City to Flood: A new urban planning model for urban adaptation to climate change induced flooding in Dunedin

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Fig. 1.1. Front cover - South Dunedin (2017)

Fig. 1.2. Base waterlevel (2017)

Fig. 1.3. 500mm water level rise (2017)

Fig. 1.4. 1000mm water level rise (2017)

Fig. 1.5. 1500mm water level rise (2017)

Fig. 1.6. 2000mm water level rise (2017)

Fig. 1.7. 2500mm water level rise (2017)

City to Flood :

A new urban planning model for urban adaptation to
climate change induced flooding in Dunedin

By

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A thesis

Submitted to the Victoria University of Wellington
in Partial Fulfilment for Master of Architecture
(Professional) Degree

Victoria University of Wellington

2018

Abstract

Currently 40% of the world's human population lives within 100km of a coast. With the Intergovernmental Panel on Climate Change (IPCC) predicting that sea levels will rise between 0.52 and 0.98m by 2100, and with increasing climate change induced extreme weather events affecting urban settings, the ways in which people reside in coastal areas needs to be addressed. As water levels rise, both permanently through sea level rise, and temporarily through storm surge events, areas of high population in low lying areas will have to reconsider their typical housing and infrastructure design methods, and/or their lifestyles to address this more frequent or potentially permanent influx of water into towns and cities.

Current methods of flood adaptive architecture often consider solutions at just the individual house or building scale, despite the clear need to be able to analyse and design with wider changing urban landscape conditions driving decision making. In response, this research investigates possible design strategies for adapting housing to climate change induced flooding, while enhancing the liveability of changing local community environments. This is investigated through a case study design-led research process, and is complimented by a survey of residents. The case study site is a flood prone suburb in the city of Dunedin on the east coast of the South Island in Aotearoa New Zealand.

Key findings of the research point to the importance of employing not just a purely technical approach to flooding adaptive housing, but also to using a community-led approach to re-design to understand how people will react to, use, and adapt to repurposed built environments that respond to climate change. This reinforces the need to conceive flood adaptive housing at least at a street and neighbourhood scale, and preferably at a whole suburb landscape scale, rather than just as a single housing typology solution. The research concludes that combining flood adaptive housing with ecosystem-based adaptation solutions to climate change induced flooding could lead to a different, more ecology-integrated way of living for inhabitants of low lying coastal areas. This in turn is likely to have positive social and psychological benefits for inhabitants while increasing community resilience.

Acknowledgements

Firstly thank-you to Maibritt Pedersen Zari whose supervision and guidance throughout this research has been fundamental to its success. Further thanks to the whole of the ecologies design lab for their input and critiques throughout the year.

Thank-you to my family, Justin and Lucas for their constant support and joy you have brought to this process, and most importantly to my Mum, Rebecca, for the endless encouragement and moral support not just during this study, but also over the last twenty-two years.

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1.1 - Project Background

According to the Parliamentary Commissioner for the Environment, from the years 2015 to 2065 sea levels are expected to rise by 30cm (Wright, 2015). This change can be attributed to warming air temperatures in three ways - firstly the water in the sea is becoming warmer and therefore expanding, secondly mountain glaciers are retreating and thirdly the polar ice sheets on Greenland and Antarctica are melting/shrinking (Wright, 2015)

As New Zealand is an island nation, over the next decade these changes in climate will have a major toll on how people reside in our mostly coastal, lake-side and harbour towns. These changes can already be seen in South Dunedin where, not only the effects of sea level rise are being seen through an increased rate of dune erosion for example (these dunes are the city's main line of defence against coastal storms and sea level rise), but the suburb also has high ground water levels which are also influenced by rising sea levels. So as sea levels rise, these already high ground water levels will also rise, causing surface ponding throughout the area (Michael Goldsmith, 2016).

This, in combination with increased rainfall which is also caused by rising temperatures, means that Dunedin will need to adapt to increased water from all directions, the combination of which will cause more regular flooding events, and more permanently flooded areas, not only within South Dunedin, but throughout the whole city (Michael Goldsmith, 2016).

With 2,683 houses on the South Dunedin flood plain residing less than 50cm above sea level, and a total of 3,604 being less than 150cm above sea level, this impact of climate change will have significant and ongoing effects on both those who currently live within these areas, but also the entire infrastructure and social functioning of the city of Dunedin (Wright, 2015)

The Dunedin City Council is currently in a state of indecision regarding what the next steps should be to address these issues. The most common solution discussed involves moving residents to other parts of the city and leaving the plain to flood. Challenging this response makes the South Dunedin plain a great test case to determine how other types of urban changes can be applied to a New Zealand environment that is already seeing the major effects of climate change.

These changes will need to be looked at in three scales. The first is at an individual residential scale in terms of examining, how individual residential buildings can continue to be functional within this changing landscape. Secondly at a community, or suburb scale, questions arise regarding how these dwellings will work with one another to allow residents to continue to go about their everyday lives. Thirdly an investigation at a city wide scale is required to understand wider implications of suburb scale interventions.

1.2 - Aims and Objectives

- Investigate potential urban solutions to Dunedin's flood problem that does not involve losing valuable land.
- Create potential solutions that will be suitable for the maximum predicted impacts of climate change effects, specifically flooding, over the next 100+ years
- Design an urban landscape that could withstand predicted tsunami levels and storm surges
- Provide a framework of solutions to fit the range of flooding problems that will happen throughout the South Dunedin suburbs. These will need to take into account in particular erosion, sea level rise, the high underground water table and an increased number of devastating storms
- Create a connection between the proposed interventions and the past wetlands, highlighting how the land is reverting to its original state
- Provide solutions that allow the current residents to go about their everyday lives (such as going to work/school) during times of flood.

1.3 - Methodology

As this is a design-led research project, the main findings were found through the act of research, design and then evaluation. A series of different methodologies were employed, specifically:

- A three week 'quick-start' process was employed to take initial research and precedents and apply them to the site in the form of four independent interventions.
- Quick start critique with supervisors of ecologies design lab steam (Maibritt Pedersen Zari, Mark Southcombe and Peter Connolly) and guest critic Daniel K. Brown to discuss the feasibility of quick start interventions.
- Literature based research was carried out investigating New Zealand Climate Change impacts – specifically Otago and Dunedin changes in sea levels and increased storm events.
- Spatial and literature based analysis of past flood events of the last century in Dunedin, and research predictions of future flood patterns was conducted.
- Precedent analysis of existing International flood resistant techniques at the three scales; individual dwelling, the street and the community.
- Presentation of site and precedent findings at design review one.
- From precedent analysis, research and feedback from the design review, a series of concept designs were devised, focusing on the three different scales
- Survey current residents of Dunedin and the South Dunedin flood plain about their way of life and reactions to current methods of flood resistant architectural design in relation to current lifestyle.
- The survey was conducted through a partially anonymous online means (such as through survey monkey) and used a snowball technique to survey 100 people of varying ages who either currently, or in the past 3 years have lived, worked, studied or used any recreation services in the South Dunedin area.
- Review of surveys on ways of life, and preferred interventions and a presentation of this surveyed data.
- Conceptual design at the individual dwelling scale.
- Developed design at three scales, focusing on the use during different flood levels ranging from no flood up to a tsunami storm surge of 2.5m
- Presentation of developed design at design review two, where a focus on the neighbourhood scale was given
- Feedback to be applied to final developed designs.
- Development of a flood resistant design for the South Dunedin flood plain, involving master planning of the site, development of shared community areas and the development of new flood resistant dwellings presented at design review three. This is the thesis itself.

1.4 - Research Question

How can innovative architecture and urban design become a medium for successful adaptation to climate change induced more frequent flooding in South Dunedin, New Zealand?

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Fig. 1.8. South Dunedin site (2017)

The first half of chapter two focuses on the problems facing the south Dunedin flood plain in both an environmental context, a historical context and predictions of future problems. The second half of the chapter focuses on the current architectural landscape and the people who currently live there.

2.1 - South Dunedin area overview

The South Dunedin plain which is discussed in this chapter is outlined in Figure 2.3. The flood plain contains 6960 People residing in 4341 dwellings. Of these Dwellings 2683 of them lie lower than 500mm above sea level, and 604 between than 500mm and 1000mm above sea level. The highest parts of the plain (the small percentage which lies three meters above sea level) are mostly on the outskirts of the plain, including parts of Caversham, Fourbry, St Clair and the Ocean Beach dunes along the pacific coast as seen in (Michael Goldsmith, 2016)

The South Dunedin Plain is said to be very new in geological terms. 18000 years ago, during the last 'ice age' sea level was 120m lower than it is now, resulting in the coast lying roughly 35km further out than the current coastline (Michael Goldsmith, 2016). After the peak of the ice age, through to roughly 7000 years ago seas levels began to rise, resulting in the sea level we have now (Barrell, Glassey, Cox, & Lyttle, 2014)

A combination of both the sea level rise and the coastal location of the site resulted in an open ocean passage through what is now the South Dunedin plain. At this time the dunes along the South Dunedin area were formed from material 'sourced from the long-shore drift of fine sediment from the Clutha River and other small catchments' (Michael Goldsmith, 2016). A barrier was also formed at the head of the Dunedin Harbour. The sea then became shallower, and a build-up of sediment to just above sea level turned most of the South Dunedin plain into a coastal wetland.

