

An aerial photograph of a coastal city, likely Wellington, New Zealand, showing a dense urban area with a large floating structure, possibly a VLFS (Very Large Floating Structure), in the water. The image is overlaid with a blue tint.

Floating Development, An Alternative to Land Reclamation for Waterfront Development

– A Case Study for Design and Construction of VLFS in Wellington

Xin Sharyn Qu

VICTORIA UNIVERSITY OF WELLINGTON
Te Whare Wānanga o te Ūpoko o te Ika a Māui



FACULTY OF ARCHITECTURE & DESIGN
Te Wahanga Waihanga-Hoahoa

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A thesis presented in partial fulfilment of the requirements for the degree of Master of Architecture
[Prof] at School of Architecture, Victoria University of Wellington, Wellington, New Zealand.

Abstract:

In countries Japan, Netherlands, and Singapore they experience increasing land scarcity due to concentration of population or flooding issue. The growing concerns over environmental degradation and political conflicts due to land reclamation means land-filled is no longer an acceptable way. Thus these countries put greater emphasis on investigating and application of other alternatives, such as floating structure, to allow for urban expansion. In particular, Very Large Floating Structure (VLFS) is becoming increasingly popular and promising.

This thesis presents a range of water-based development that include urban and architectural scale, historical and recent, and focuses on analysing the urban aspects. Projects of Japan, Netherlands and Singapore are researched at lesser detail for understanding technical, economy and political considerations in a floating development. The purpose of this thesis is to investigate the possibilities of having floating structure as a way to expand the city. The case study used is of VLFS on the Lambton Harbour of Wellington city, New Zealand, to demonstrate the feasibility.

Keywords: Water-based Development, Floating Development, Very Large Floating Structure (VLFS), Urban Expansion.

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Chapter One: Introduction

The thesis exams the practicalities and possibilities of floating structure as an alternative to land reclamation for urban expansion in coastal city, the case study used is of Very Large Floating Structure (VLFS) in Central Wellington City to test the research. It focuses on urban aspect, and would also acknowledge technological, economic, and political aspects.

This introductory chapter will serve as a frame for the rest of the thesis. Chapter One starts with identifying the reasons of why to look for an alternative to land reclamation, using land reclamation project in Singapore as an example and why floating structure is used as an alternative. The chapter then goes into detail about the aim of the thesis. This is followed by a brief description of the existing research, and a discussion on the chosen context for case study, Central Wellington City. Lastly, structure and significance of the thesis are explained.

1.1 Why an alternative to land reclamation

Land reclamation is a common way to accommodate growth in coastal or riverside cities. It is the process of creating new land from sea or riverbeds. Urban expansion of coastal area is essential because 1) there are significant growth in demand for coastal land, due to the fact that coastal land often holds great importance in providing finance, culture, and transportation services, as well as providing amenity value for many of world's largest cities; therefore, coastal lands are more desirable and valuable; and 2) population of the coastal regions continues to expand at an increasing rate due to life style choice, tourism, greater employment opportunities, which leads to even greater need for land.

However, land reclamation has significant adverse environmental and political effects. For example, land reclamation in Singapore requires supply of sand for land filled from Malaysia and Indonesia. The excessive digging caused by the demand for sand has a negative impact on the lands of Malaysia and Indonesia. Furthermore, Singapore's reclamation projects, in particular, *Inter Alia*¹, attracted political conflicts about impingement on Malaysia's territorial waters, because the reclamation work in Singapore caused adverse harm to Malaysia's marine environment.

As a result, new land reclamation projects are increasingly unacceptable. Reclamation in Singapore is becoming more difficult and controversial as Indonesia, following Malaysia's lead, banned the export of sand due to irreversible environmental impact and concern for territory². This means a new

