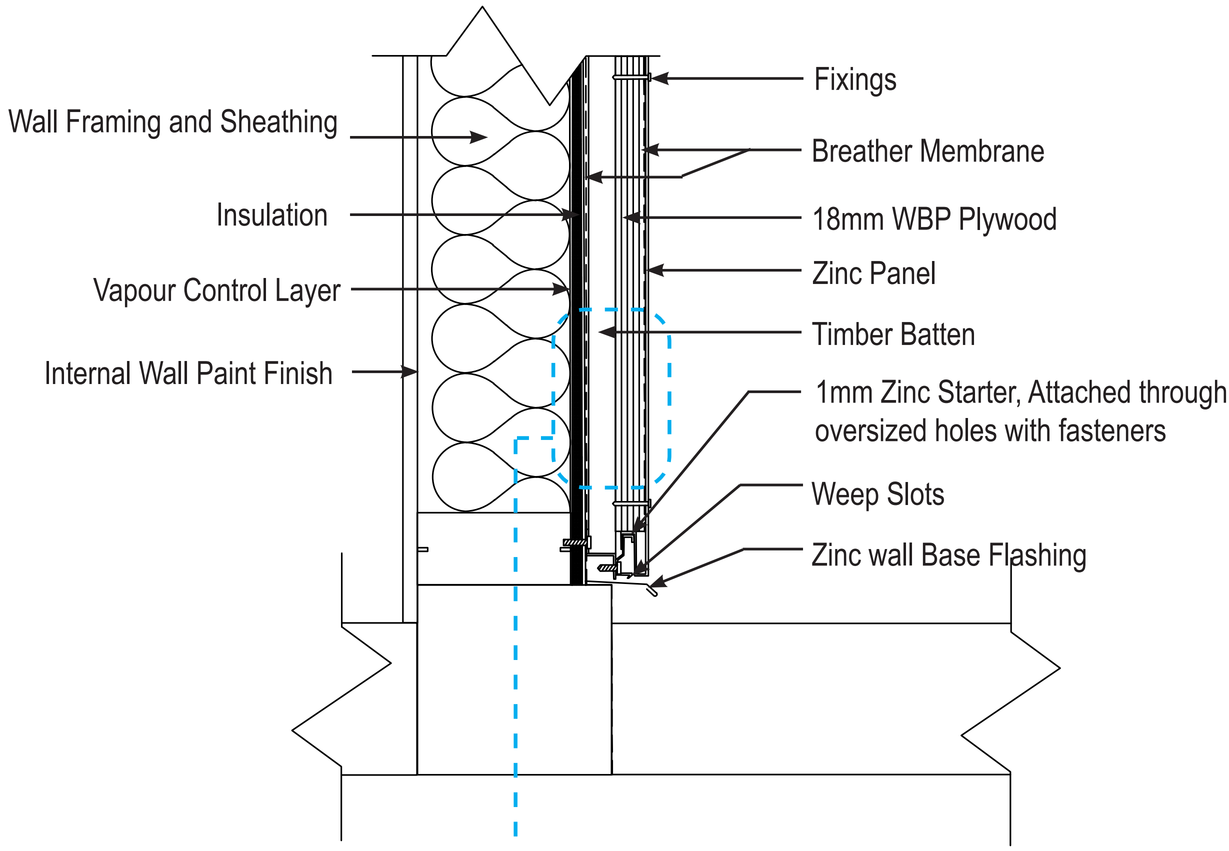


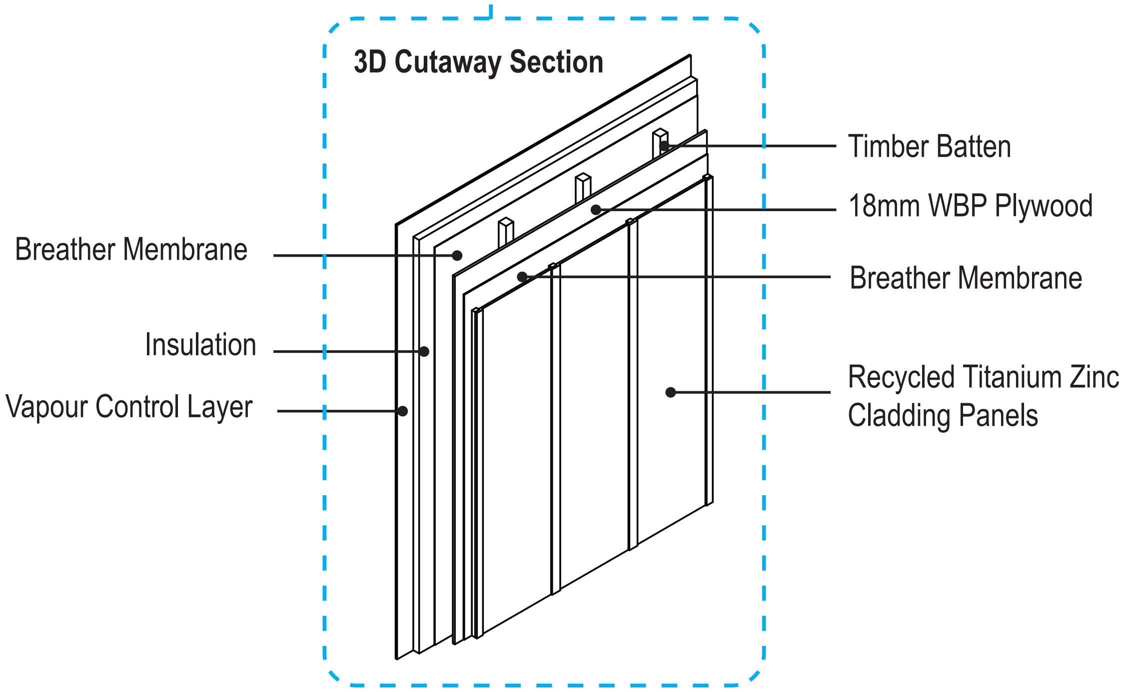
D2 Skylight Integration Detail with Ridge, 1:5



D3 Base of Wall Flashing Detail, 1:5

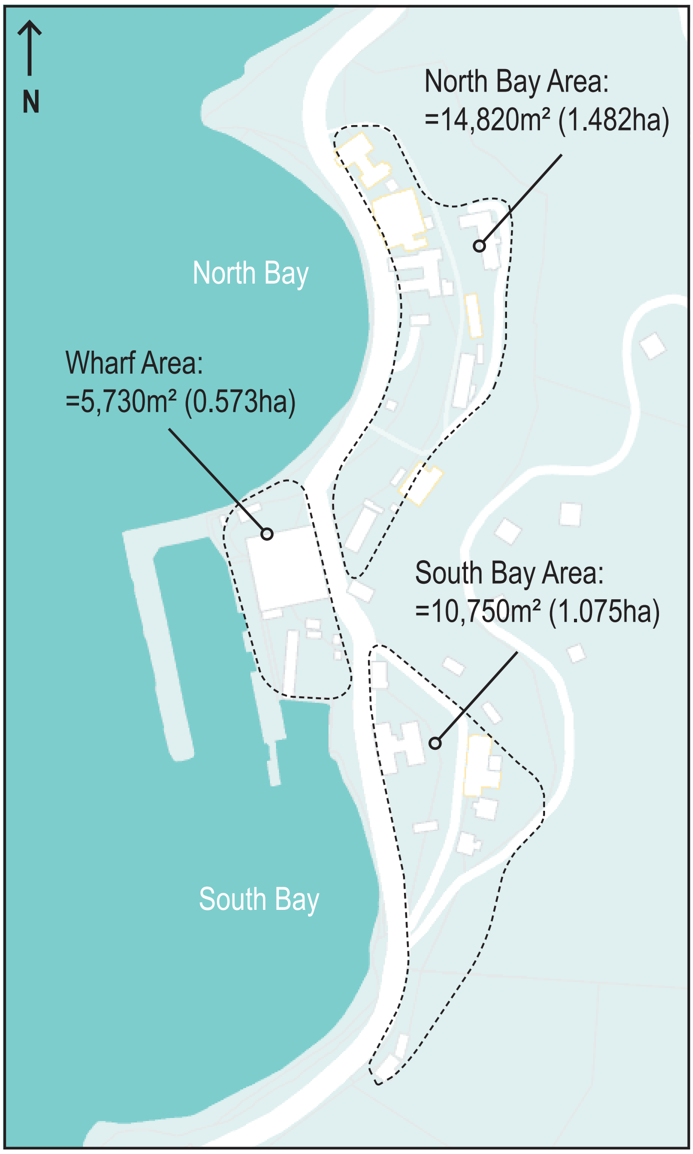
Zinc Cladding on Ventilated Plywood





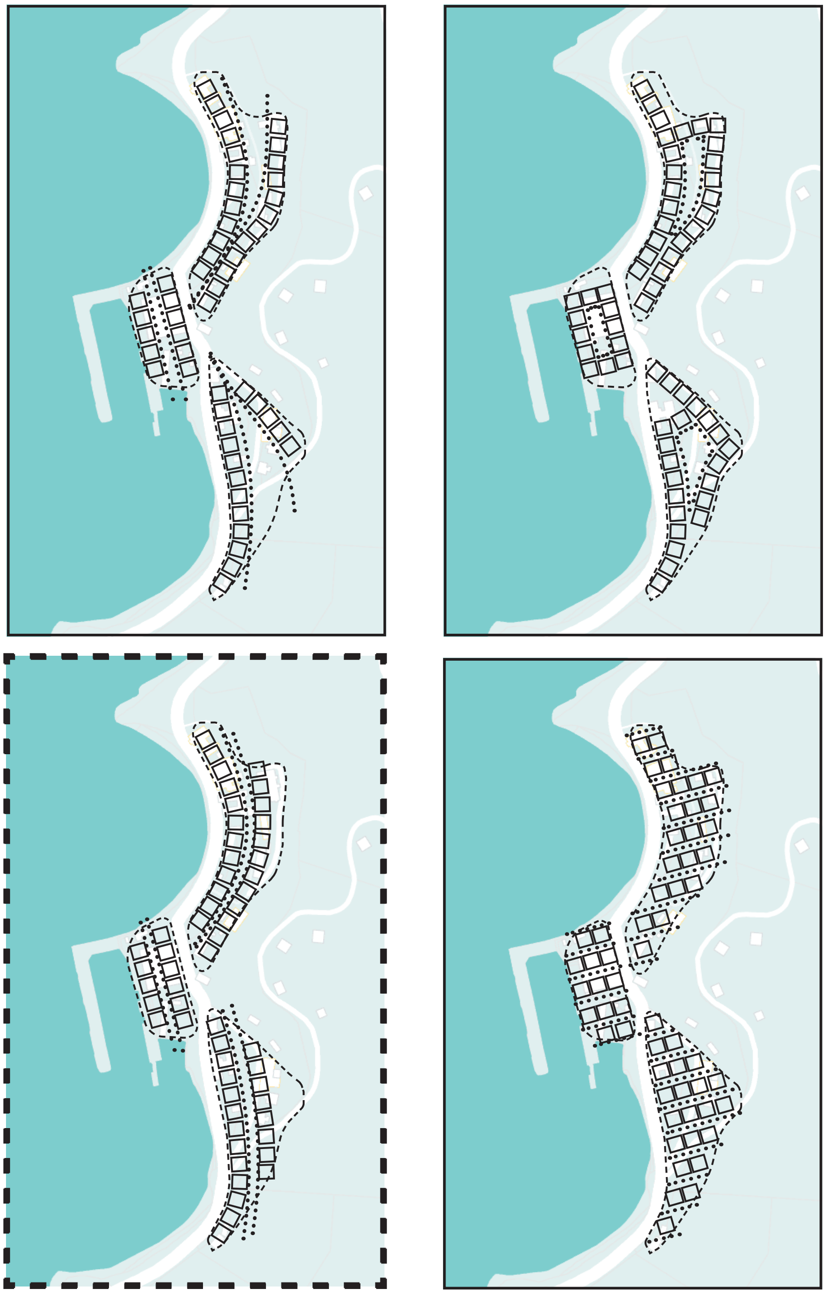
8.6. Dwelling Placement on Site

The three flat areas of Shelly Bay are the areas in which the housing will be situated on. The three flat areas consist of the north bay area (1.48ha), the south bay area (1.08ha) and the wharf area (0.57ha).