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Fig. 2.1. 1865 View of Otago harbour and South Dunedin (2016)

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Fig. 2.2. 1864 View from mussleburgh across South Dunedin plane (2016)

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Fig. 2.3. Topography of South Dunedin flood plane, with highlighted site (2016)

2.2 - Ocean Beach Dunes

The coast of South Dunedin has evolved significantly since the 1850's. The most significant change to the coast bordering the Pacific Ocean is the change in the dunescape, caused mainly by mining of the dunes in the late 1800's and 1900's (Pope, 2010). The dunes at the turn of the century were much wider and lower, compared to the dunes currently which take up a thinner area at a steeper angle.

The mining of the dunes began because the South Dunedin plain originally contained two lagoons and a low-lying wetland. With the urban growth of Dunedin in 1876, housing was being pushed to the edge of the sand dunes. To make this land liveable, which was as discussed originally wetland, and to conform to standard building methods at the time, sand from these dunes was removed by local households to raise section levels (Pope & Todd, 2003)

In addition to the existing dunes, a sea wall was built at the south west end of the beach in 1884. Over the years it has been rebuilt three times, with the current wall having been built in 2003/2004 (Dunedin City Council, 2009). While the wall provides protection to the South Dunedin flood plain in areas the dunes were not as strong, the wall has also caused many problems, including increased erosion at the eastern end of the dunes (where the dunes meet the wall), and damage to the wall restricting beach access from the upper dunes and esplanade.

This change in the shape of the dunes, and the location of the sea wall has caused them to erode over time, and thus has drastically changed the beach landscape. Because of this, the local city council and other groups have had to take action to strengthen the dunes through the addition of extra sand, bags, vegetation and restricting public access in some areas)

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Fig. 2.4. Ocean Beach sea wall (1890)

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Fig. 2.5. St Clair beach to Ocean Beach (2017)

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Fig. 2.6. Sand sausages designed to stop erosion (2016)

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Fig. 2.7. Exposed sand sausages and rocks post storm (2016)

2.3 - Bedrock Contours

As seen in fig, the actual bedrock of the South Dunedin flood plain lies between 20 and 60m below ground level. This further highlights the fluid connection between the Pacific ocean and Otago harbour that existed through wetlands and marshlands prior to settlers arriving in the mid 1850's (Michael Goldsmith, 2016). The bedrock itself is made up of Caversham sandstone covered by volcanic rock, with the space between the bedrock and the current ground level being made up of mostly of poorly consolidated sand and silt (Bishop, 1996). Due to this, the area between the South Dunedin plain and the bedrock are saturated with groundwater (see next section on South Dunedin groundwater).

Fig. 2.8. South Dunedin bedrock contours (2017)

2.4 - South Dunedin Lagoon

Before settlers occupied the land there was a connection between what we now see as the Otago harbour and the Pacific Ocean through ocean beach.

As first introduced in section 2.1 the site of what we now call the South Dunedin flood plain was made up of marshland and wetlands prior to settlers arrival. Shown in figure 2.9. the boundary of the lagoon that was once located within the wetlands and marshlands, but like the rest of the area, after settler arrival these water bodies were filled in using the sand from the adjacent sand dunes.

Fig. 2.9. Recreation of 1850's lagoon/wetland map

2.5 - Sea Level Rise

In South Dunedin, the ground water level is connected to sea level. So even if the coast is protected by way of sea walls and dunes for example, flooding as surface ponding will continue to happen due to the already high water table increasing beyond ground level as sea levels continue to rise.

Fig. 2.10. Surface ponding at 0.11m sea level rise

Fig. 2.11. Surface ponding at 0.28m sea level rise

Fig. 2.12. Surface ponding at 0.4m sea level rise

Fig. 2.13. Surface ponding at 0.6m sea level rise

Fig. 2.14. Sea level rise, Stringent mitigation (2015)

Fig. 2.15. Sea level rise, Very high greenhouse gas emissions (2015)

	Stringent mitigation	Very high greenhouse gas emissions
2018 - 2038	100mm	100mm
2038 - 2068	140mm	200mm
2068 - 2118	230mm	570mm
Total between 2018 and 2118	470mm	870mm

Fig. 2.16. Sea level rise values (2017)

2.6 - Ground Water

Not only are sea level rise and major storm events causing stress to the suburbs (St Clair, Forbury, St Kilda and South Dunedin) in relation to flooding in the greater South Dunedin area, but with sea level rise also comes a rise in ground water level.

As discussed in section 2.4 the location of the 1850's lagoon matches up with the location of where the high water table around Hargest Cres is currently causing major surface ponding and flooding. This gives the impression that the landscape and its hydrology is perhaps beginning to recreate the currently filled lagoon .

Fig. 2.17. South Dunedin groundwater levels (2017)

2.7 - Coastal storm events

In addition to sea level rise the coastal location of South Dunedin also makes it vulnerable to storm surges and tsunamis.

Fig. 2.18. Sea level rise effects on storm events

2.8 - Residents of South Dunedin

A survey titled 'South Dunedin flood plain residents: their way of life, climate change and reactions to current methods of flood resistance' was granted ethics approval and conducted through Victoria University of Wellington. Survey responses were gathered from June 13th to the 1st of August 2017. Responses were recorded from 100 residents who either lived, worked or used the amenities or recreation facilities of South Dunedin. Participants were anonymous for this voluntary survey as they were recruited through online social media groups of the South Dunedin area.

The survey was divided into two parts, consisting of 17 multi-choice questions, where respondents were also given space below each multi-choice question to expand on their answers or add any additional information. Part one consisted of the following nine questions about how the respondents use the South Dunedin flood plain

1. How do you occupy the South Dunedin Flood Plain?
2. How long have you lived/studied/worked or used the amenities/recreation facilities in the South Dunedin flood plain?
3. What is your main means of transport around the South Dunedin flood plain?
4. What were the reasons for choosing to occupy the South Dunedin flood plain?
5. How did the June 2015 floods alter your everyday life?
6. Do you feel like you were prepared for a major flood or other natural hazard prior to the June 2015 Floods?
7. If you answered yes to question 6 – in what way were you prepared?
8. If you answered no to question 6 – now that you have experienced a major flood event in the Dunedin area, have you taken steps to become more prepared for any future events?
9. Who do you feel is responsible for preparation for these flood events?

	<i>Less than 1 year</i>	<i>1-2 years</i>	<i>3-4 years</i>	<i>Over 5 years</i>
Lived	1	6	6	29
Worked/ Studied	4	3	10	22
Used Amenities	1	3	7	73
Used Recreation facilities	1	1	4	69

Fig. 2.19. Time occupying South Dunedin (2017)

Fig. 2.20. Main means of transport (2017)

	<i>% of people</i>
I was unable to attend work/school	20
I had to leave my house and find shelter elsewhere	2
The flooding caused damage to my house and/or possessions	14
The flooding caused damage to my place of work/study	8

Fig. 2.21. Effects of June 2015 floods (2017)

(A copy of the survey questions can be found in the appendix)

The second section focused on people's perceptions to current methods of flood resistance seen around the world. This involved showing each respondent three flood adapted houses: a pile house; a wet proof house; and a floating house, and asking how likely they would be to want to live in each one, ranging from yes to maybe to no. These three flood adapted houses were chosen as a result of the literature review (in chapter 3) showing these as the most common types of past flood resistance. People were then asked if they had to live in one of the three options, which one they would choose. This method was then repeated with three more designs, but at a suburb scale with the options of a house on raised land, one placed above or on the edge of a wetland and one alongside a canal. Finally, respondents were asked if they were in a position where they had to choose an environment to live in which it would be.

Survey Section 1 findings

The first question of the survey found out about ways the residents use the South Dunedin flood plain. This resulted in finding that of those surveyed, 30 lived there, 27 people worked or studied there, 79 used the amenities of the area, and 66 people used the recreation facilities.