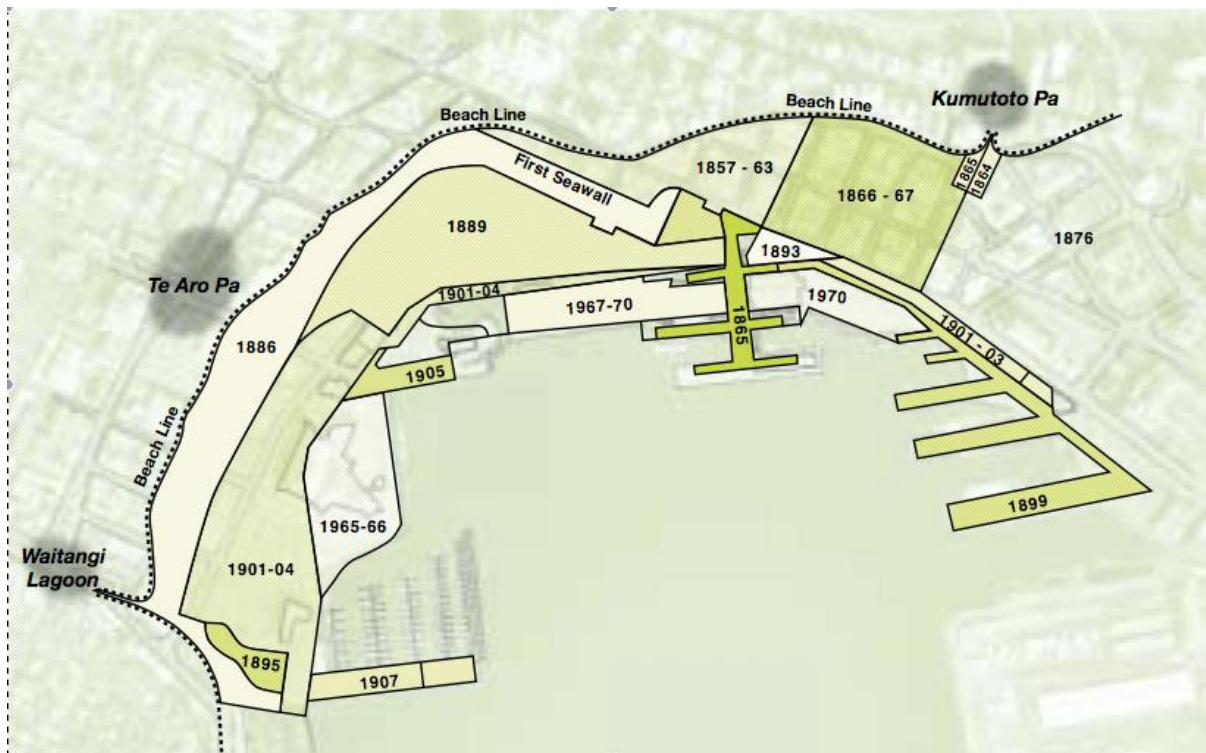


↑ Figure 1-1 The Float @ Marina Bay, Singapore
Source: Marina Bay Singapore



↑ Figure 1-2 The Palm Project, Dubai
Source: Flesche, F. *Water house*, (London: Prestel, 2005), pp. 39.

↓ Figure 1-3 Reclamation in Central Wellington City
Source: *The Wellington Waterfront Framework*. Wellington City Council (April. 2001). pp. 7.



water-based approach for creating dry land from areas covered by water is crucial in order to continue urban expansion in the coastal regions.

1.2 Why choose floating structure

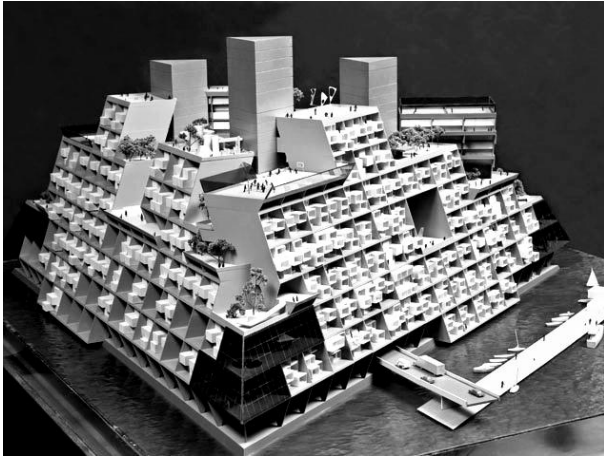
Meanwhile, regions of Japan, Singapore and Netherlands have been looking at floating developments, as alternatives to land reclamation to create more land. The idea is relatively new to the early 21st century, and it is still at its experimental stage. The great potential of floating structure is demonstrated in the recent completed project of *The Float @ Marina Bay*, Singapore (figure 1-1). The main advantage of a floating structure is the fact that it does not take up valuable and maybe even limited area on the shoreline and it has a small environmental impact compared to land-filled project such as *The Palm Project* off the coast of Dubai (figure 1-2). These advantages make floating developments ideal for the creation of land aiming at urban expansion in the coastal regions.

1.3 Aim of this thesis

The aim is to find out what would be possible if floating structures were available instead of reclamation as a form of urban expansion, with emphasis on urban aspects while briefly acknowledge the technological, economic, and political aspects. The idea is tested by a case study. The brief of this case study is to propose a feasible long term plan of a different future for Central Wellington City beyond 2040, that continues to expand its waterfront using VLFS development.