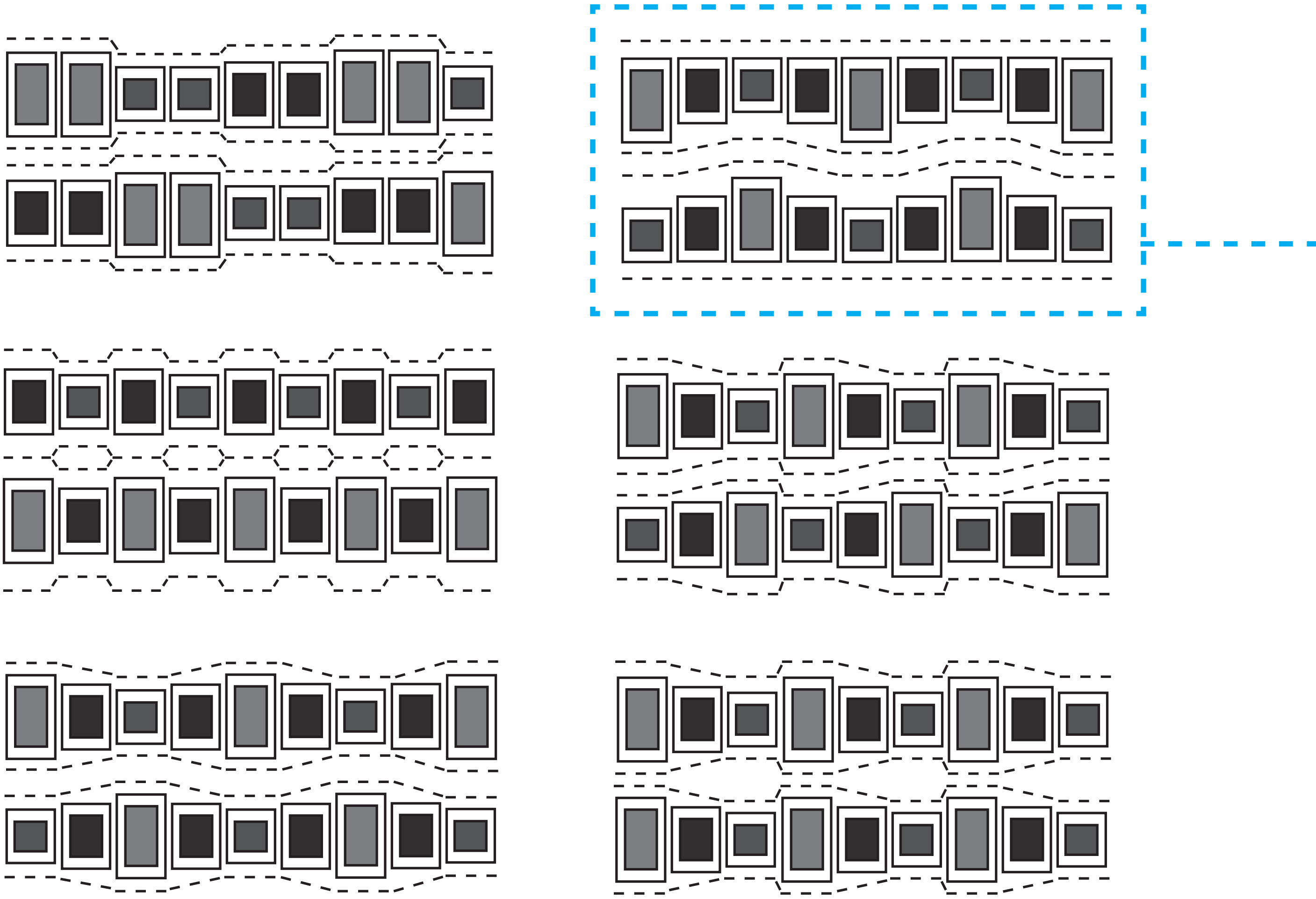
Exploring Different Urban Alignment Options to Maximise Space

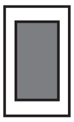
Different urban alignment configurations and dwelling placements were explored on the site to maximise the space available, whilst still considering spaces between the dwellings for access and general movement. The third option was deemed to be the most appropriate to move forward with. The way in which the dwellings follow the shape of the two bays provides for excellent views over looking the water, and having two rows of dwellings provides less housing density and more space between the dwellings, so when the sea levels begin to rise, those spaces would accentuate that watery context.

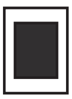


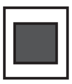
Exploring Dwelling Alignment Configurations

Working with the three different sized dwelling shapes, various dwelling alignment compositions were explored. Aligning the dwellings to create a wave like pattern between the two rows of dwellings and aligning the ends to make for a linear front edge was the most fitting to work with on the site.



 = 4 Bedroom Dwelling

 = 3 Bedroom Dwelling

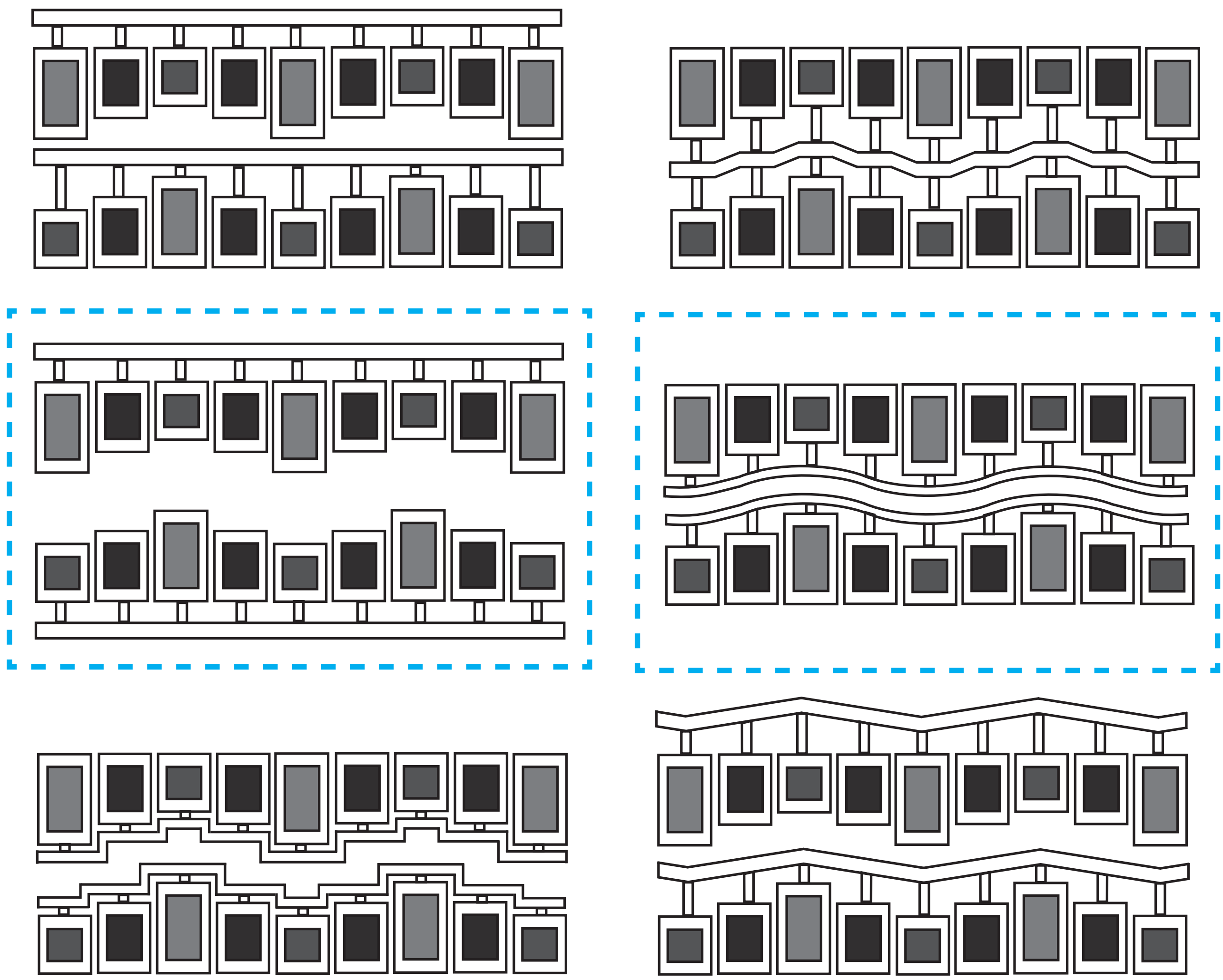
 = 2 Bedroom Dwelling

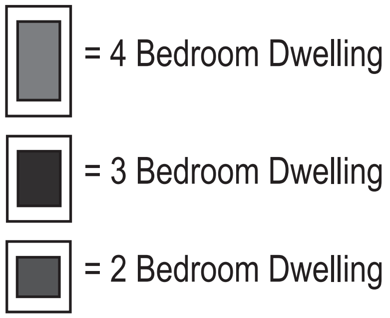
Site Plan

Site Plan

8.7. Floating Jetty Design

Working with the chosen dwelling alignment composition, various floating jetty access ways were explored to provide different experiences when moving between the dwellings. The two options considered to work the most with the dwellings alignment are the third and fourth options. Both were explored on the site plan.