The survey showed that 69% of those surveyed have lived in the South Dunedin flood plain for over five years, with only 17% having lived in the area for less than two years. This showing that South Dunedin made up of long term residents, rather than people who move around a lot. This outlined the need to design for those who currently live there, and will want to continue living there in the future even as the relationship of land to water changes.

The second part of the survey showed that people like the architectural landscape and the character that the current Victorian housing typologies bring to the community. Therefore, through the designed research process, elements of the current housing styles were incorporated into the design of the new community.

As society evolves, the need for better environmentally friendly methods of transportation need to be included in urban planning to reduce reliance on personal cars. Currently in the South Dunedin

flood plain, the main means of transportation is by car (83%). While the whole city of Dunedin has an active bus transport system that extends into the South Dunedin flood plain, only 7% of those surveyed stated that public transport was their main means of transport. This showed the need for incorporation of convenient public transport systems into the design.

People were asked about how the June 2015 floods in South Dunedin affected their everyday lives. Results are shown in fig 2.21.

The final finding of the first section of the survey was that residents felt was responsible to prepare for future flood events. Of the responses only 14% felt it was up to the individual to prepare their homes for future flood events however. This compared to the other 86% who felt it was either the local council (41%), Regional Council (29%) or the New Zealand Government (16%) that are responsible for preparing the communities for future flood events.

Survey Section 2 Findings

In the second section of the survey residents were asked their likelihood of living in each of the three following housing types: house on stilts; wet proof house; and floating house.

A House on stilts is one which allows people to live on water without being moved by water. They are built in areas where water fluctuations are predictable and are a way of building on land that is usually unusable for common land based building methods. These houses provide a stable connection to the ground, but there is a lack of flexibility so if water levels were to pass the level the house was built for, the building would flood (Nillesen et al., 2011).

A Wet proof house is designed to flood. Often the main living area is raised above the flood level. The lower level is designed to be used during dry seasons, but during wet ones, allows water to enter the lower levels of the building. These lower levels are made of materials that can withstand periods of water without damage.

The third housing type option was the floating house. Ideas adapted from house boats allow floating houses to rise and fall alongside water fluctuations. While still seen as a 'boat' the main difference between

	<i>Number of people</i>
The Government at a country wide scale	16
The Regional Council at an Otago scale	29
The City Council at a city/suburb scale	41
Individuals should be responsible for own houses flood protection	14

Fig. 2.22. Who is responsible for future flood events (2017)

Fig. 2.23. House on stilts (2017)

Fig. 2.24. Wet proof house (2017)

Fig. 2.25. Floating house (2017)

	<i>Yes</i>	<i>No</i>	<i>Maybe</i>
A House on Stilts	35	41	24
A House Designed to flood	50	26	24
A Floating House	23	18	59

Fig. 2.26. Likleyhood of living in different housing types (2017)

	<i>Number of people</i>
A House on Stilts	37
A House Designed to flood	46
A Floating House	17

Fig. 2.27. Housing preference (2017)

these and floating houses is the focus on movability. Floating houses are securely attached to the areas they are located in and are not often moved from place to place, whereas boats and house boats move around (Nillesen et al., 2011).

After being asked the likelihood of each resident of living in each of the housing types they were asked if they were in a position where they had to live in one of the three provided, which would they choose?

These results show that South Dunedin residents have a strong preference for flood adaptive housing that has a strong connection to the ground (which both the house on stilts and the house designed to flood have). This also suggests that residents will likely be opposed to any major flood adaptive change that will drastically change the way in which they live, because the least common housing preference was the floating house, a typology that would have the largest impact on the way people currently normally go about their everyday lives.

3.0 - Resilient Cities flooding - Cruital theory

Chapter three contains all the theory that was researched in relation to flood resilient cities, focusing on both housing typologies that can resist flooding and fluctuating levels of water, as well as community alterations in both public and community areas.

3.1 - Dwelling

Fig. 3.1. Floating Dwelling Section (2017)

3.1.1.1 - Floating Dwellings

Until recently the idea of 'floating dwellings' related either to converted ships or house boats built on concrete barges. In the past decade a lot of design activity and experimentation in this areas, means the floating dwelling typology is evolving to look more like land dwellings, only they float on water.

Though the change in the overall look has attracted more people to the idea of living on water, the noise and dynamic-ness still seems to be the deciding factor in terms of desirability to live there. Some see this as a 'charm' of the dwelling, while others see it as a drawback (Nillesen et al., 2011).

A focus on the word unmoveable is taken into consideration when deciding if a floating house is a dwelling or a boat. If the dwelling can be moved from place to place it is a boat, if it 'is securely attached' it is a dwelling' (Nillesen et al., 2011).

Fig. 3.2. Amphibious House section no flood (2017)

Fig. 3.3. Amphibious House section flood (2017)

3.1.1.2 - Amphibious House

An Amphibious House is defined as 'a dwelling type that sits on land but is capable of floating' and typically are built in areas of flooding and in areas near large bodies of water (Nillesen et al., 2011).

While they can seem similar to floating dwellings, the main differences include:

- The base of the building is exposed when there is no water
- The dwelling can become isolated during floods as the infrastructure may not work during floods
- Two or more mooring poles are part of the design so the dwelling stays in place before and during a flood event

3.1.1.3 - Pile Dwelling

These are dwellings allow people to live on the sea without being moved by the sea. Pile dwellings are usually built in shallow water on concrete or timber piles. They are built in locations where water fluctuations are predictable and are a way of converting land which is unusable for periods, into areas that can accommodate common land based dwellings.

Pile dwellings share some commonalities with land based dwelling, these include:

- They provide a secure and stable connection with the ground (Nillesen et al., 2011).
- There is a lack of flexibility, if water exceeds the level the dwelling has been built for, the property will flood

These dwellings can realistically be built in any depth of water, but those designed to cope with deeper water will have higher construction costs.

3.1.1.4 - Terp Dwelling

Terp Dwellings are where buildings are built on top to mounds on flatter landscapes. These have mainly occurred in parts of the Netherlands, Denmark and Germany. The dwelling remains dry and protected until a maximum water level has been reached. So, while these dwellings are less safe than floating dwellings, they 'feel safer and more secure than a floating dwelling' (Nillesen et al., 2011).

During flood or high-water levels the mounds become islands surrounded by water and can become isolated.

Fig. 3.4. Pile Dwelling section no flood (2017)

Fig. 3.5. Pile Dwelling section flood (2017)

Fig. 3.6. Terp Dwelling section no flood (2017)

Fig. 3.7. Terp Dwelling section flood (2017)

Fig. 3.8. Levee House section (2017)

3.1.1.5 - Levee House

A Levee house (also known as a dyke house) provides a way of occupying structures that are built to protect other land from water. With levees built to protect buildings on flat land from the effects of water, there are sometimes opportunities to use these levees as land for additional houses.

Levee houses can both sit on top of the dyke, as well as on the side (usually on the landward side, but if built on the side towards the water another of the water design methods would need to be incorporated). If dwellings are built on the side of the levee the top can be used for infrastructure such as roads.

Fig. 3.9. Waterside Dwelling section (2017)

3.1.1.6 - Waterside Dwelling

A waterside dwelling is defined as a 'dwelling with one or more sides in the water' (Nillesen et al., 2011). These dwellings usually have a view of the water while being a safe distance or height from the water, with a garden or another space as 'a transition zone leading down to the water' (Nillesen et al., 2011) This can also provide privacy as the water is a public space.

New waterside dwellings in the Netherlands now require 10% of the total land to be allowed for surface water to help accommodate climate change and rising waters (Nillesen et al., 2011)

3.1.2 - Dwelling Alterations

While there are a number of flood resilient designs for new dwellings which can be used to re build houses which have already been damaged by flooding or are reaching the end of their life, in situations where houses have been built in the last 5-50 years in areas which are now prone to flooding, it is not always feasible to tear down and re-build. In this case retro-fits to existing buildings are an option in combination with larger street and suburb scales to reduce the effects of future floods. Ann D. Horowitz groups these retrofit elements into two categories: dry flood proofing and wet flood proofing. Dry flood proofing prevents flood water from entering a building and wet flood proofing 'accommodates interior flooding' (Horowitz, 2016).

3.1.2.1 - Dry flood proofing

- Sandbags to keep flood water away from buildings. This works when floods can be anticipated and there is time to gather and move sandbags into place
- Drainage ditches and earthen berms built close to the structure needed to be protected. These are permanent and are made out of natural materials to absorb excess water. They only works up to a certain level/amount of flood water.
- Floodgates or shields prevent water entering buildings through openings such as doors and windows.
- Backflow valves to plumbing keep sewage and storm water from entering the building through the plumbing

3.1.2.2 - Wet flood proofing

- Keep utilities and electrical equipment to upper floors to protect critical building elements during floods
- Flood vents in foundations to allow water to enter and exit the building to reduce structural damage
- Use of natural building materials. Materials such as wood, concrete and brick work better in floods by not absorbing or holding flood waters, where materials such as plasterboard and insulation do.