1.4 Background of Central Wellington City

Historically in Central Wellington City, the CBD underwent a number of land reclamations (figure 1-3) out onto the coast to provide more usable flat land for trading port, marine transport and railway. These reclamation projects were aimed to fulfil the need and wants of the city that was required for urban growth. The reason was being that the city has hilly topography on the west that was more expensive and difficult to turn into flat road surface or to build upon. An example of a past project, that during the 1920s, in one of the largest projects, 250,000m² of new land was added for railway purpose, which still remains an important transportation network. However, reclamation is no longer acceptable for Wellington City mainly because of environmental concern.



↑ Figure 1-4 Triton City, 1965, Tokyo Bay, Japan
Source: Mark, R., *The Dymaxion World of Buckminster Fuller*, (Garden City, N.Y., Anchor Books, 1973), pp.231.



↑ Figure 1-5 Aquapolis, 1975, Okinawa, Japan
Source: Kaji-o'grady, S. & Raisbeck, P., *Prototype cities in the sea*, The Journal of Architecture, Vol, 10, No. 4, (London: E. & F.N. Spon, 2005), pp. 450.



← Figure 1-6 Lilypad, 2008, Dubai, UAE
Source: Vincent Callebaut Architect, *Lilypad, a floating ecopolis for climate refugees*, (2008), <http://www.vincent.callebaut.org/>, accessed on 01/11/10.



← Figure 1-7 Amphibiou homes, Maasbommel, Netherlands
Source: Kengen, G., *Amphibious houses, a sustainable alternative?*, Facor Arohitecten, (Presentation, 22/11/07) <http://www.vereniging-bwt.nl/>, accessed on 09/01/11.

↙ Figure 1-8 TRAM project, 1995-2001, Tokyo Bay, Japan
Source: Suzuki, H., *Overview of Megafloat: Concept, design criteria, analysis, and design*, Marine Structures, Vol . 18, (Amsterdam: Elsevier, 2005), pp. 126
Phase 1 on left, Phase 2 on right.



1.5 Existing research

Currently, there has been no solid research on the urban aspect of floating structure in city expansion, because it is very recent with few literatures devoted to it. Thus, the materials are both fragmented and very limiting. Some of the researches focus on theorising the concept of inhabiting the sea and briefly describes the projects. Others are touched on the surface of the technical issue regarding engineering calculation, the main structural components and some detail designs, and basic applications of floating development. Furthermore, very few of the proposed floating developments have been actually built and stayed, which makes the investigation even more difficult. Notable examples include *Triton City* by Fuller (figure 1-4), *Aquapolis* by Kikutake (figure 1-5), which was towed away to be scrapped in 2000, and futuristic design *Lilypad Floating City* by Callebaut (figure 1-6).

During the last couples of decades, design and construction of floating development has been practiced extensively by Singapore, Japan and Netherlands. So floating development becomes more promising and researchable. Netherlands focus on building Hull structure residential scale houses with hollow foundation that works in the same way as the hull of a ship, for example, *Floating Amphibious homes*, Maasbommel (figure 1-7). On the other hand, Japan and Netherlands have been looking at VLFS. An example is the TRAM projects of *Kansai International Airport*, Tokyo Bay (figure 1-8), that has been built and tested for take off and landing, proved the soundness of this concept.

1.6 Thesis structure

This thesis consists of five chapter (figure 1-9) carried out in a chronological order: 1.0, Introduction, 2.0, Literature Review; 3.0, Wellington condition; 4.0, Design; 5.0, Conclusion.

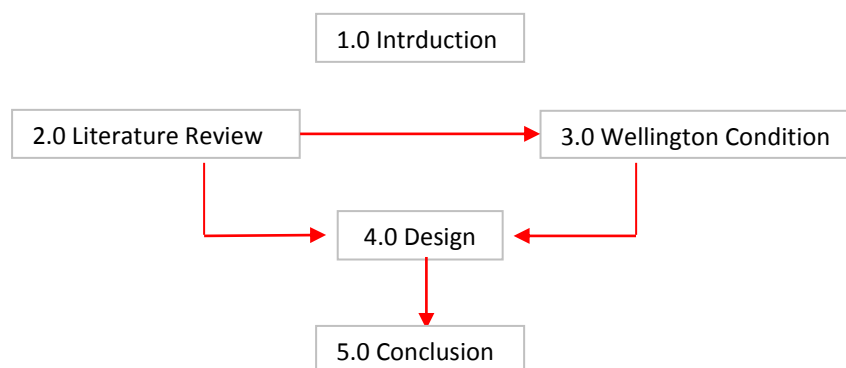


Figure 1-9: Thesis structure

- Introduction chapter, introduce the rational behind the research, aim and structure of the thesis.
- Chapter Two aims to give an overview of water-based development and identify urban issues through survey of past floating developments
- Chapter three and four are the case study of building a VLFS development on Lambton Harbour of Central Wellington City, to test the feasibility of the idea. Chapter Three aims to address the condition of the Central Wellington City to determine what opportunities opened up for and threats encountered by the city
- This is leading to Chapter Four, Design, which propose and evaluates the design of VLFS development on the Lambton Harbour as a form of urban expansion.
- The conclusion chapter analyses how well the thesis achieve its aims, and gives findings and recommendations regarding the whole research.