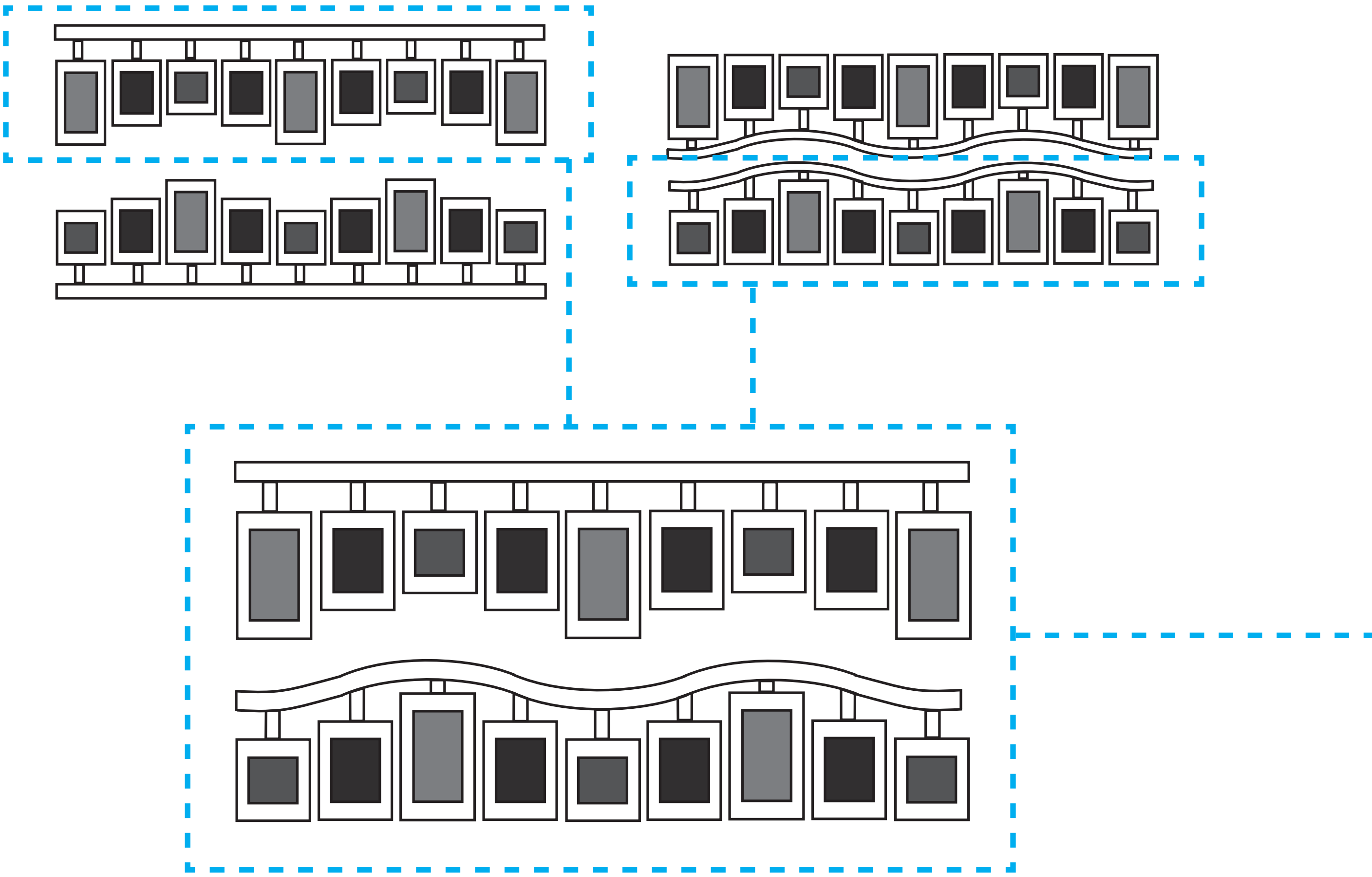


Site Plan - Jetty Option One

Site Plan - Jetty Option Two

Floating Jetty Design

The linear jetty option obstructed the views of the water from the front row of dwellings, whilst the wave jetty option seemed to make the space between the two rows of dwellings appear smaller and confined. A hybrid of the two was established and solved both of those issues. This jetty design works more cohesively with the dwellings alignment, whilst remaining unobstructive from the first row of dwellings and provides for a larger space between the two rows of dwellings.



Site Plan - Jetty Hybrid of Two Options

Design Critique Two: 6 month progress review - 16 September 2021

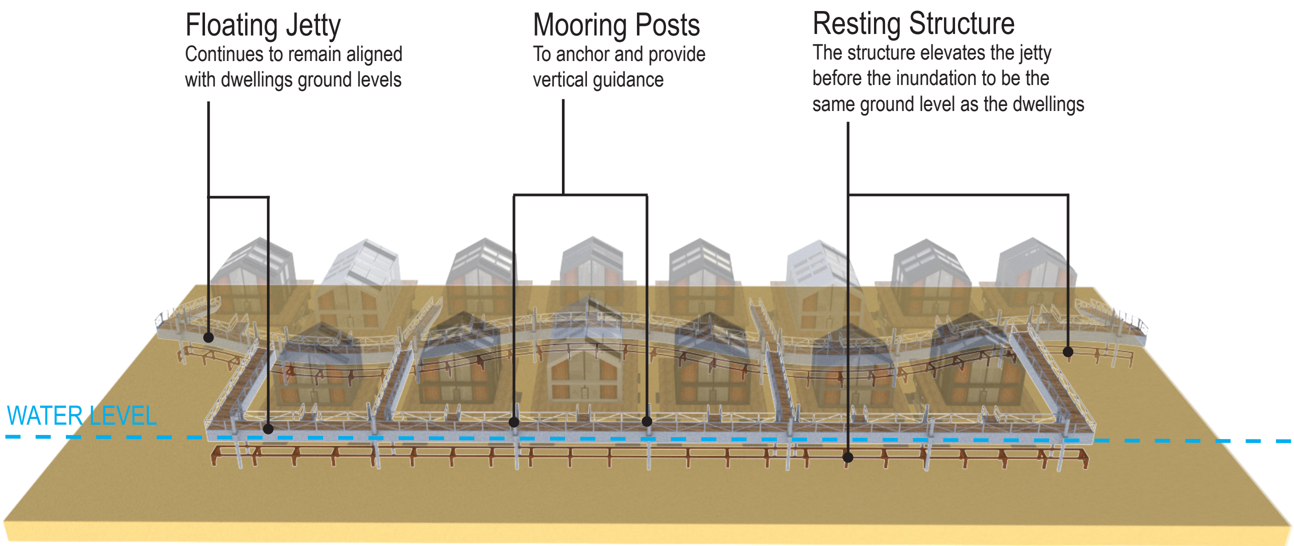
Own Critique Based on Review Comments:

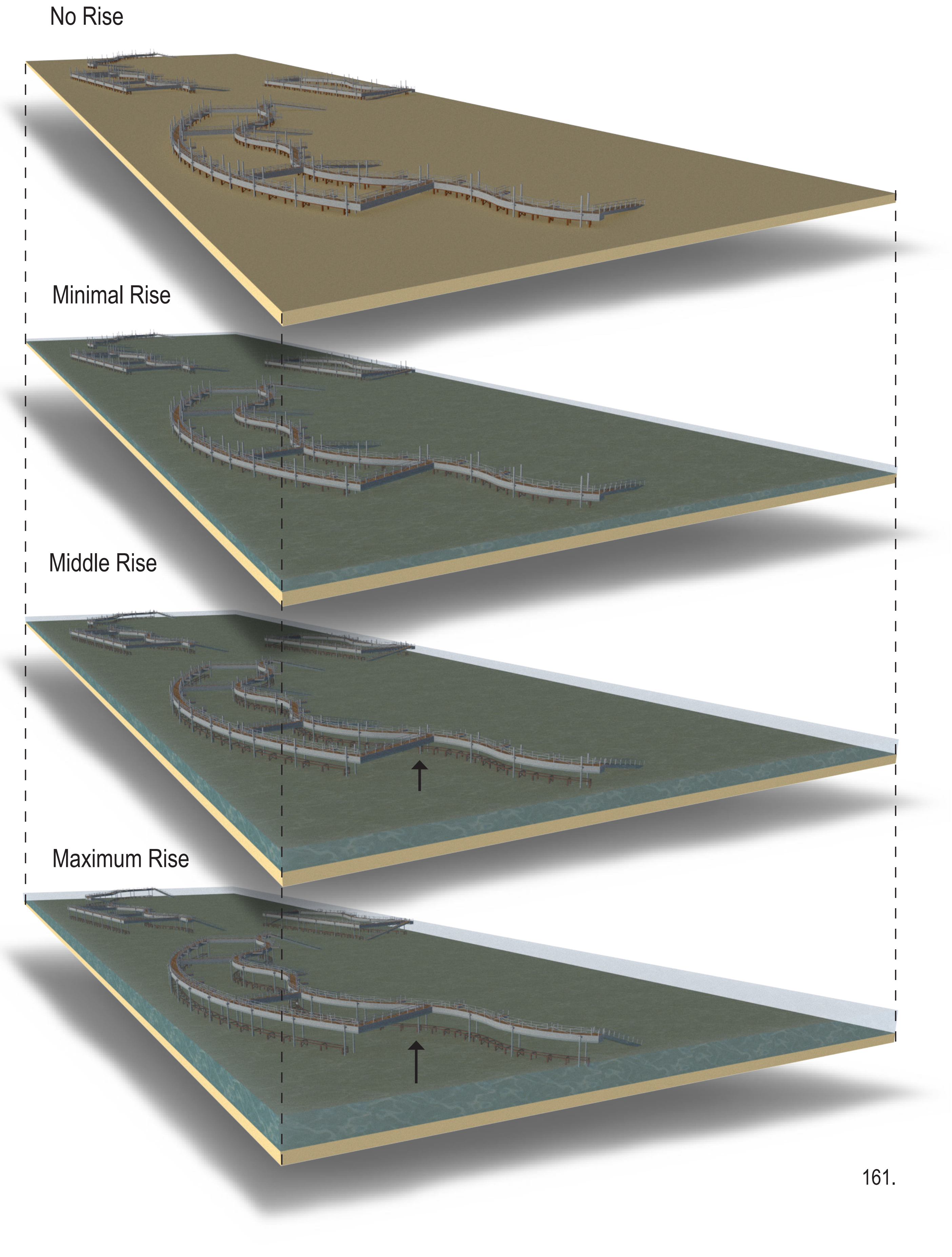
At this stage, a well informed research project is evident and is easy to engage with. The project research and design provides a clear understanding of how we can learn to increase housing density with less land. Through the sustainable and ecological considerations, the design provides a compelling new way of living in the environment through a low carbon way of living. A lot of design progress has been made since the previous review. Some areas in the literature review, however, may need more defining and research. Defining this idea of “attack” a little bit more with several more references outlining this strategy as an opportunity would make for a stronger argument. Also more refinement on why some design choices were made were not very strong in the presentation. Going back and clarifying these choices will show the iterative development through the design.