3.2 - Street

This section looks into the way 'streets' are recreated in waterborne areas, and how the land based model of the street can be applied to this more area. This is in terms of accessibility between land and the dwellings, privacy between dwellings and how they can deal with water fluctuations.

3.2.1 - Accessibility

Accessibility needs to be addressed in terms of physical access to the dwellings, and how these accessways are occupied and by whom.

The three main terms of physical access to the dwelling types are:

Direct access, where the dwelling is directly beside a public accessway

Access by bridge, where you move from a public accessway to the dwelling along a fixed bridge

Access by boat, where there is no physical connection between public accessways and the dwelling. Three examples of this are shown in the following figures.

Through the investigation into accessibility, it was concluded that one method is not better than the others, rather different methods work for different scenarios. For the case study of South Dunedin where the aim was to have little to no change to the way people lived in their new environment in comparison to the way they live today, the best option would be to have access directly off the land in the form of building and having access from the a bank or spit. In these scenarios there would only be a requirement to rearrange land and dirt or even use the existing land formations, rather than building additional infrastructure through a jetty. Also introducing access by boat to new land formations would not necessarily work in relation to keeping the existing ways of life.

Fig. 3.10. Jetty Plan (2017)

Fig. 3.11. Spit Plan (2017)

Fig. 3.12. Island Plan (2017)

Fig. 3.13. Bank Plan (2017)

3.2.2 - Privacy

Fig. 3.14. Distance (2017)

Fig. 3.15. Buffers (2017)

Fig. 3.16. Orientation (2017)

Most design of water dwellings treat the water as a private space, such as looking at the space behind the dwelling as a backyard. Actually, it could be the opposite. Water is usually a public space, and as such these dwellings are not designed for views from passing boats and roads. Privacy can also be a problem between adjacent dwellings. While on land based dwellings a fence is used to create this definition between houses, this is rarely possible with water based dwellings.

There are at least three methods of solving this privacy problem in water dwellings including: creation of buffers between dwellings or public spaces; providing distance between homes; and the strategic orientation of the dwellings to increase privacy.

The first method, and probably the most simple is providing distance between dwellings and public spaces. As space is increased, visibility is reduced, providing more privacy. While the most simple method, it does not work in all environments, especially in environments where dry, buildable space is limited, or in areas where you want a high density of housing.

Buffers between land based dwellings typically take the form of front gardens or splits in levels. These principles are used in creating buffers for water based dwellings by creating floating back gardens or patios and private jetties. Plants can also be positioned in or around the water in front of dwellings to give more privacy, or fences can be placed around patios. While both of these provide privacy from the overlooking eye, they also reduce the openness of the space and potentially the views.

The final method is using orientation strategically particularly in situations where ample space between dwellings cannot be provided for privacy. The first point to determine is if privacy is needed from the public, or from neighbours. If it is the former a solution is to orientate the dwelling's most private spaces towards the least public area. In most cases this will be open water with long unobstructed views and having the facade of the building which faces the public closed off (Nillesen et al., 2011). Though if it is privacy from the neighbours that is wanted, it may be best to have an open front and back facade with closed off sides which face the neighbours.

3.3 - Suburb

Fig. 3.17. Build Over (2017)

Fig. 3.18. Build Alongside (2017)

Fig. 3.19. Build For (2017)

3.3.1 - Build Over

Building over existing green and blue spaces allows the natural process to continue to occur, while not losing valuable land and giving opportunity for new ways for people to interact with these spaces.

3.3.2 - Build Alongside

In developed areas, giving back specific areas to Blue and green spaces

3.3.3 - Build For

Building for water gives the ability to manipulate water flows and how water influences the built environment

4.0 - Cruital theory & Precidents

Chapter 4 takes the theory surrounding flooding housing design and community spaces and applies and analyses it against real world and designed buildings and environments. The goal of this chapter is to decide the design types to take onto the concept design stage.

4.1 - Theory application to Key precedents

Once determining the elements of flood resistant housing in chapter 3, these elements were then used to review key precedents for each of the flood resistant dwelling types and community adaptations to determine the type of adaptation that would be taken into the design stages.

4.2 - Dwelling Adaptation

Four possible design strategies have been taken from the analysis in the flood resistant theory chapter and will now be assessed against physical housing designs in their categories, these being

- Floating House
- Amphibious House
- Pile Dwelling
- Room to flood house

These four groups will be evaluated in terms of how the theory of each category work in relation to their built counterparts and whether the designs do what the theory aimed to do.

Floating House

Fig. 4.1. Floating House (2017)

Amphibious House

Fig. 4.2. Amphibious House (2017)

Pile Dwelling

Fig. 4.3. Pile Dwelling (2017)

Room to flood

Fig. 4.4. Room to flood (2017)

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Fig. 4.5. Floating House (2010)
Fig. 4.6. Water Villa Ijburg (2017)

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Fig. 4.7. The Amphibious House (2016)
Fig. 4.8. The Float House (2012)

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Fig. 4.9. Hind House (2013)
Fig. 4.10. Flood House (2011)

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Fig. 4.11. Floating House (2016)
Fig. 4.12. Tsunami House (2014)

4.2.1 - Floating House

Fig. 4.13. Floating House model section (2010)

Fig. 4.14. Floating House at dusk (2010)

Fig. 4.15. Floating House front facade (2010)

Floating House

Built as a structure to be used as a holiday home the dwelling would have to adapt to water fluctuations independently without human intervention as the house would not be lived in all year round. Initially built offsite, the house is built on a pontoon made up of 2.4m long cylinders is able to rise and fall with large changes in water levels (Ryan, 2010). The designed rainscreen made of cedar wood on either side of the structure reduces the wind load and the resulting rocking on the floating structure, while also keeping the structure cool. Due to the varying water levels from month to month, the structure is connected to both sides of the lake through two walkways, one on each house level.

The structural layout of this house is helpful to understand important structural and environmental design problems around building a house on water, and ways to reduce these problems. Whereas the physical house, and the environment in which it is built is vastly different to that of south Dunedin, in particular the house use, the population density (there is realistically no one else living on this part of the island) and the actual connection this house has to the natural environment it is in.

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Fig. 4.16. Water Villa IJburg rendering (2017)

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Fig. 4.17. Water Villa IJburg from pier (2017)

Water Villa IJburg

Designed and built as a way to evaluate the way in which coastal waters in the Netherlands can be urbanised (Waterstudio.NL, 2017a). Built in 2008, Watervilla is made up of three stories contained by a continuous line of framing making up the roof, a wall, and the ground level floor (Waterstudio.NL, 2017b). The dwelling itself can be towed to different locations/more desirable conditions, and are connected to the coast by a pier (which in this case acts as a street when multiple watervilla's are arranged) (Meinhold, 2013). Due to the continuous framing, there is one solid wall, located coast side, to allow for privacy from other dwellings, while allowing the other three walls open to the views of the site.

This method of locating most structural elements along one external wall, helps with both privacy from other residents, while also allowing the other walls to be open of the views and environment. In areas such as Dunedin where buildable land will have to be reduced to account for the reintroduction of environmental elements, such as the wetlands, this could be used as a way to allow for houses to be built closer to one another, while allowing the open walls to overlook new wetland areas.

4.2.2 - Amphibious House

Fig. 4.18. Amphibious House front and rear facade (2016)

Fig. 4.19. Amphibious House section (2016)

The Amphibious House

Built by Baca Architects, the Amphibious House is built upon a small island along the Thames river. As this area is prone to flooding due to the fluctuations in the water levels of the Thames, the existing housing on the island are typically raised on timber piles to protect from flooding (Coutts, 2016). The Amphibious housing type was chosen to be explored rather than building on piles. The house itself is connected to the ground through four guide posts to support any movement as the building rises, and when flooded can float above 2.5m of water. Services are connected to the house through flexible pipes that can stretch up to 3m allowing for continues power and water, even during times of high water (Anderson, 2014).

This House is a great example of Amphibious Houses can work to prevent flood damage to within the building shell, and for showing in great detail how Amphibious Housing works as a whole. The problem is, like with most current amphibious housing design is, that the house becomes isolated during times of high water. Where in this example, this doesn't seem to be much of an issue and the existing housing built on piles have the same problems and the residents already have the lifestyle of using boats for access during floods, but for the Dunedin context how the house fits into the landscape would need to be altered/further considered.