1.7 Significance of the research

A specific urban focus of the research indicates this is a material that will probably be of interest primarily to urban designers, or the city councils as a reference guide. The significances of the research are, 1) the research looks into the urban dimension of floating development, which is an area that has not been well researched; 2) the research has a pragmatic emphasis, which takes a step forward from the growing visionary and 'Paper Architecture' project.

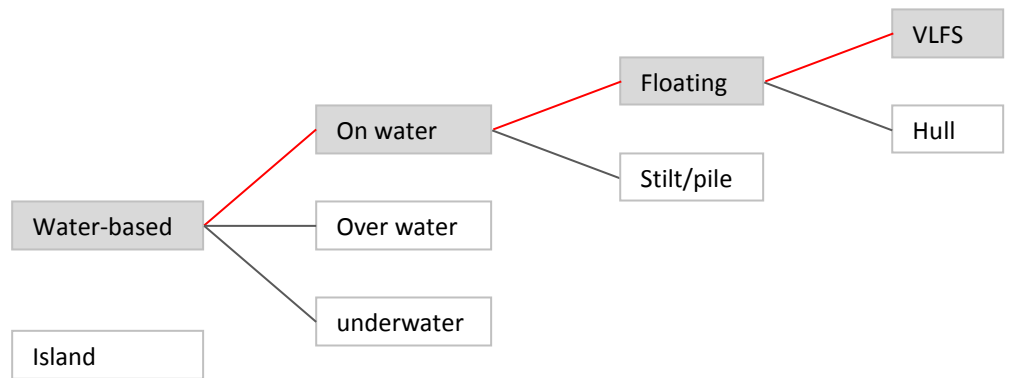


Figure 2-1: relationship graph of water-based development
Chapter two is looking at the ones shaded in grey

Chapter Two: Literature Review

Chapter two explores past and present water-based developments, in particular VLFS development through literature review, with a special focus to urban dimension. The chapter starts with a discussion of research subject followed by a discussion of the methodology and limitation involved in the literature review. Subsequently it gives an outline regarding the overall water-based development in general from 1950 to, 2010. Later Relationship with existing urban fabric and Styles are investigated and analysed in detail. This is followed by brief technical, legal and cost analysis centres around *Floating Amphibious Homes*, *The Float @ Marina Bay* and Phase 2 of TRAM project.

2.1 Discussion of research subject

Because the research subject is loosely coined so it is not able to be described by a precise term. It overlaps between the domain of engineering, science, and architecture and it appears in a wide range of industry sectors from building, shipbuilding, oil drilling, to submarine. In the research, the term water-based, floating, and VLFS are used. The relationship between them is shown in figure 2-1. In which, water-based represents a broad range of development that is build on / over / under water. While VLFS stands for Very Large Floating Structure, a type of floating structure, that rely on the buoyancy force of water in order to support themselves.

2.2 Methodology and limitation

This literature review looks at uncollected example of water-based development across the last 60 years from different location, built for different purpose, and gives an brief overview and an in-depth detailed investigation of selected projects. An overview is important to background understanding because it has never been looked at collectively in the past. Victoria university of Wellington's library catalogue, and internet search engine 'Google' are used in combination to gather information about water-based developments.

This research excludes conventional land reclamation, but includes some artificial islands because their motives for such structure and design solutions differ from conventional reclamation so are valuable to the research. The research is chosen to focus on literature from Netherlands and Japan mainly due to the fact that they are the pioneer countries. However, the limitation is that these existing research are often non-English resources which are harder to find. Furthermore, they require



↖↑ Figure 2-2 Brunei's Water Village / Kampong Ayer
Source: Remy Blanc

↙↓ Figure 2-3 Brunei's Water Village / Kampong Ayer



↖↑ Figure 2-4 Wood pilling in Astoria, Oregon

research are often non-English resources which are harder to find. Furthermore, they require translation with Google online translator, and the original meaning of the text may be slightly different to the 'translated'.