Floating Jetty Design

The floating jetty access ways rest on structures to elevate the walking level to be the same height as the timber decking that surrounds the dwellings. This is done so by utilising ramps that rotate at the connection to accommodate the varying height levels as the water rises and falls. In doing this, once the sea levels begin to rise, the jetty constantly remains at the same height as the dwellings ground level. These ramps however, would eventually become submerged underwater and therefore would transition from a dry access way, to a platform that swimmers and kayakers can use to decend and ascend into and out of the water.

Once the waters have risen enough to cover the surface of the land, the road and footpaths would become completely underwater and a new means of access would need to be considered. In the future, a new road could potentially be built higher up on the hill to provide an adequate way of access. Once the buildings and jetties are floating, they become four island like areas, that would require access via a water vehicle, whether that be a water taxi, a ferry service or individual kayaks and boats.



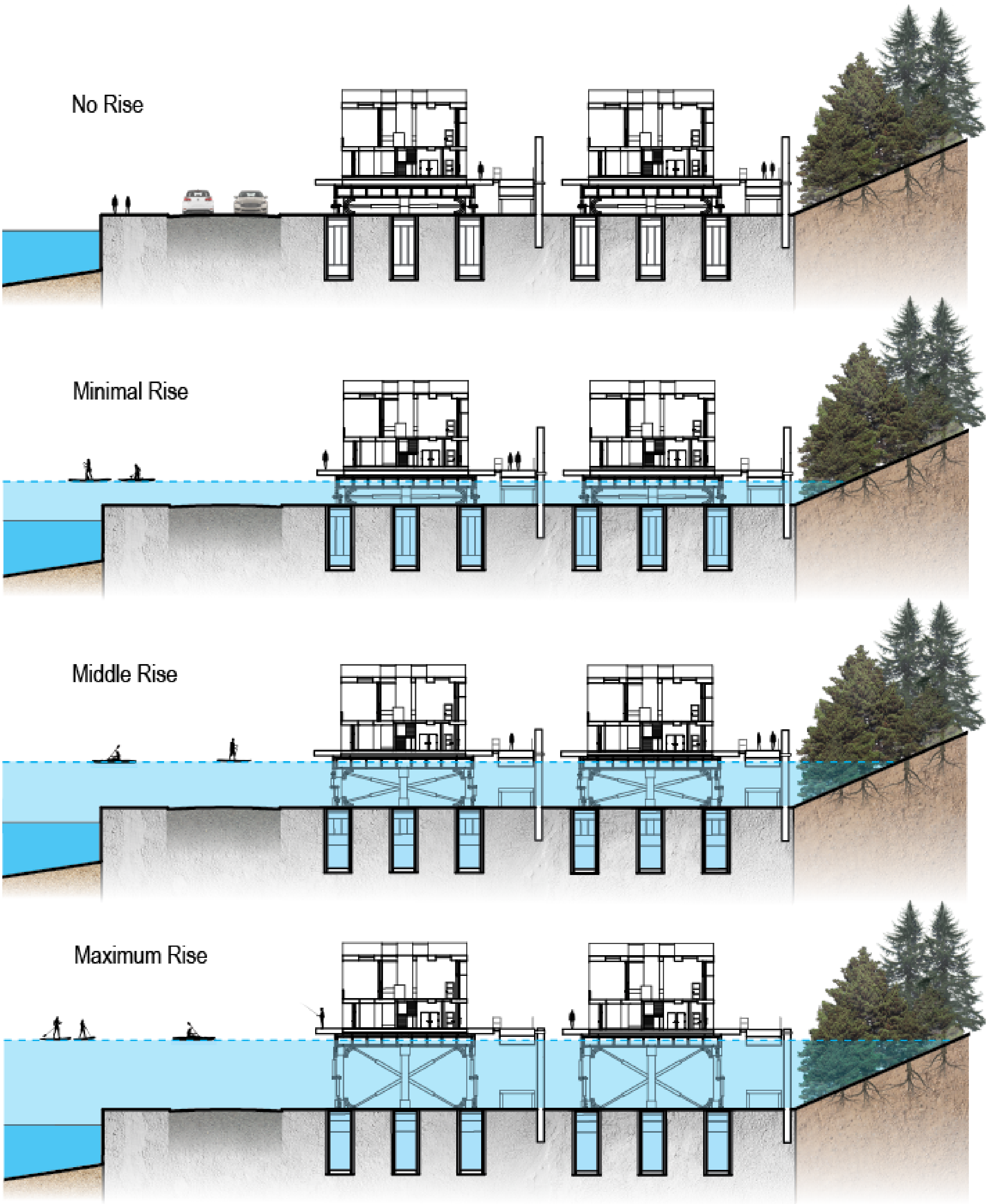

No Rise
Minimal Rise
Middle Rise
Maximum Rise

Site Plan

Current Site Plan

Site Plan with Water Rise

Contextual Site Sections A'A



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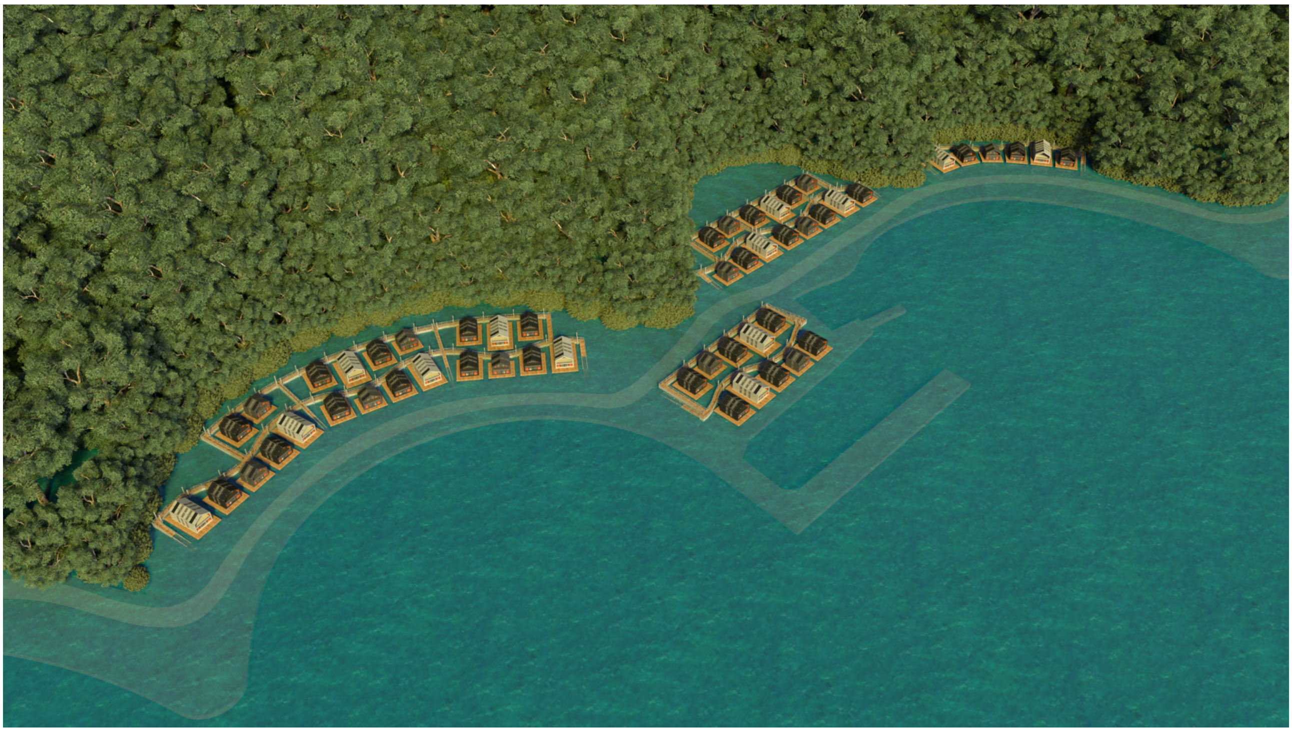
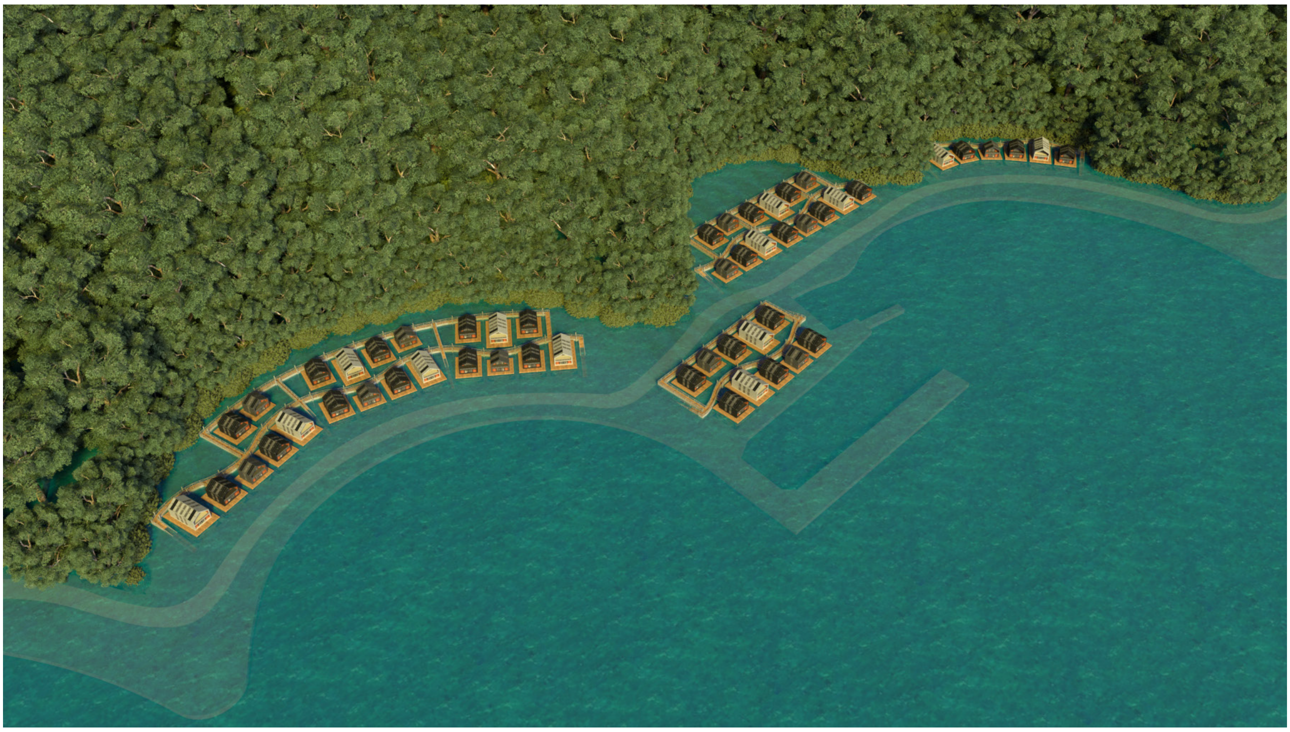
9.1. Renders of Dwellings on Site