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Fig. 4.20. Float House side elevation (2012)

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Fig. 4.21. Float House exploded assembly (2012)

The Float House

Designed as a combined effort between Morphosis Architects and the University of California (UCLA) the Float house was designed in response to the damage caused to New Orleans by Hurricane Katrina in 2005. The style of the house itself takes on the traditional New Orleans Shotgun typology. Rather than build these new houses 10 feet (3m) above ground level, like a number of new houses in the area were doing, the Amphibious Housing typology was chosen so to preserve the new houses connection to the ground (Henrique). The house contains two guide posts to anchor the house as water levels rise, and can accommodate water up to 3.7m (Plaisance, 2009). All the electrical and plumbing services for the house are located in the foam and concrete base, in addition the building can provide its own water and power needs through solar power generation and rain water collection (Smith, 2009).

Like the Baca architect's precedent, the Float House provides a great built example of how amphibious houses work to protect the building itself and those living within from flood waters. The location for this housing design, in New Orleans, means that the house only needs to be able to deal with short term flooding (such as storms and hurricanes that bring with them heavy and large amounts of rain), and not long-term flooding caused by sea level rise and/or high groundwater levels. Therefore, the fact that, like the Baca House, it becomes isolated during flooding is not as big of a deal as the waters will retreat at some point. Where as in the South Dunedin location this is not the case, and this problem of isolation would need to be solved.

Fig. 4.22. Hind House flood (2009)

Fig. 4.23. Hind House section (2009)

Fig. 4.24. Hind House from lake (2009)

Hind House

Built on the flood prone edge of the river Loddon, John Pardey Architects designed this flood resistant house in 2008. Due to the seasonal flooding of the site, with a maximum flood level of just over 1 meter, the whole house is raised on steel columns to accommodate this (DAVIDSON, 2013). Permission to rebuild on this site was only granted when the architects were able to prove that the proposed new design would have less of an impact on the floodwaters passing through the area compared to the existing house on site (Network).

Like many Pile Dwelling precedents, Hind House is just another house that has been designed to just hover above the flood levels. While doing so in this case, alongside the design and openness of the house, it does allow for great views out into nature during both the dry and wet seasons. But the main problem with these types of designs are, that they protect the house from becoming flooded, but the connection to the rest of the world is lost. To leave the house requires certain attire to be able to walk through the flood waters to higher ground where you can move around freely. To bring this type of housing into the South Dunedin flood plain with minimal change would just result in people walking around in gumboots and fishing waders for months out of the year.

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Fig. 4.25. Flood House rendering (2011)

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Fig. 4.26. Flood House plans (2011)

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Fig. 4.27. Flood House section flood (2011)

Flood House

F9 productions designed Flood House to be both self-sufficient while also protecting the home from common natural disasters. With many of the teams members originating from the flood prone area of North Dakota, the thought of what would happen if the flood dikes protecting the area failed (F9 Productions Inc.). This resulted in the design of the Flood house, a two-levelled house, where the ground is mostly open to the outside, with only storage and the stairwell to the main living area on the second level. The house is protected by the living areas being raised in addition to sliding steel guards surrounding the house from debris. The house itself is also self-sufficient through water collection, solar panels and insulations. In addition the second level's balcony also acts as a boat dock for times when the house is only accessible by boat (Jett, 2011).

While this house has no exact site and is designed so it could be built and altered to work in many locations, it does seem to be designed for extreme cases, and would need to be redesigned a lot to work in the context of South Dunedin where a large number of houses need to be protected, rather than just one.

Fig. 4.28. Floating House from street (2016)

Fig. 4.29. Floating House entrance courtyard (2016)

Fig. 4.30. Floating House section (2016)

Floating House

Designed Nha Dan Architects in 2015 for Ho Chi Minh city in Vietnam, the house is located in an area that is prone to frequent flooding due to poor storm drainage systems. This resulted in the entire house being supported by four concrete columns, with the main structure located on the third floor with the first and second floor being suspended from this. This allowed for an open terrace at ground level, with a 0.7m dug out basement for water storage. This all allowing for the illusion of the house floating above the ground and the water (Archdaily, 2016).

The design of the house works well with allowing the house to feel open to the elements, making the surrounding nature feel like it is one with the house. The water collection below the house was an important element for the type of flooding that would occur here, but if it was applied to the South Dunedin context, with its high ground water levels, any dug out bits of land would just result in permanent ponds of water, at the level of the aquifer.

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Fig. 4.31. Tsunami House from
coast (2014)

Fig. 4.32. Tsunami House living
area (2014)

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Fig. 4.33. Tsunami House section (2014)

Tsunami House

Tsunami House, by Designs Northwest Architect, built on the coast of Camano Island, is built to withstand any future tsunamis. The house is made up of three levels, with the main living areas and bedrooms located on the second and third floors. The First floor is designed to allow water through in the event of a tsunami or large storm event, with columns being the main structural elements in the building and parallel glass doors located on either side of the building are designed to break away and allow water through the lower level (Nguyen, 2014). The lower level uses floodproof materials so allow for easy clean-up after a flood, and the building itself can withstand high velocity waves up to 2.4m, a magnitude 7.8 earthquake and 136.8kph wind loads ("Tsunami House / Designs Northwest Architect," 2014).

The house is a great example of how you can protect important parts of the house from floodwaters by raising them above expected water levels, but still be able to occupy the area underneath. As discussed room to flood houses are basically an extension of pile dwellings, but instead of having open space below, you can actually use the spaces below if they are designed to be able to withstand water. They are also better in comparison to pile dwellings as they continue the dwelling to street connection that most existing houses have, and that people want, whereas pile dwellings loose this.

4.3 - Community Adaptation

Like the previous experiment, this section will analyse the theory around community resilience to flood water and analyse them against physical community designs. These categories being

- Build over - wetlands
- Build alongside - cut & fill
- Build for - multipurpose areas

Build Over

Fig. 4.34. Build Over (2017)

Build Alongside

Fig. 4.35. Build Alongside (2017)

Build For

Fig. 4.36. Build For (2017)

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Fig. 4.37. Miami Beach (2015)

Fig. 4.38. Qunli Stormwater
Wetland Park (2013)

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Fig. 4.39. Taasinge Square (2018)

Fig. 4.40. H2O wonen (2011)

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Fig. 4.41. Enghave Park (2018)

Fig. 4.42. Rotterdam water square
(2018)

Fig. 4.43. Miami Beach residential street section (2015)

Fig. 4.44. Miami Beach coast (2015)

Fig. 4.45. Miami Beach comercial section (2015)

Miami Beach

Designed by Isaac Stein for his senior thesis project, the Miami Beach project proposed a solution for Miami beach to survive the next five feet (1.5meters) of sea level rise. The main idea was to adapt the city to sea level rise by bringing back a layer of the natural landscape, including storm-surge reducing plants that historically occupied the coasts of Miami beach (KAMP, 2015b). Through the creation of recreational walkways and canals six feet (1.8meteres) of fill was proposed to raise the surrounding streets by 1.5 feet (0.45meters).

Miami Beach itself has a very similar land type to south Dunedin, with unconsolidated ground along with a high water table (KAMP, 2015a). Due to this, Isaac Stein's proposal for Miami using methods to recreate the past water landscape to adapt to sea level rise could realistically be adapted to the South Dunedin landscape by recreating the 1850's wetlands. His focus on improving public transport to reduce the reliance on cars is a great example of being able to reallocate the space that roads take up to spaces to hold water.

Qunli Stormwater Wetland Park

Designed by Turenscape to revitalise a dying wetland in the middle of a city, Qunli Stormwater Wetland park decided to transform the existing wetland into a multipurpose stormwater catchment area for the city. The aim to bring back a thriving wetland while adding to the aesthetic of the city and adding new recreational experiences for the city (Schofield, 2015). The method of cut and fill was used to create a 'necklace' of stormwater ponds and mounds surrounding the wetland (Archdaily, 2013).

While the South Dunedin flood plains wetland is not exactly dying (its just been forced down) this method of revitalising the wetland could benefit the flood plain, by not only bring back the wetland, but also having it act as a stormwater catchment area. The cut and fill method used in this precedent also seems to be the best way for the South Dunedin area to bring back the wetland areas, while also being able to raise the existing housing.

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Fig. 4.46. Qunli Stormwater Wetland Park entrance (2013)

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Fig. 4.47. Qunli Stormwater Wetland Park site plan (2013)

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Fig. 4.48. Qunli Stormwater Wetland Park walkways (2013)

Fig. 4.49. Taasinge Square walkways (2018)

Fig. 4.50. Taasinge Square site plan (2018)

Taasinge Square

Built in the centre of Denmark's first climate resistant neighbourhood, GHB designed Taasinge Square is designed to retain rainwater that falls around the square and surrounding roofs. In addition to the focus on rainwater and stormwater storage, Taasinge Square attempts to have people interact with this storage with a number of sculptures that also act as storage tanks with handpumps so people can physically interact with using the collected water to and release it onto the vegetation (GHB Landskabsarkitekter).