2.3 Trend

Water-based development is not particularly new. As long as thousands years ago, in Brunei³ (figure 2-2), Venice⁴ (figure 2-3), and Astoria⁵ (figure 2-4), there are traditional houses that built in water. But it is not till the late 1950s, water-based development becomes more of an independent research topic, which started to appear widely in the architecture, urban and engineering field. Since then, water-based development became increasingly popular, and has undergone two major periods of developments⁶:

- During the first period, the idea of inhabiting the sea was prevailing, reached its peak in the early 1970s, but soon declined due to technological, political, and economical impracticality⁷. Japan was the lead in the field of water-based design at that time, with Kyonori Kitutake and Kenzo Tange being the pioneers. Raisbeck's two literatures *Marine and Underwater Cities 1960-1975* and *Prototype Cities in the Sea* co-written with Kaji-o'grady are the few articles focused on the overall development of the era.
- The second era starts after the late 1990s and carries through into the 21st century. The present is the prosperous time of building and living on water, as iterated by Tsutomu, is set to be 'The Century of Ocean'⁸. Japan continues to take the lead in participating in the designing and building of water-based development, followed by Singapore, Netherlands, and Dubai. Literature resources regarding design of water-based development are available all over the internet.

The trend of water-based development will continue into the future and become mainstream. This is predicted in an animation display in Pavilion of the Future⁹ at Shanghai Exposition 2010. It showcased a city in the future called 'Water City' that has a different, attractive and freed aquatic lifestyle. People will enjoy life away from the busy and crowded urban centre, where they will adapt with artificial gills to live between life on land and underwater¹⁰.



↑ Figure 2-5 Freedom Ship, Nixon, N. (2000)
100,000 population mobile city
Source: Freedom Ship International
<http://www.freedomship.com>



← Urban Scale /
Architectural Scale

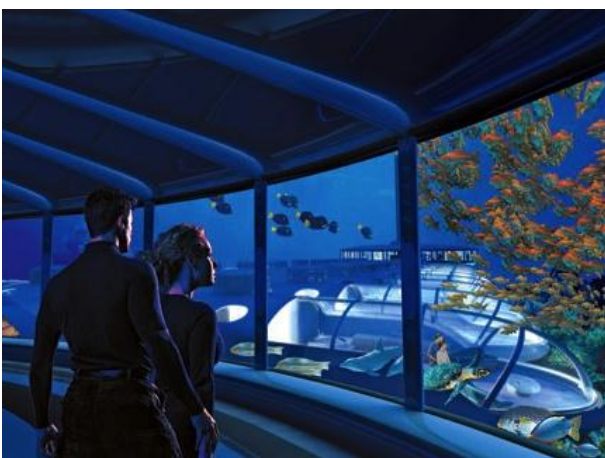
↑ Figure 2-6 Mur Island, Acconi, V. (2003), Austria
amphitheatre, café and playground on an artificial floating
platform for 350 visitors
Source: Flesche, F. *Water house*, (London: Prestel, 2005), pp. 5.

↓ Floating on water / Submerged in water / building on stilts



↑ Figure 2-7 Watervilla, Hertzbrger, H. (2002), Middelburg, Netherlands
a floating house island that stands on a hexagonal pontoon
Source: Architectuurstudio HH, <http://www.ahh.nl/>

↖ Figure 2-8 Ontario Place, Zeidler, E. (1968-71), Toronto, Canada
an exhibition building that is lightweight structures supported by pylons
with wire-hung trusses
Source: Zeidler Partnership Architects,
<http://www.zeidlerpartnership.com>



← Figure 2-9 Hydropolis, Hauser, J. (2004-07), Dubai, UAE
underwater luxury hotel that connected to the mainland by a tunnel
Source: Joachim Hauser, www://hauser.hydrovisionprojects.com/

2.4 Motive

Water-based development are reflective of the concerns and belief of society and citizens at the time. Table 2-1 outlines the motives and the resulting outcomes over the last two century. Key motives are:

- During the 1960s and 1970s, one of the motives for water-based development is to look for more efficient use of waterfront to cope with rapid increase in population and progress of industry¹¹, this is represented by a various The Tokyo Plan¹² proposed for Japan. Another motive is to show off the economical, technological, and political advances and capability¹³, this is evident in some of the wealthy first world countries, United States, France, German and Russia in their development of underwater habitats¹⁴.
- Since the 1990s, the main drive for water-based development is to survive adverse natural condition of grounds that is at risk of flooding; and to promote city identity and popular lifestyle of living close to water, a commercial motive¹⁵, which are found in projects of Netherlands and Dubai City respectively.