No Rise (0m)

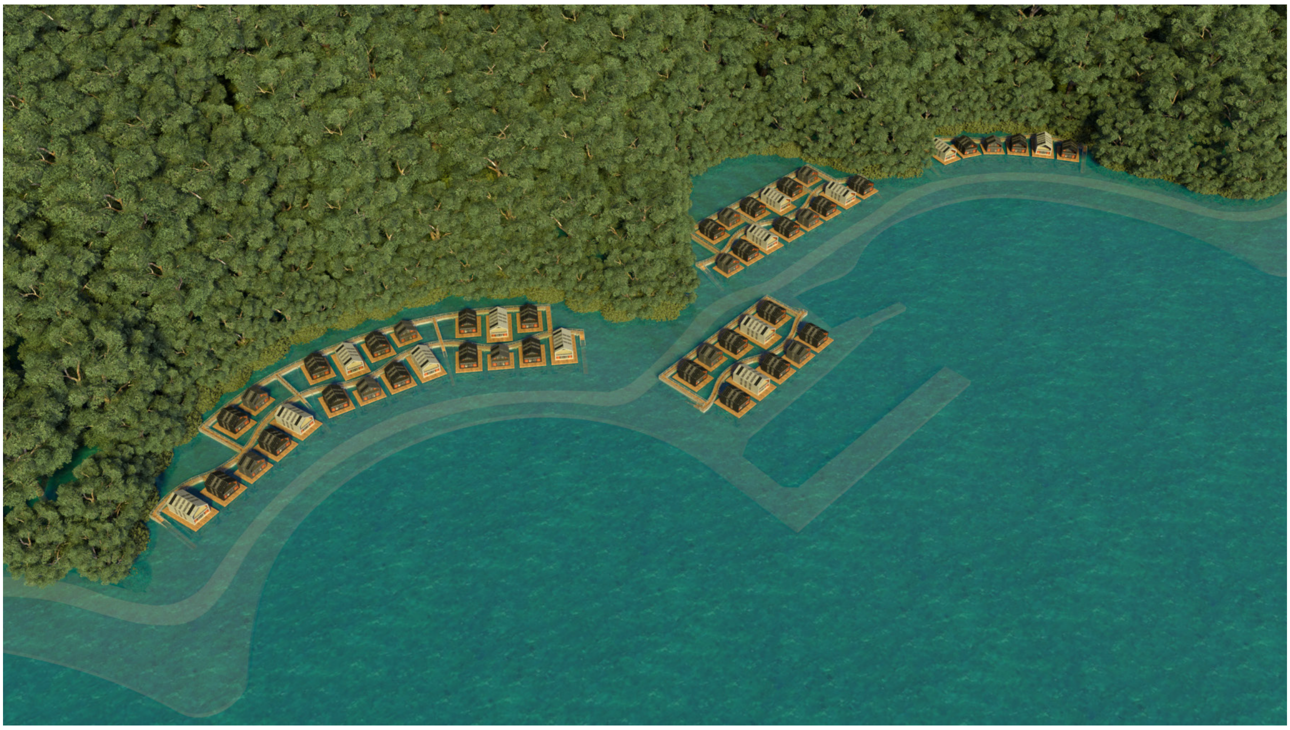
Minimal Rise (1.7m)



Middle Rise (4m)



Maximum Rise (6.6m)



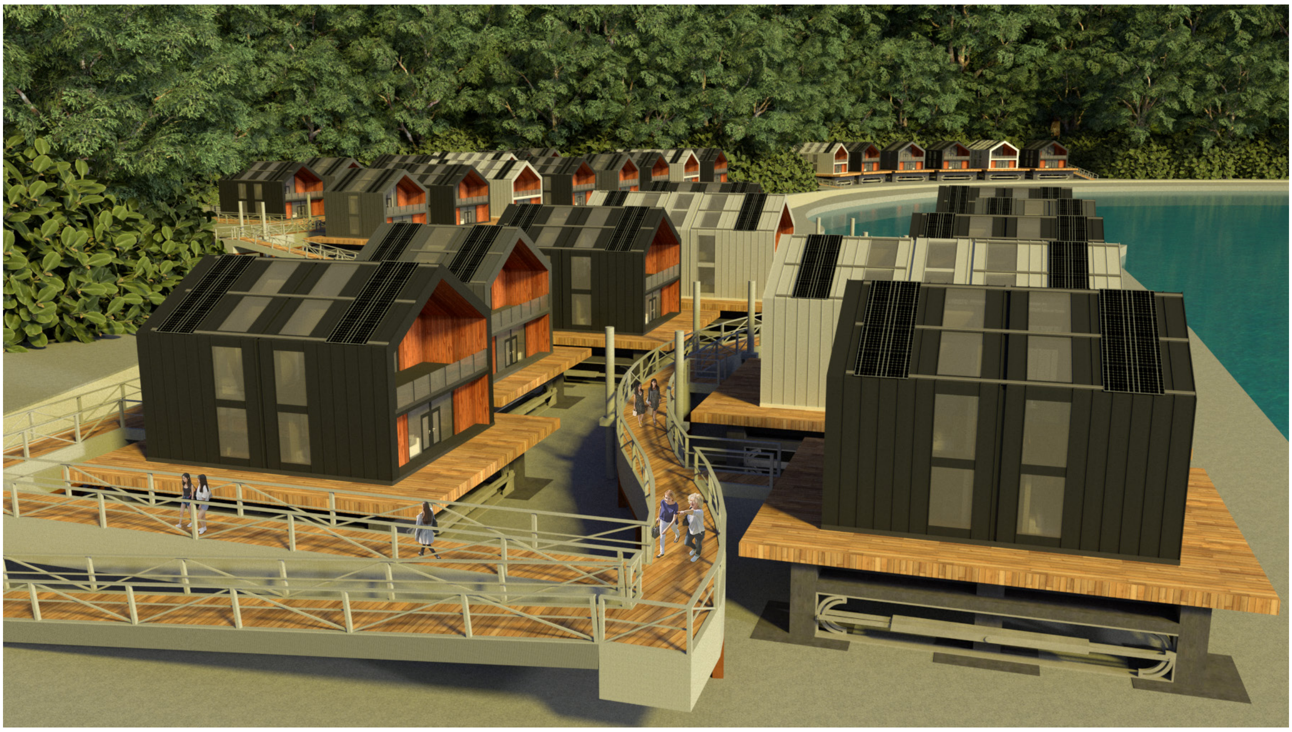
No Rise (0m)

Minimal Rise (1.7m)

Middle Rise (4m)

Maximum Rise (6.6m)

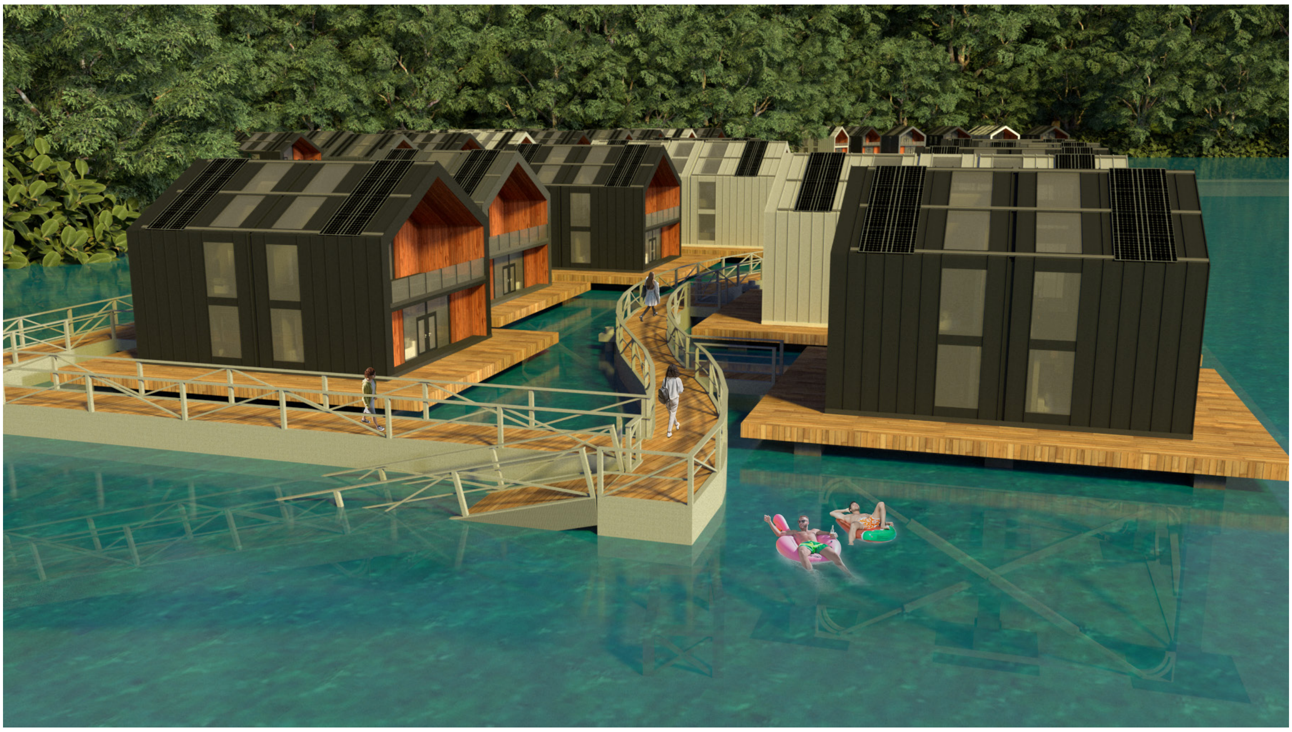
No Rise (0m)