While, Taasinge Square addresses the collection and storage of rainwater at a small scale, in a South Dunedin context it could be replicated throughout the floodplain creating connected hubs of storage. The focus on human interaction is also an important aspect that could be incorporated into any South Dunedin flood plain interventions, as it is just as important to solve the problem of flooding as it is for people to understand it.

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Fig. 4.51. H2O Wonen site plan (2011)

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Fig. 4.52. H2O Wonen site rendering (2011)

H2O Wonen

H2O Wonen is an amphibious neighbourhood designed for the small town of Zeewolde. The plan explored the how 1400 amphibious houses could be built as a community. Rather than having a continuous closed body of water, which most amphibious neighbourhoods are designed for, this project proposed a number of semiprivate water gardens surrounded by residential dwellings, rather than one large body of water (Nillesen et al., 2011). Through cut and fill methods the ponds would be dug out, and raised banks would be created using the cut out fill.

The idea of using water gardens in south Dunedin to store water allows residents to still have the sized gardens that they currently have, while allocating space to bring back wetland and marshland areas. Connecting these gardens like in this precedent could also allow for new interactions between residents and community, but also between the residents and the land they occupy.

Fig. 4.53. Enghave Park site rendering (2018)

Fig. 4.54. Enghave Park no flood/flood (2018)

Enghave Park

Designed as a multipurpose park, Enghave park by Third Nature (Tredje Natur) Is designed to be a public park within Copenhagen which doubles as a stormwater retention pond. Able to hold 24,000 cubic meters of rainwater the park aims to relieve stress on the surrounding areas during times of heavy rain (Grozdanic, 2016). During dry months the park contains an amphitheatre sports courts and public walkways, all of which are designed to fill up with and contain water collected on site and from surrounding rooftops (Thrid Nature).

The method of creating multipurpose spaces for locations where flooding is not year round could be very helpful. In particular the use of sports field and courts, due to the two large fields within the South Dunedin site that are used often for sporting events. Creating spaces that could both accommodate these events during the year, while also being able to hold stormwater during periods of high rain, could both reduce flooding while also relieve stress from the existing stormwater systems.

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Fig. 4.55. Rotterdam water square no flood (2018)

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Fig. 4.56. Rotterdam water square flood (2018)

Rotterdam water square

Like with the sport courts within Enghave Park, the water square in Rotterdam in the Netherlands aimed to improve the urban landscape while integrating water storage for the community. The square contains three basins, two of which will receive water from the immediate surroundings whenever it rains, with the third only filling when there is consistent rain that cannot be handle by the first two basins alone (De Urbanisten). During dry periods the square each of the basins serve a different purpose, the first for people using wheels (such as bikes and skateboards), the second as a smooth dance floor and the third a sports pit for football, volleyball and basketball.

The use of Multipurpose spaces and water catchment areas will be an important aspect in the proposal for the South Dunedin flood plain. While this precedent works well for creating these multipurpose spaces, the spaces themselves are very hard and impermeable, surrounded by large tall buildings. Where this aesthetic works in the scenario, for South Dunedin if this method was applied, an integration into the proposed wetlands and low height housing would need to be considered.

Amphibious housing was chosen as the housing type for Dunedin for three main reasons

1. The connection to the ground, as Dunedin is going to experience both sudden flooding, caused by storms and weather patterns as well as increased water levels over time, the connection to the ground, reduces the 'major changes' residents will have to go through. Currently the people of the South Dunedin flood plain live in land based dwellings, directly on the ground. The choice of a floating house in this area would be seen as to much of a jump from what is currently in place.
2. It's the right type of middle ground between a land dwelling and a floating house. As discussed in earlier chapters, it is no longer reasonable to live in basic land based dwellings at the South Dunedin's flood plains currently elevation. Bar increasing the actual land masses of the site (which would be extremely costly) the houses themselves would have to move to avoid the water. The amphibious house seems to be the best fit for introducing people to new ways of living on water.
3. The development of this method that is currently happening within the architectural community. This type of flood adaptable housing is fairly new with most of the major developments having happened within the last decade (Baca's amphibious house and the buoyant foundation project), and is continuing to be researched today.

This Chapter focuses on analysing existing amphibious housing designs alongside how they were built. While the theory around how amphibious housing actually float is the same, the materials and building methods range from project to project. This chapter looks into these different methods to decide on the building method and materials to use for South Dunedin.

5.1 - Baca's Amphibious House

Designed by Baca Architects, the Amphibious house provides a new method of building on the river thames. On a site that regularly floods throughout the year, the Idea for the house was to build a dwelling that would raise as the thames rises, and then returns to its original position as the water recedes.

This was achieved through the designing of a double concrete foundation, where the first fills with water as the water rises, allowing the house to rise up due to the second watertight foundation. The House stays in place due to the four mooring posts on the outer walls, guiding the house as it rises (Coutts, 2016).

The house itself is lightweight timber framed, and has a traditional construction (Winston, 2014). This allows the centre of mass within the building to be very low to reduce rocking when it is floating.

Fig. 5.1. Amphibious House section (2016)

Fig. 5.2. Amphibious House concrete foundation (2014)

Fig. 5.3. Amphibious House Timber framing (2014)

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Fig. 5.4. Gouden Hust section (2011)

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Fig. 5.5. Concrete Hull
construction (2011)

Fig. 5.6. Concrete Hull moved into
water (2011)

5.2 - Gouden Kust, Netherlands

Located outside of the Maasbommel dikes, the Maasbommel amphibious homes were built as part of the Netherlands' Ministry of Transport's EMAB (experimentation with adaptive construction) and have been 'granted permission to experiment using adaptive methods of construction' (Factor Architecten bv, 2011). The development is made up of 32 amphibious houses and 14 floating homes. At times of NAP +2.6 (NAP = amsterdam national water level) the amphibious dwelling is on the ground, and at times of NAP +5.1 the 'dwelling floats free' (Factor Architecten bv, 2011).

The dwelling is made of timber framed construction to limit the weight, and resides on a concrete caisson which acts as the dwellings pontoon. Houses are arranged in pairs to increase stability and two mooring poles are placed between the dwellings to keep the dwellings in place.

At times of high water both the amphibious houses and floating dwellings cannot be reached by car as the access road that runs along the outside of the dyke is submerged. (Factor Architecten bv, 2011)

5.3 - The Float House

A design as part of the 'Make it right foundation' was developed to allow people to relocate to the lower ninth ward of new Orleans in response to the damage caused by hurricane sandy. Students of UCLA along with the architecture firm Morphosis joined together to design and build a dwelling that both fit with the character or New Orleans as well as being able to withstand another flood/hurricane/storm.

The design of a redefined shotgun house they came up with consisted of two parts, like a car, the chassis and the shell.

The first component, the chassis, is what keeps the building safe from water, it is what floats. Made up of a 'prefabricated foam and concrete base' allows the house to be buoyant as waters rise, while also containing all the electrical and plumbing systems (Smith, 2009).

The second component is the shell, the house itself. Taking the form of the classic shotgun house, the dwelling contains a living area, kitchen, two bedrooms and a bathroom, all in a liner pattern.

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Fig. 5.7. Float House assembly (2009)

6.0 - Design Led Research, experiments
and critical reflection

6.1 - Establishment & Quickstart

The goal of the quick start process was to create four completely different interventions for the South Dunedin Flood plain in a short time based on previous literature based observations and initial design hunches about suitable responses. Through these quickly produced design outcomes, the research question was developed alongside design-led testing and evaluation of spatial concept ideas.

The four concept ideas which were produced in this quick start design each focused on a separate environmental problem or future prediction of environmental problems facing the South Dunedin flood plain. These were

South Dunedin land elevations and road widths

Predicted flooding for 0.6m sea level rise

The landscape of South Dunedin in the 1850's

Predicted Flooding of a Sea level rise of 4mm/year

This then resulted in the four interventions as followed

Canals along South Dunedin Streets

A series of wetlands throughout Tonga and Bathgate park

Recreation of the South Dunedin Lagoon from the 1850's

A series of catalysts throughout South Dunedin

Fig. 6.1. South Dunedin road with plan (2017)

Fig. 6.4. South Dunedin park ponding (2017)

Fig. 6.2. Hargest cres canal no flood (2017)

Fig. 6.5. South Dunedin park ponding no flood (2017)

Fig. 6.3. Hargest cres canal flood (2017)

Fig. 6.6. South Dunedin park ponding flood (2017)

Fig. 6.7. South Dunedin 1850's lagoon and wetland (2017)

Fig. 6.8. 1850's lagoon and wetland overlay with surface ponding (2017)

Fig. 6.9. surface ponding catalysts (2017)

Fig. 6.10. surface ponding park (2017)

6.2 - crit feedback

The overall view was that the project may be at too large of a scale which would then result in emphasis on a landscape intervention rather than an architectural intervention which is what was wanted. So, rather than looking at the three scales of dwelling, suburb and city, the decision was made to look instead at dwelling, street and suburb.