Time	Motives	Outcomes
before 1900s	<ul style="list-style-type: none"> ▪increase of population ▪traditions and cultures 	<ul style="list-style-type: none"> ▪land reclamation ▪water villages
World War II	<ul style="list-style-type: none"> ▪military defences ▪transportation 	<ul style="list-style-type: none"> ▪military bridging & sea fort ▪shipbuilding industry
1960s – 1970s cold war oil crisis	<ul style="list-style-type: none"> ▪rapid increase of population ▪oil exploitation ▪overconfidence about technology ▪futuristic fantasy literature ▪funding from government organisation 	<ul style="list-style-type: none"> ▪offshore drilling rigs ▪visionary marine cities ▪underwater habitats (figure 2-9) ▪movement of Arcology, Biotecture, Megastructure, Metabolism
1980s	<ul style="list-style-type: none"> ▪early projects accused of being ‘paper architecture’ 	<ul style="list-style-type: none"> ▪storage base ▪hotels
1990s - 2010 green age information age	<ul style="list-style-type: none"> ▪concentration of urban population ▪land at risk of flooding ▪focus on brand attributes and lifestyle ▪sustainability ▪biotecture movement ▪arcology movement 	<ul style="list-style-type: none"> ▪bridges & airports (figure 2-10) ▪amphibious residential complex (figure 2-11) ▪cruise ships (figure 2-5) ▪artificial islands ▪explore and exploit ocean resources

Table 2-1: motives and the outcomes over the last two century



← Figure 2-10 West India Quay Footbridge, Anthony Hunt Associates (1996) London
The bridge is steel structure supported by the splayed legs welded to circular plates that are bolted to the foam-filled pontoons above the water surface.



← Figure 2-11 New Water, Waterstudio (2010), the Westland, Netherland
hosts a multitude of water-related developments including 1200 dwellings,
Source: Waterstuio.NL. <http://www.waterstudio.nl/>

← public-oriented infrastructure project / private residential housing

↓ Figure 2-12, New Babaylon, Constant, N. (1950)
Source: Heynen, H., *Architecture and Modernity: a critique*, (Cambridge, Mass: MIT Press, 1999), pp. 174



↓ Figure 2-13, Silodam, MVRDV (1995-2002), Amsterdam, Netherlands
Source: MVRDV, <http://mvrdiv.nl/>



2.5 Outcome

The resulting project is rich in variety, shown by images on page 12 and 14. Existing research has no significant achievement on categorisation of these developments. Water-based development are loosely grouped by the structural system used, i.e. VLFS, Hull, Stilt/pile, etc; by whether it is standing, floating or submerged, etc.; or by its application, i.e. airports, offshore port facilities, habitats, etc. But these are rather ambiguous because there is a lot of overlapping between each of these approaches. Baisbeck¹⁶ raised the idea to perceive the marine cities of the 1960s and 1970s as 'Prototype', which is one of the very few that precisely and strictly classify a collective development. According to the model he developed, design outcomes can be categorised as either 'Prototype' or 'Precedent' and each is explained as follows:

- **Prototype** is a conceptual idea, or a partly built and tested structure that other projects is based. Many project rarely move beyond the prototype stage because issues regarding economic viability, physical construction and testing of prototype could not be resolved¹⁷. For example, Constant's *New Babylon* (figure 2-12), expressed a symbolic idea of proto-community life, and also presented technical and construction detail, such as the detail of the gigantic constructions supported many meters above the ground at only three points. Yet whether the element really can have a supporting function is doubtful.¹⁸
- **Precedent** is a complete structure that 'works' successfully in the real world context and it serves as an example for future development to follow. These projects tends to be commercially driven, and based on function, therefore, they tend to be more successful in term of buildability. For example, *Silodam* by MVRDV (figure 2-13), a 300-metre-long complex is embedded into the ground of the harbour using massive concrete pillars. It provides homes for a broad social mix, from privately owned luxury apartments, to low-income public housing, as well as artists' studios and commercial premises.¹⁹



↑ Figure 2-14: 4 type of relationship between building and coastal land
 From, left to right, 1) Right on the shoreline; 2) Next to existing dry land; 3) Alongside pier or connected via access bridge; 4) Island type with no physical connection.
 Source: Kuroyanagi, A., & Sasaki, R., *Exterior Composition of the Oceanic Architecture with a Plane Form*, Journal of Architecture, Planning and Environmental Engineering, No. 546, (Tokyo: AIJ, 2001), pp. 317, <http://ci.nii.ac.jp/>, accessed on 06/08/10.



↑ Figure 2-15 Aluminium Forest, Haas, M. (1997-2001). Nouten, Netherlands
 a museum supported by aluminium tubes provided to offer load bearing function and house services
 Source: Flesche, F. *Water house*, (London: Prestel, 2005), pp. 26.