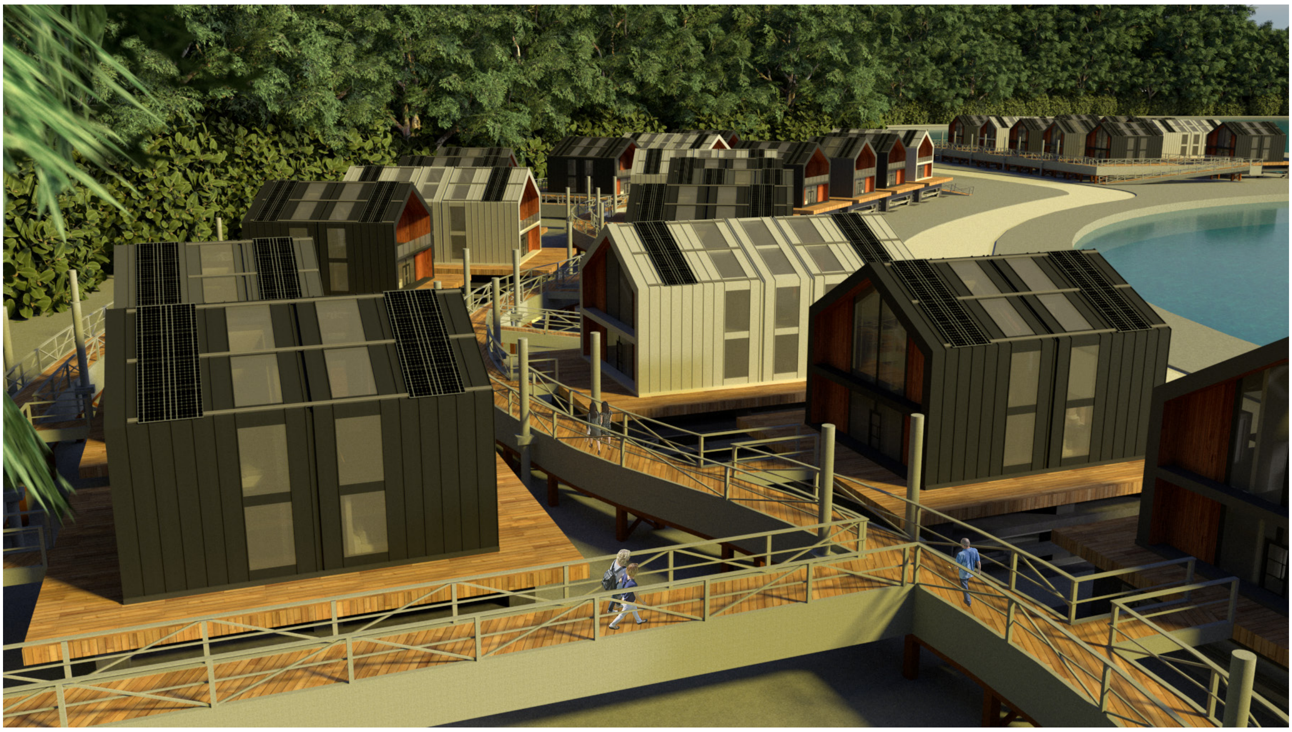
Minimal Rise (1.7m)

Middle Rise (4m)

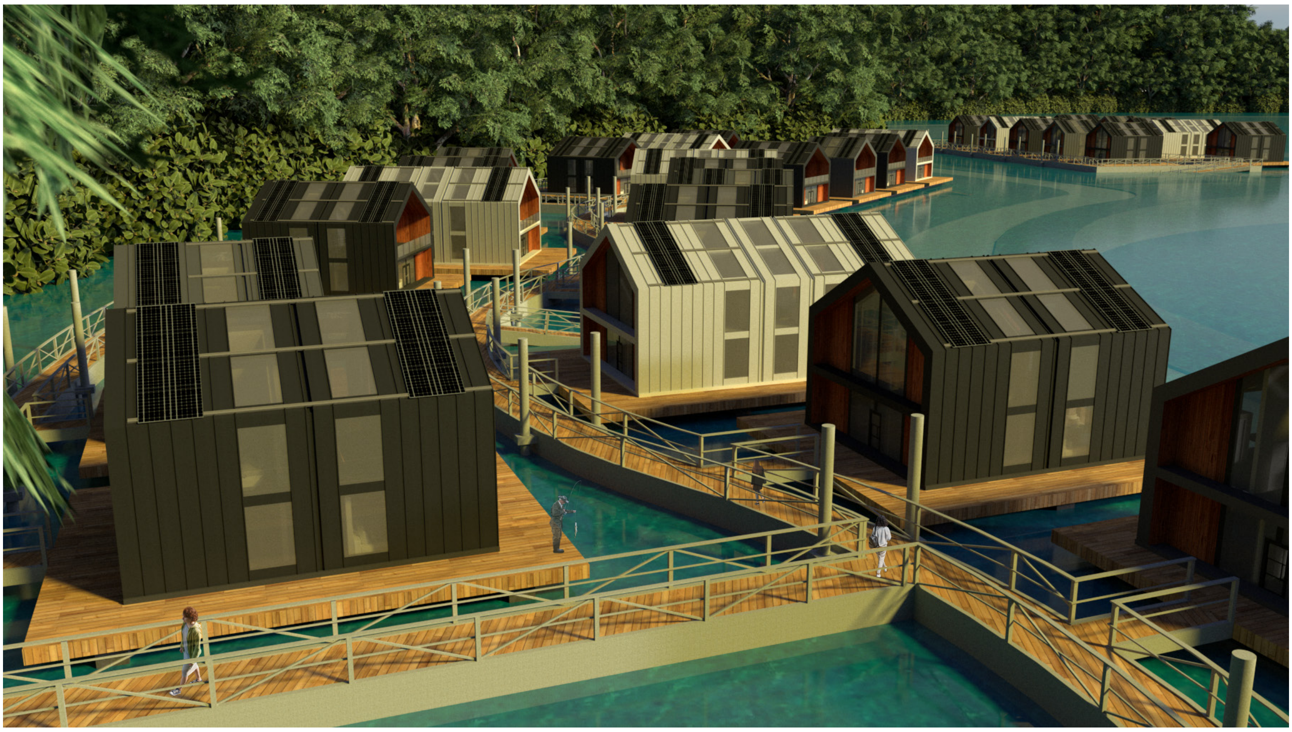
Maximum Rise (6.6m)



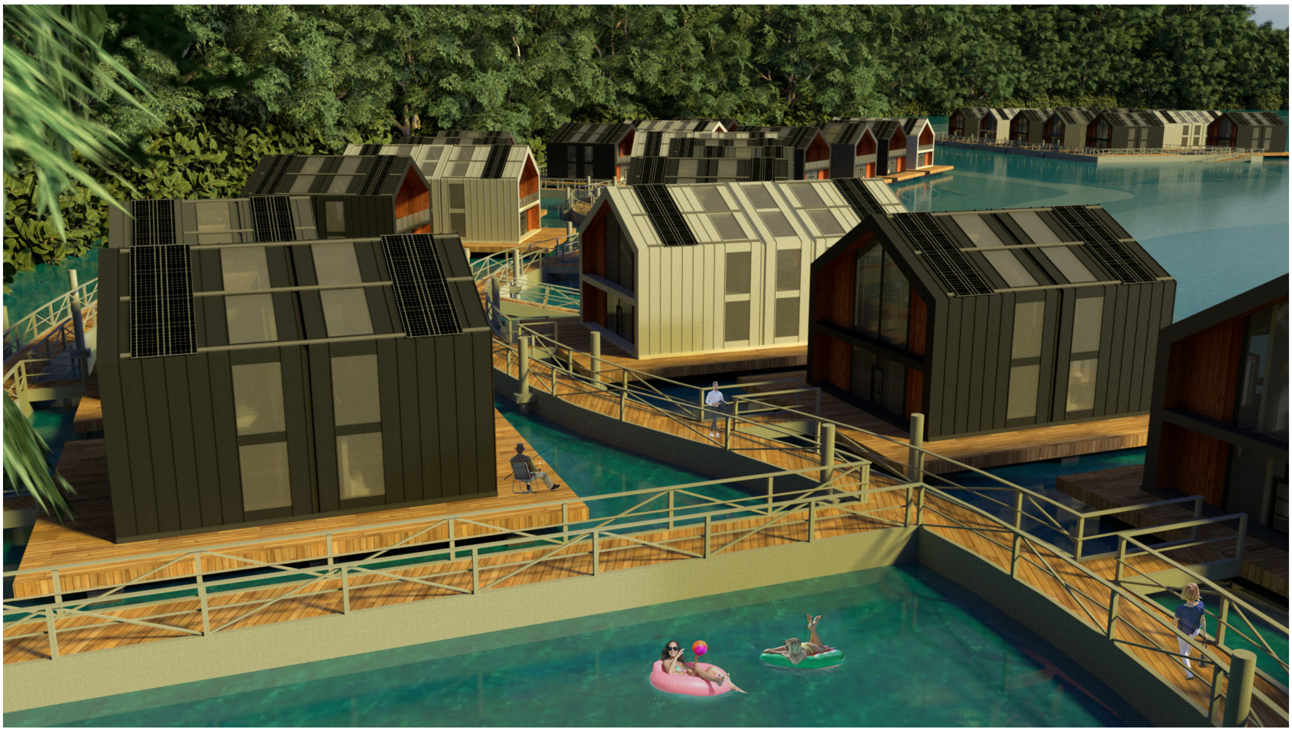
No Rise (0m)



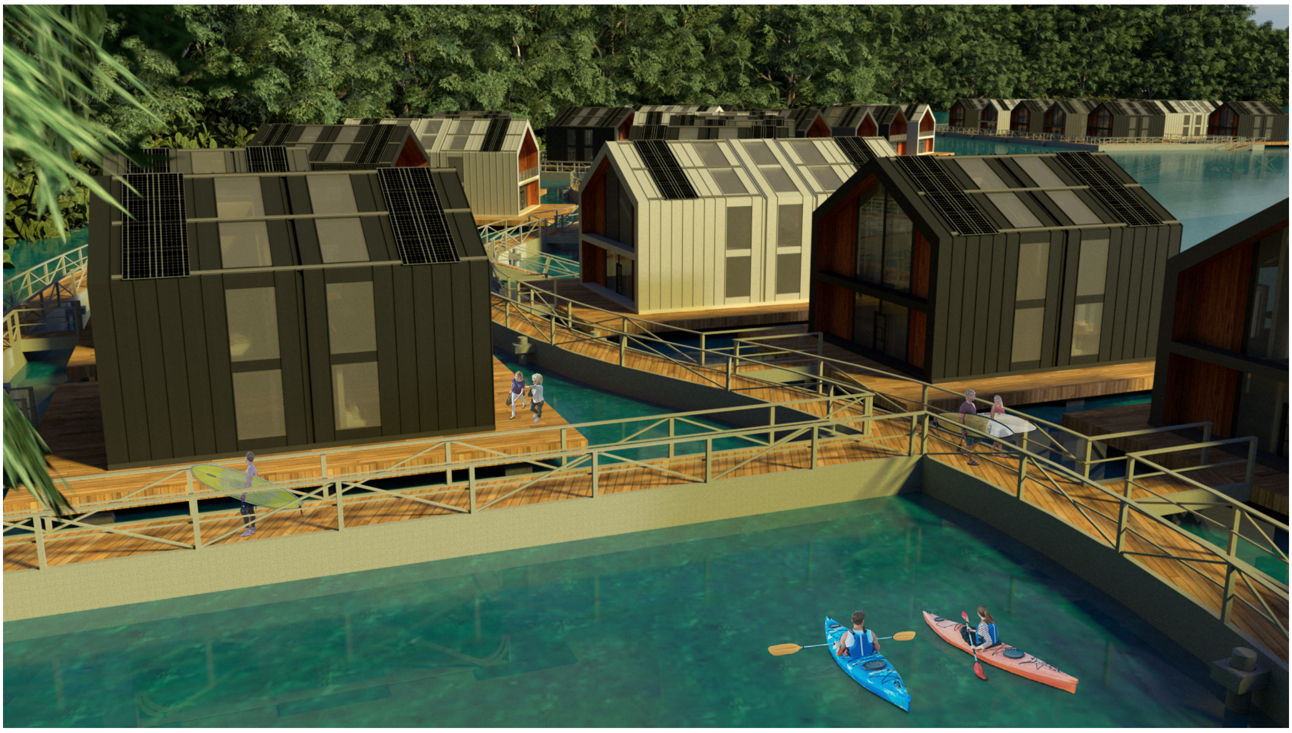
Minimal Rise (1.7m)