It was suggested that examination of both natural and designed wetlands occur further in order to understand how they work during floods and to further understand how they can work as flood prevention measures. It would also be beneficial to then look to how architecture is designed and incorporated into the landscapes alongside and within wetlands.

Looking into the Netherlands as a case study was also suggested to see how that country have solved flooding issues on an industrial, community and an individual housing scale.

Considering how the architecture itself could be a barrier for water could be beneficial rather than looking at two design interventions, first the flood land and then the house on top.

It was decided in the discussion that the intervention/interventions decided upon must not waste the valuable land of the South Dunedin area by replacing a large amount of the landmass that is allocated for housing with blue spaces.

6.3. - Research refinement

The first formal design review focused on the refinement of the research question along with the analysis of the site itself, solidifying this research's positioning within the South Dunedin community . The site analysis focused mainly on the problems the South Dunedin area was dealing with, in particular the high groundwater levels, the erosion of the sand dunes and sea wall, the low elevation of the site and the site's history of being a wetland.

A presentation of the crucial theory in relation to the design of flood resilient housing and communities along with key precedents at this stage of design at the three scales in which design was to happen, the house, the street and the community.

Fig. 6.11. Design review one presentation (2017)

6.4. - Critical Feedback

The main suggestion from this critical review was to not forget the existing architectural context which defines the South Dunedin area. Where the environmental context had been well explored, a further and better exploration into the existing and historical architectural context of both New Zealand and in particular Dunedin could be very beneficial when concept design and development began.

The second suggestion was regarding the defined levels of flooding and the timeframes. Where the different environmental elements had been investigated individually, it would be helpful to define the specific time frames and water levels the designs will work with, for example 10 year, 50 year, 100 year sea level rise predictions and storm events.

6.5 - Concept iterations and ecologies design lab critiques

After design review two, the next month was assigned to the concept design of flood resilient houses. At this stage the housing type of amphibious housing had not been decided upon just yet so a range of concept designs were explored in response to the problems found with the different housing typologies through the precedent housing analysis.

During this time the focus was on designing wetproof houses and amphibious houses (for reasons explained in chapter 3).

The following figures show the range of concept designs that were produced and the ones which were chosen for continuing onto the developed design stage.

Fig. 6.12. Stairwell movement design 1 (2017)

Fig. 6.13. Stairwell movement design 2 (2017)

Fig. 6.14. Stairwell movement design 3 (2017)

Fig. 6.15. Concept designs (2017)

6.7 - Design Development and design review 2

The second design review focused on presenting the dwelling research findings, the developed concept design for the new hybrid amphibious house and the overall masterplan scheme for the South Dunedin flood plain.

Fig. 6.16. Design Review 2 masterplan (2017)

Fig. 6.17. Design Review 2 masterplan 10 year (2017)

Fig. 6.18. Design Review 2 masterplan 50 year (2017)

Fig. 6.19. Design Review 2 masterplan 100 year (2017)

Fig. 6.20. Design Review 2 amphibious house street section (2017)

Fig. 6.21. Design Review 2 amphibious house water walkways (2017)

Fig. 6.21. Design Review 2 amphibious house s

street level (2017)

Due to all three reviewers being landscape architects, most of the feedback was situated around the master planning and the use of the canals.

- Focus on improving the landscape - if people are going to have a smaller plot of land - it needs to be better

One of the major critiques of this design was regarding the movement of water around the site. To create the environment I was hoping for, the design needed to create or allow for water movement so that the blue spaces didn't become static and stagnant. This opened up a possibility for connecting / reconnecting the Otago Harbour to the Pacific Ocean through St Clair and St Kilda beaches, to create a flow of water throughout the site, while also including these two existing public spaces into the design development.

The second critique related to the location of the public walkways along the street. Through having the central walkway down the middle of canal, potential for water transport was limited which was an important part of the initial concept.

The suggestion to include more of a response to the existing street layout was proposed. While this suggestion would not really work in relation to the space needed for the new blue area walkways, it was taken on to include better consideration to the existing roads around the edges of the site to improve better connections onto and through the site.

6.8 - Design refinement and ecologies design lab critiques

Fig. 6.22. masterplan developments (2017)

hal map?

7.0 - Final Design

Fig. 7.1. Final design masterplan (2017)

The canals in the final design were updated, by using a hierarchy of smaller shallower canals incorporated into the wetlands alongside the existing and new amphibious housing, with wider and deeper canals connecting the Pacific Ocean and the Otago Harbour along with the perpendicular with the ones that boarder the houses. The canals were created using the cut and fill method, by cutting down at least a meter and using the fill to raise up the planned roads and old housing above flood water levels. The spaces between the cut out canal and the new raised roads is where the major interventions happen with the incorporation of the designed 3 attached amphibious houses.

7.1 - Sunny everyday environment

This new community layout is designed to allow for people to continue on with their lives, no matter the weather. This first example focuses on the environment where there has been no rain of recent, the canal water level is at its base level, and there is access to all aspects of the community.

At this stage the amphibious houses are grounded at their base, all aspects of the backyard are habitable, including the canal walkways, bridges and piers. Public movement around the community is happening at both street level and canal level, including the connecting walkways between them.

Fig. 7.4. Amphibious complexes 1, 2 and 3. Upper and lower levels (2017)

Fig. 7.2. View from street towards existing housing (2017)

Fig. 7.3. Amphibious house 1 kitchen view onto wetland (2017)

Fig. 7.5. Amphibious house 1 livingroom view onto wetland walkway (2017)

Fig. 7.6. Wetland walkway onto canal (2017)

7.2 - Storm environment - 500mm of rain

The second example looks at a scenario where it has been raining for days on end and the water levels have risen by 500mm. At this stage the amphibious houses are still grounded (they do not begin to float until 1000mm of water has risen). The canal walkways, piers and bridges are still usable, but the wetlands have begun to flood resulting in waters being up to the edge of the walkways.

The occupants are still free to move throughout the canal walkways and bridges without having to walk through flood waters, and the piers are still available for people to use row boats and canoes as their form of transport.

Fig. 7.7. Amphibious house 2 kitchen onto living area (2017)

Fig. 7.9. Wetland walkway up to street level (2017)

Fig. 7.10. Amphibious house 2 living area onto flooded wetland (2017)

Fig. 7.8. Amphibious house 2 section (2017)

Fig. 7.11. Wetland walkway during yearly flood (2017)

7.3 - Flood environment - 2500mm of rain

The final environment looks at a maximum flooding scenario where waterlevels have increased by 2500mm of rain. At this point the canals, wetlands and walkways have been flooded, so the street level walkways are the main means of movement around the community. Water has risen to the edges of the old houses backyards, without reaching or flooding the house.

The amphibious has risen to its maximum level, and the main access to the houses have moved from the canal side to through the street level carparks.

Fig. 7.12. Amphibious house 1 section (2017)

Fig. 7.13. Amphibious house 3 section (2017)

Fig. 7.14. Access to amphibious housing from street through parking (2017)

Fig. 7.15. Amphibious house 3 at maximum flood level (2017)

Fig. 7.16. Amphibious house 3 from kitchen onto front entrance (2017)

Fig. 7.17. Amphibious houses at maximum flood from bridge (2017)

7.4 - Construction

The floating base of each of the three amphibious houses is made up of a 0.85m deep precast hollow shell concrete, which in dry conditions sits within a 0.85m deep foundation basin which when the base is sitting within the first floor level lines up with the level of the front courtyard and backyards. As water rises filling the basin the hollow shell base rises, guided by the four steel guiding posts.

The house itself is made with light timber framed construction, and is externally clad with timber weatherboard. the internal furnishings of the house can be altered and customised by the user, but for this example the internal walls are covered in painted jib with wooden fixtures.