↓ Figure 2-16 Blur, Diller Scofidio (2002), Yverdon-les-Bains, Switzerland
 Source: Diller Scofidio + Renfro <http://www.dillerscofidio.com/>



2.6 Relationship with existing urban fabric

An article of *Journal of Architecture, Planning and Environment Engineering*²⁰ is the only literature found during the researches dealing with this issue. It analyses the relationship between oceanic architecture and existing coastal land and divides these relationships into four types (figure 2-14). To follow on with this approach, Section 2.6 illustrates and analyses each of four types of relationships and two desired designs from an urban perspective.

2.6.1 Right on the shoreline

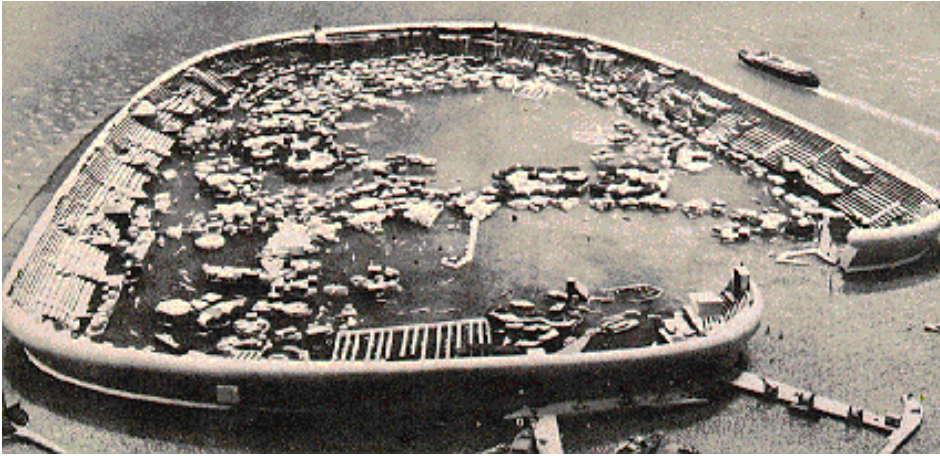
This type of composition is like conventional development existing in land-based city. Furthermore, it enjoys the benefit of having the privacy and security of being on water while still intimately connected to the existing land-based city. However, the shoreline is lost and privatised by the development, as a result, the development degrades the experiences of the pedestrians alongside the coastal land and disrupts the view of other inland developments to the water. This is demonstrated by Micha de haas's *Aluminium Forest* (figure 2-15).

2.6.2 Next to existing dry land

These development suggests merging with the existing coastal land so it can be integrated into the existing urban fabric. This type of composition is desirable from an urban perspective. Yet the survey of different design proposals did not show evidence of support. This is possibly due to two reasons: firstly, floating developments in particular would require some sort of 'cushions' placed between floating structure and coastal land to prevent collision damages and special connection system to keep the two piece of 'land' attached during wave action, but such technology is not fully developed; secondly, one of the purpose of building on water, is to differ and become independent from existing urban fabric, is lost.

2.6.3 Alongside pier or connected via access bridge

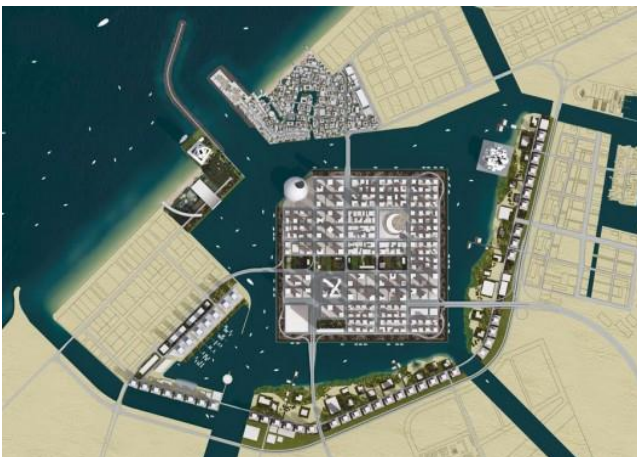
In this type of development, connection is ill-considered. An example is Diller Scofidio's *Blur Building* (figure 2-16). The exhibition structure is dispersed around a gently rolling landscape and links with the shore via a fibreglass catwalk. Although it is architecturally wonderful, but from an urban perspective, it is an isolated design. The design provides a single mode of transportation, by foot, and a privileged single point of access for the exhibition structure. Therefore, it does not add value to the existing wider urban context.



↑ Figure 2-17 Sea City, Moggridge, H. (1970)
Source: Spencer, C., *Sea City-circa 1971*, TV21 Annual 1971, (UK: Century 21),
<http://www.aiai.ed.ac.uk/~bat/sea-city.html>, accessed on 24/04/10.