Middle Rise (4m)



Maximum Rise (6.6m)



No Rise (0m)

Minimal Rise (1.7m)

Middle Rise (4m)

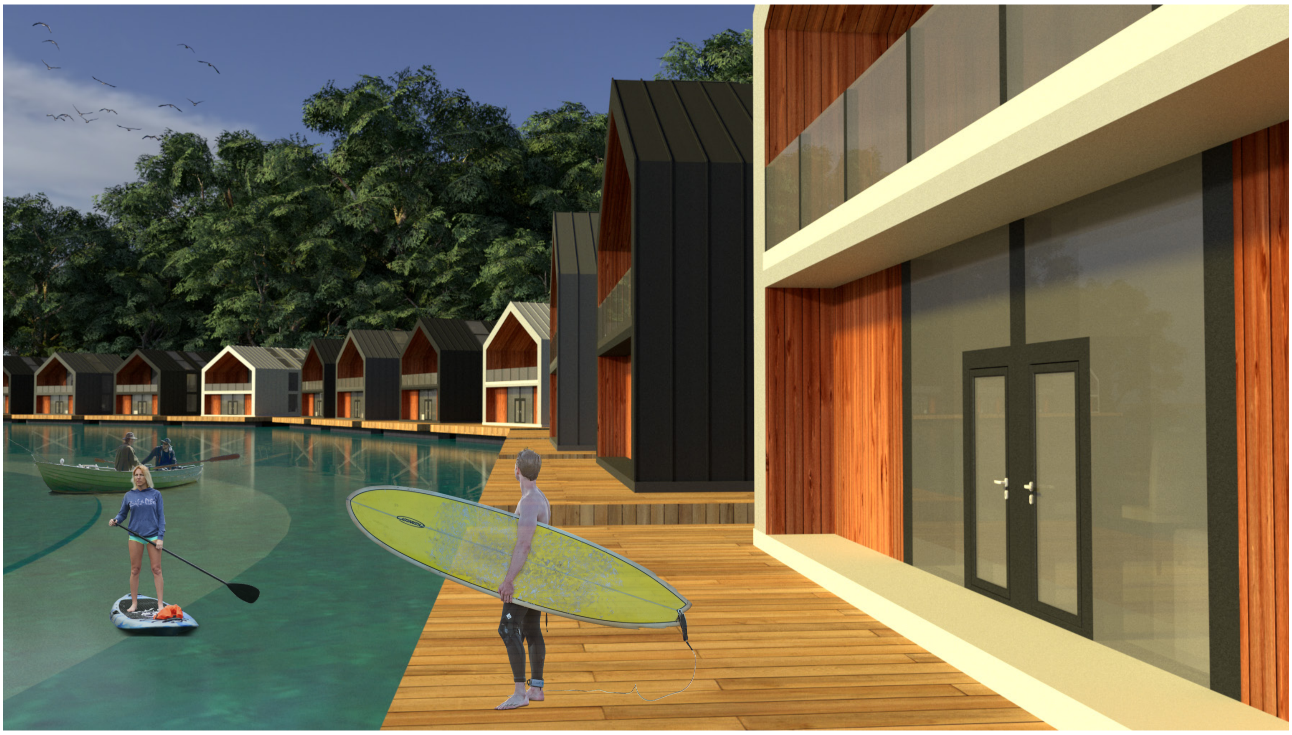
Maximum Rise (6.6m)

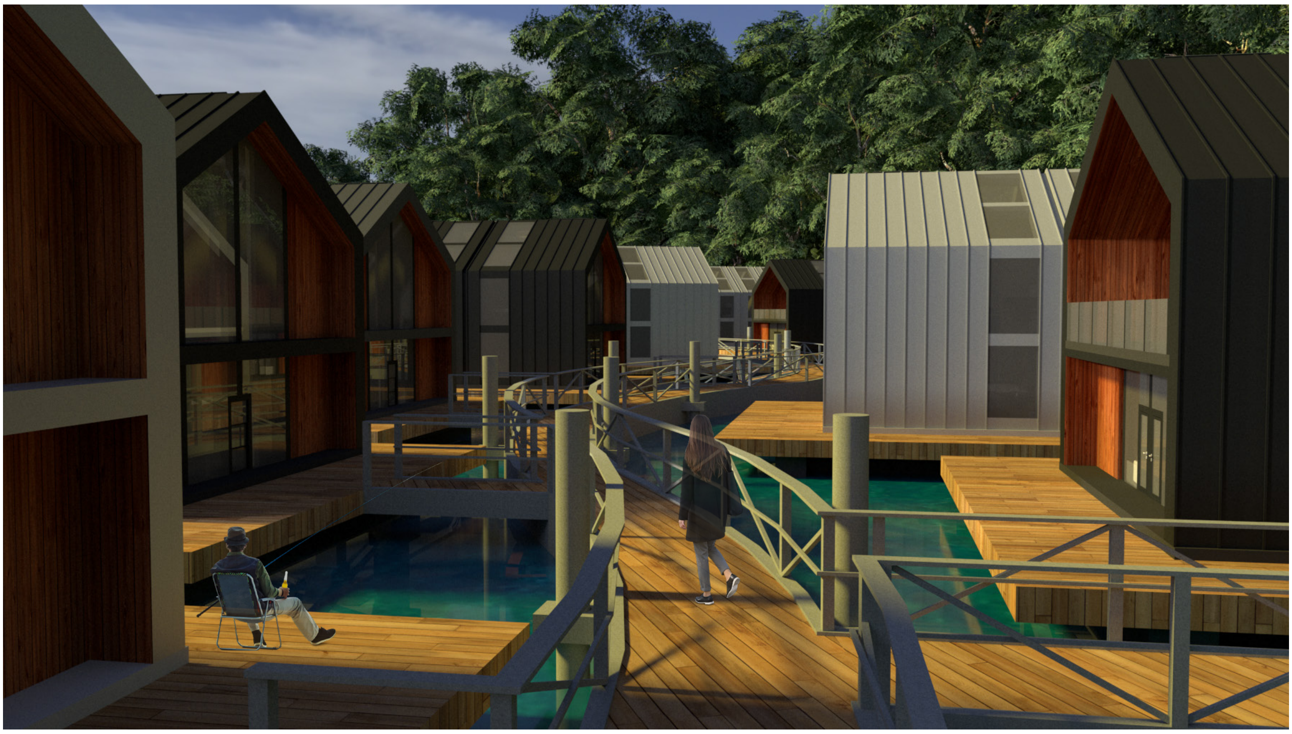
No Rise (0m)

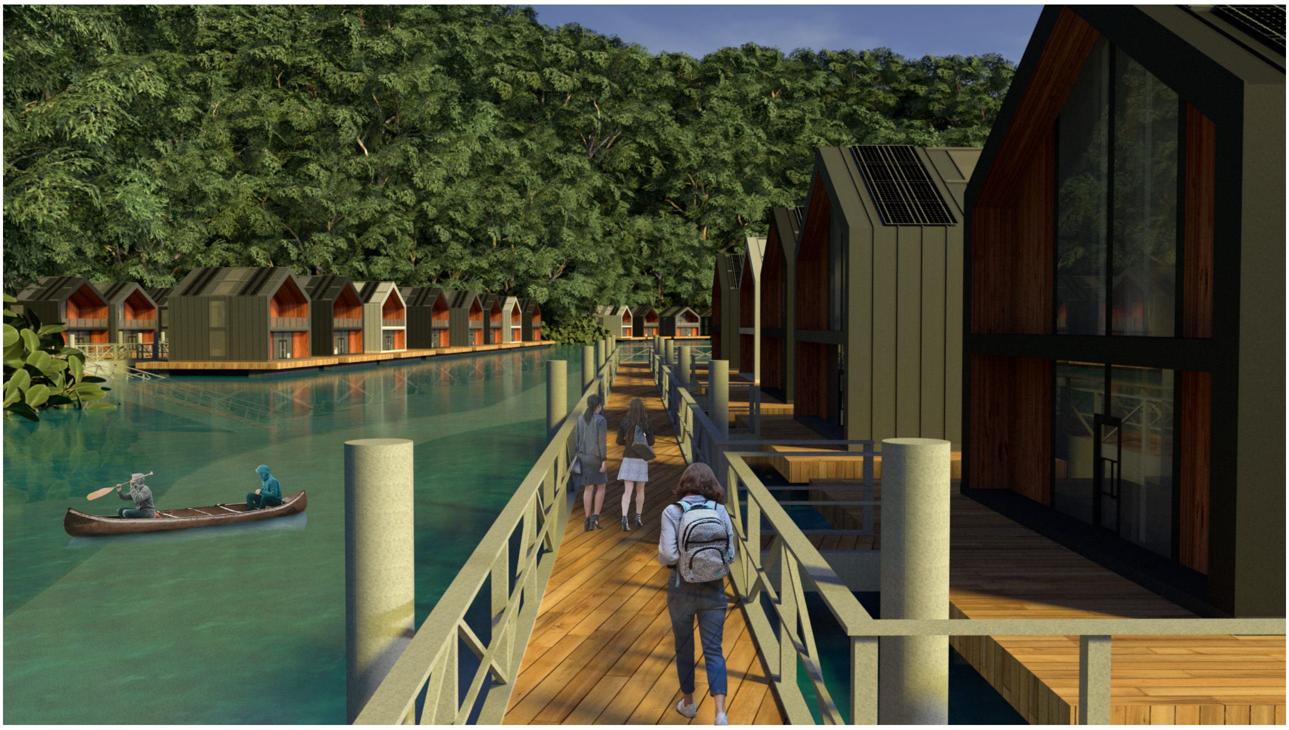
Minimal Rise (1.7m)