The house is able to float due to the following calculation

<u>Total Load</u>	==	Minimum depth
Weight of water	==	of foundation
Dead Load - House	=	200kgm ²
Dead Load - Foundation	=	300kgm ²
Live Load - Ground Floor	=	150kgm ²
Live Load - First Floor	=	150kgm ²
Live Load - Roof	=	50kgm ²
Total	=	800kgm ²
<u>800</u>	==	0.85m
1000

Fig. 7.18. Amphibious houses exploded axonometric (2017)

8.0 - Research Reflection

8.1 - Discussion / Research Findings

1/ Flood resistant housing will only be effective when people can go about their everyday lives during flooding events. This can only happen when the community and urban design around the houses works in concert with the flood adaptation methods employed within the houses themselves. As new flood resilient housing typologies are developed and built, the problem of isolation during floods becomes more apparent. These houses are still being designed with the idea that floods arrive fast and they leave just as quickly, just in time for people to move back to the normal ground level and continue to go on with their lives as they did before the flood. But this is likely to no longer be the case in the near future, because floods will likely become more frequent in many parts of the world, and last longer as a result of climate change. The first key finding of this research therefore is that it is no longer effective to consider just individual dwellings when designing for flood adaptation in an era of climate change. Flood adaptive design needs to be addressed at the urban scale, looking at both the street and the neighbourhood / suburb context, in order to create designs that work just as well in dry seasons as they do in wet ones or during floods. Understanding the ecological history of site, and likely climate change impacts in the future is crucial in this regard.

2/ People tend to live in areas that are desirable to them. The architectural landscape of South Dunedin is Victorian, with Dunedin being known as the 'Victorian City' of New Zealand. This is an aspect that many of those surveyed liked about the area of South Dunedin. In part two of the survey, which evaluated new methods of flood resistant housing design, many comments were made about the technical solutions not fitting in with the existing Victorian streetscape and landscapes. This was also discussed during critical reviews of the design work where the research was better received when the interventions incorporated elements of the existing housing stock, and therefore the existing character of the suburb's buildings into the design. This highlights the second key finding of the research, which is the importance of not just taking a technical approach to

designing housing within a flood prone landscape, but the need to also incorporate the existing residents' and urban landscape's character into the design where possible. As residents would already need to adapt to a new way of living alongside water in the proposed design, it is more important to keep the connections residents have to the original environment. Understanding the cultural history of the site is crucial.

3/ When the outdoor spaces of residential properties need to be reduced (to allow for spaces for waters to rise and fall without damaging infrastructure), shared public spaces can be used to mimic in part aspects of the private spaces lost. This is important with higher density communities becoming more common as a way to provide housing for a larger number of people. When applying this idea to the low-density suburbs of South Dunedin, density was increased in the outcome suggested by the design-led research process by both moving from single story dwellings to multi story, but also through the reduction of private outdoor and garden spaces to take into account the extra space needed to allow water to rise and fall without damaging buildings or infrastructure. This change allowed for extra public spaces to be created through the canals and wetlands that border all of the existing and new amphibious housing designs. So although private outdoor spaces have been reduced by roughly 50% compared to the existing houses on the site, public outdoor space is still included in the design to allow the residents to use and experience their new communities in different ways. These include having the public spaces look like extensions of the private backyards, and provide much better views (over the wetlands and canals) compared to the existing fenced in grass backyards.

8.2 - Conclusion

As sea levels rise and flooding and surface ponding become more frequent, communities on the edges of water bodies and coasts will need to improve the way in which humans live with water as it rises and falls. As housing and infrastructure on low lying land is engulfed by water, the way in which people not only reside in these houses, but also how they continue with life during these events, or even permanent changes will need to adapt. Throughout this research it has always been an aim not to just design a flood resistant building, but a way in which communities can go on with their lives alongside fluctuating water levels.

Through this design led research it has been found that the way in which architects typically currently design and build for flood resistant dwellings, by simply looking and designing within the house's site boundary, is no longer effective when one considers that whole communities will become uninhabitable as time, and sea level rise, and as in the case of South Dunedin, ground water table rise goes on. This means that architects, developers and governments need to look at solving and adapting to flooding at larger community wide scales, rather than just at individual dwelling scales. With sites like South Dunedin, larger governmental interventions will need to occur to fund these developments.

At this time where flooding is still related to temporary events, the Dunedin still has the option to move and rearrange buildings and infrastructure within South Dunedin to accommodate the water level changes while incorporating and/or relocating the existing character housing. If the city waits until the floods become more permanent due to sea level rise, much of the housing and infrastructure that is still currently useable, will be ruined, along with millions of dollars of investment. This will obviously also greatly affect people who live there negatively in multiple ways. Perhaps instead the inevitable flooding of South Dunedin can be seen as a unique opportunity in New Zealand to experiment with a new kind of urban development that allows flooding and in fact celebrates it while increasing the liability of a suburb and therefore the wellbeing of the people who live there. What has been proposed in this design-led research is one of many possible alternatives to a simple relocation of people and abandonment of land in South Dunedin. What is crucial at this stage is opening up a wider dialogue that goes beyond a purely technological response and incorporates creative approaches to solving this problem, before several options become permanently unavailable due to inaction.

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Fig. 8.7. 1500mm water level rise (2017)

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Fig. 8.8. 1750mm water level rise (2017)

- ☐ It has the best amenities and/or recreation facilities
- ☐ I have Family and/or Friends that live there
- ☐ I grew up in the area
- ☐ Other _____
- ☐ Feel free to expand in the space provided

5. How did the July 2015 floods alter your everyday life

- ☐ I was unable to attend work/school
- ☐ I had to leave my house and find shelter elsewhere
- ☐ The flooding caused damage to my hous

9. Who do you feel is responsible to prepare for these flood events?

- ☐ The government at a country wide scale
- ☐ The Regional councils at an Otago scale
- ☐ The city Councils at a city wide or suburb scale
- ☐ Individuals should be responsible for their own houses flood protection.
- ☐ Feel free to expand in the space provided

Fig. 8.9. 2000mm water level rise (2017)

Section 2 – The Future of the South Dunedin Flood Plain

In this section you will be asked to respond to current methods of flood resistance and how you feel about these potentially being applied to the South Dunedin Flood plain.

The flood resistant examples you will see are mainly international examples and work at two different scales, first the individual house and second the street. Try not to overthink your answers, what we want to find out is the appeal of these different methods to you as someone who occupies the South Dunedin flood plain, and whether or not you would use these spaces if they were available to you.

Individual House Scale

1. A house on stilts – **NYC Parks** – By Garruson Architects

These lifeguard stations are built to be flood proof by being elevated above the 100-year flood plain.

Figure 1 NYC Parks view from beach.

- ☐ Yes
- ☐ No
- ☐ Maybe
- ☐ Feel free to explain why in the space provided

2. A house designed to flood – **Tsunami House** – By Designs Northwest Architect

This house is designed with the living area and main house amenities on the second floor with ground floor being a second living area which is designed to flood during extreme high tides and times of flooding

Figure 2 Tsunami House From the coast

- ☐ Yes
- ☐ No
- ☐ Maybe
- ☐ Feel free to explain why in the space provided

3. A floating house – **Floating House** – By MOS Architects

This floating house is built with 2.4 long, 1m wide cylinders to allow it to float and can rise and fall with lake.

Figure 3 Floating House from water

- ☐ Yes
- ☐ No
- ☐ Maybe
- ☐ Feel free to explain why in the space provided

4. If you were put in a position where you needed to live in one of the three dwelling, which would you choose

- ☐ Option 1 – A house on stilts
- ☐ Option 2 – A house designed to flood
- ☐ Option 3 – A floating house

Fig. 8.10. 2250mm water level rise (2017)

Street Scale

5. Cut & Fill – **Westflank** – By Haarlemmermeer

A cut and fill method was used by taking soil from some area to provide room for water storage, and used this removed soil to elevate the roads and the water edges.

Figure 4 Westflank street overview

- ☐ Yes
- ☐ No
- ☐ Maybe
- ☐ Feel free to explain why in the space provided

6. Canal – **ChonGae Canal** – Mikyoung Kim Design

Figure 5 ChonGae Canal from below bridge

The canal was built after a deteriorating highway was demolished to provide a public space that also doubles a flood catchment area.

- ☐ Yes
- ☐ No
- ☐ Maybe
- ☐ Feel free to explain why in the space provided

7. Wetland – **H2O Wonen** – By Zeewolde

A range of wetlands were created to reduce pressure during flooding, and elevated areas of high use and to provide connections between the wetlands

- ☐ Yes
 - ☐ No
 - ☐ Maybe
 - ☐ Feel free to explain why in the space provided
-
-

8. If you were put in a position where you needed to live in one of these street environments, which would you choose

- ☐ Option 1 – The cut and fill landscape
- ☐ Option 2 – The Cannal
- ☐ Option 3 – A wetland

Fig. 8.11. 2500mm water level rise (2017)