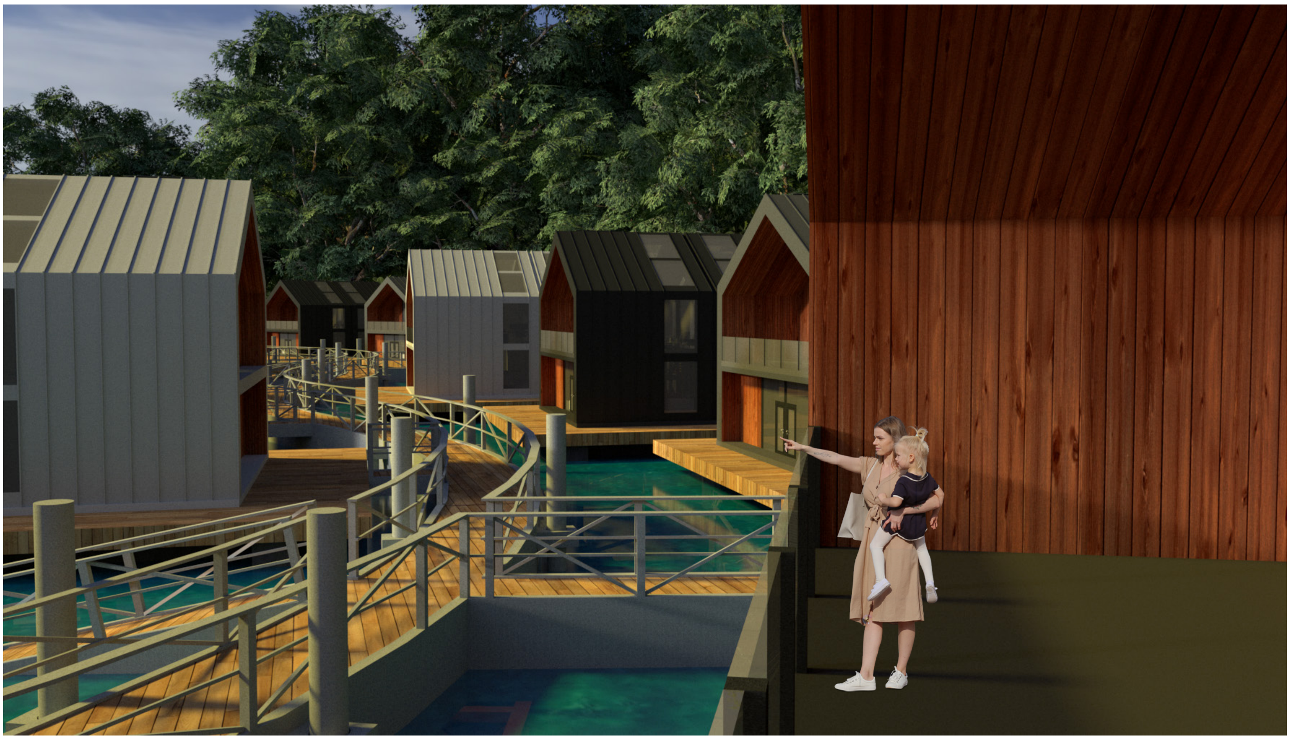
Middle Rise (4m)

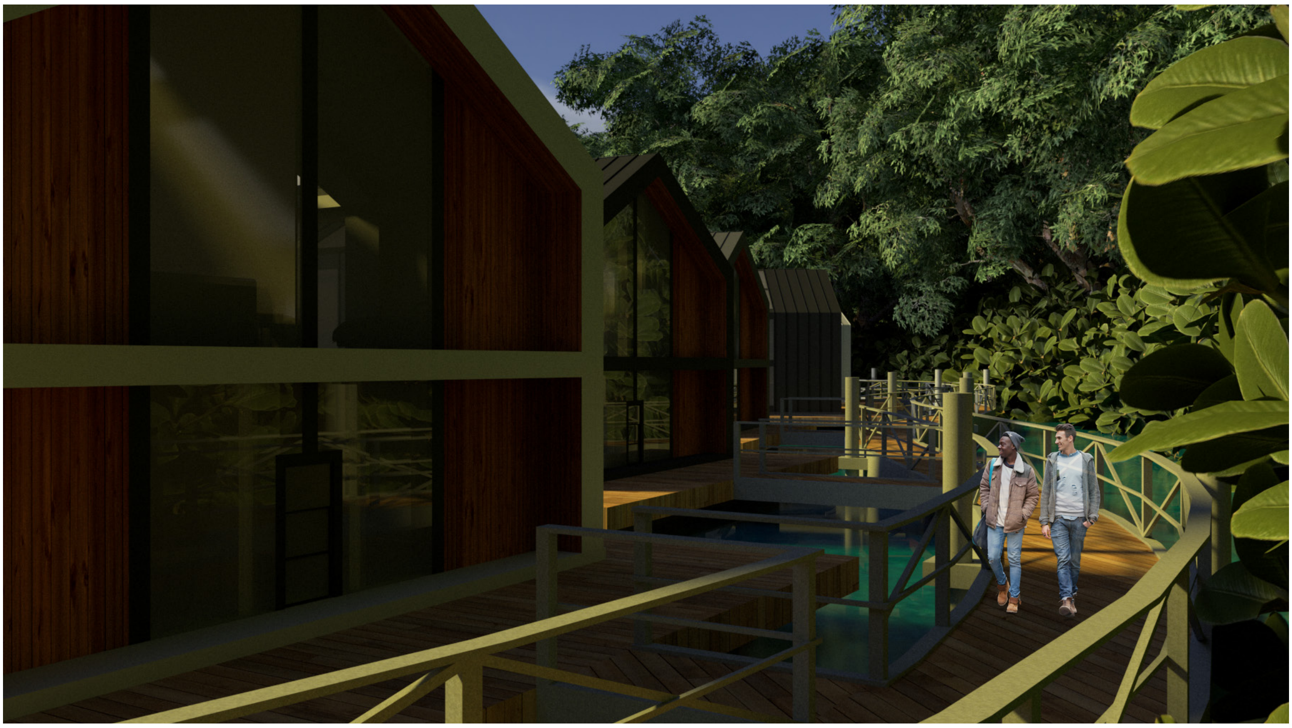
Maximum Rise (6.6m)











Chapter Ten: Research Findings

10.1. Learnings from Design Research

This idea of *attack*, as outlined by David Robinson, is a way of overcoming this issue of sea level rise in coastal cities by building out onto the water to eliminate the risk of inundation. Floating houses and buildings are becoming more and more commonplace around the world. Particularly in Amsterdam, Ijburg, where many floating houses and complexes have been built and are continuing to be built, to mitigate climate change. New Zealand however, has not delved into this new territory of exploring floating architecture, which yields for a new living opportunity. Koen Olthuis and David Keuning identified that there is a gap in the knowledge, if people had a choice to live on land or water, they would choose land every time. In order to "close the gap", floating houses will need to become equal of traditional houses on land, in every respect, including comfort, quality and price. Therefore a design framework was formed that acknowledged both of these constraints, to ensure these were met and to encourage this new way of living with and on the water. It is unlikely that residents of Shelly Bay would want to live out on the water when sea levels rising are not expected to cause infrastructure damage for another 80 years or so. Therefore, a middle ground was proposed. This less intimidating idea of amphibious architecture resolves these issues identified and respects the needs and expectations of the residents of Shelly Bay today, as well as their needs and expectations for the future with sea level rise. Building on the land, makes use of the site whilst it is still available, but also begins to float when it needs to, to overcome this issue of climate change induced rising sea levels. This design proposal eases people into the idea of living on the water, whilst also providing more awareness and understanding of the severity of this issue.

Chapter Eleven: Concluding

11.1. Conclusion and Discussion

Answering design problem/ question

Climate change induced sea level rise is placing millions of people at serious risk of coastal inundation across the globe, due to the unprecedented rate at which the sea levels are rapidly rising. In the case of New Zealand's capital city, Wellington, over 40,000 residents (or 10% of the cities population) are likely to be displaced due to their homes being at serious risk of the inundation. Even though architecture cannot solely provide a solution for fighting against this inevitable issue of sea level rise and other climate change induced effects, it can play a significant role in coastal resilience and future development. It is evident that an architectural solution is required to mitigate this disastrous issue and reduce the mass displacement that will be caused due to the sea levels rising. This thesis aimed at answering the initial research question: '*How can housing developments be designed that are resilient and adaptive to coastal site shifts (sea level rise) caused by climate change?'.* This thesis proposes an architectural housing solution that responds to the predictions of accelerating sea level rise and elevating threats of coastal flooding. The design allows residents to safely inhabit a low lying coastal site, by eliminating the risk of inundation by utilising resilient and adaptive elements within the architectural construct to work with the changing site shifts caused by climate change. This response is an innovative amphibious design, that could provide for a new sustainable way of living with the water. Due to the sea level rise accelerating at an unprecedented rate, an amphibious solution was the most appropriate to work with, as it grants the residents of Shelly Bay the opportunity to make use of the site prior to becoming submerged. Because sea level rise is not as much of an issue today as we know it will be in the future, designing amphibious dwellings that initially reside on land, increases the publics awareness and understanding of the issues, as well as pragmatically tackle the challenges posed by the phenomenon. The design effectively reacts to the uncontrollable impediments the natural world presents and therefore, the research question has been successfully answered and the architectural solution meets the design aims.

Limitations

There were a few challenges that arose throughout the design phases that were made evident in the thesis. Due to the fact that there are currently no existing floating dwellings or buildings in New Zealand as of yet, the case studies had to be derived from different locations around the globe. Each case study required specific design frameworks for the site conditions in which they were exposed to. Many of these were designed in sheltered harbours or lakes to allow for simple floatation systems. All of the resilient housing methods of providing flexible solutions for sea level rise, such as floating and amphibious houses, all possess positive qualities as well as the potential for negative downsides. Completely floating dwellings need to be designed for appropriately to suit the existing site parameters, in order to successfully prosper. Completely floating dwellings may thrive in a specific area but fail in another. Which is why this thesis developed from initially exploring completely floating dwellings to transitioning into this more adaptive and resilient approach of amphibious design. This thesis aimed at designing for an exposed ocean environment, which provides for more potential downsides, as the untamed ocean is less predictable than a more sheltered environment. Working with Wellingtons climate made the design process a little bit more difficult. Due to the strong winds, a lot more wave movement is apparent and had to be designed for accordingly. For example, the higher the dwellings rise with the water, the more force acts on the anchoring posts. In order to resist torsion and bending on the posts the architectural cross bracing system was designed. The bracing system and the sleeves in which the anchoring posts move through would also require ongoing maintenance to ensure they are working effectively, as they ought to. However, getting into the real pragmatics of designing for the oceans natural obstacles, poses some issues. Due to the bracing system and post sleeves eventually residing completely underwater, the elements that naturally exist in an ocean environment, such as seaweed and algae, may result in jamming in these components. In order to overcome this issue, some sort of filtration system would need to be designed to minimise these risks. Because this is an innovative design, it is unknown how well this sort of system would work seamlessly in a real life situation, in a location like Wellington.

Future work

There is strong potential to take this design research further. Unlike the floating architecture examples made evident in the thesis, this amphibious development was designed specifically to work with the exposed ocean, are therefore was designed to be as structurally sound and stable as possible, once inundated. If this design could withstand the untamed ocean in a climate like Wellington, it would thrive in almost any relatively flat coastal location. The innovative amphibious technology presented in the thesis, is not only limited to housing. The technology could be further developed to work with other building types, such as commercial office buildings, cafes, libraries, etc. This amphibious housing design has profound potential and could aid in the future of sustainable living design in coastal locations around the globe.

“In the future, we will not see water as a threat, but as new living space with exhaustible potential” (Stopp, 2017, p11).

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Appendix

Visual Display for On-Site Examination Presentation