↖↑ Figure 2-18 A plan for Tokyo, Tange, K. (1960), Tokyo, Japan
Left image showing traffic network
Source: Bettinotti, M., *Kenzo Tange: 1946-1996, architecture and urban design*, (Milano: Electa, 1996), pp. 88,90.



↑↗ Figure 2-19 Waterfront City, OMA (2008), Dubai, UAE
Source: OMA, <http://www.oma.eu/>

2.6.4 Island type with no physical connection

Island type of development focuses on the celebration of freedom, of being remote from the central city, for example, Hall Moggridge's *Sea City* (figure 2-17). The proposed *Sea City* is independent and unrelated to the existing city with no physical connection involved at all. Therefore, it would require other mode of transportation, by ferry or air, and a great range of amenities and specialised service facilities to be self-sustaining. This idea creates bad urban design because it disregards the wider surrounding.

2.6.5 Successful examples

In Tange's *A Plan for Tokyo* (figure 2-18)²¹, the urban growth is concentrated along the linear civic axis and streets run perpendicular to it. The design is considered to be more successful from an urban perspective because it took into account the hierarchy of transportation including high-speed road, subway, national railway and monorail and how it might be joining back to the existing urban fabric. In the proposal, monorail was running through along the axis, and railway was going in the transverse direction, nevertheless both networks connected back to the existing surrounding land-based city. Furthermore, although the proposed design imposed a new linear street network into the existing city, but the rectangular unit was carried through and merges with the radial roads on shore, which shows good integration of the new and old street patterns.

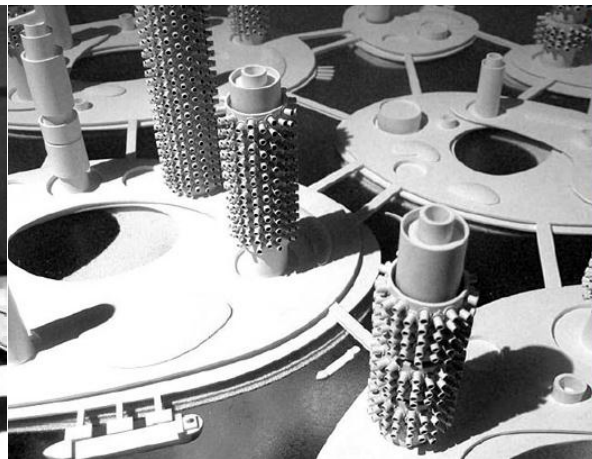
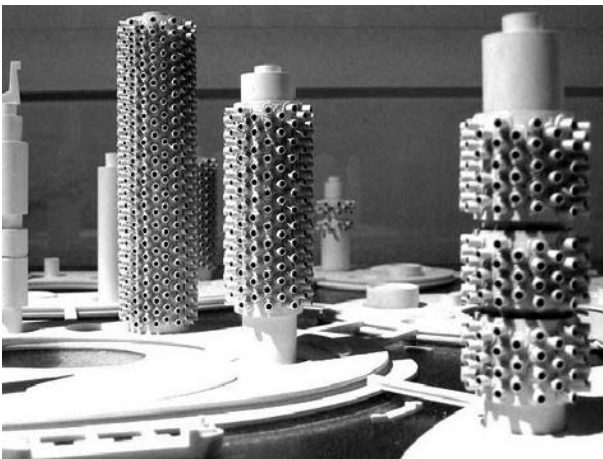
OMA's *Waterfront City* in Dubai (figure 2-19)²² shows a model of an artificial square island that helps to complete transportation of the whole district. Such urban planning means that precious coastal areas can be preserved; also make it possible to considerably increase the number of properties along the shoreline and to extend beaches. Its street grid is clearly laid out, five grids in each direction, and coherent with the existing grid plan on the nearby coastal lands. The island at the centre helps to fulfill the infrastructure needs of the area, by providing comprehensive north-south and east-west connection to the surrounding regions, so it acts as a central hub. In addition, the 'hub' improves the accessibility between the island on the far north and the regions on the east, so it offers a direct journey that is shorter than having to go around the harbour.

Zeidler's *Ontario Place* (figure 2-21 next page)²³ is also one of the successful examples, because the development further improves the amenity value of the existing waterfront land. The project creates an urban park for the city and to recapture for the pedestrian Toronto's shore-line, lost to transportation and industry. Furthermore, these islands increase amount of waterfront land and



↑ ↗ Figure 2-12 Ontario Place, Zeidler, E. (1968-71), Toronto, Canada
Source: Google Map, <http://maps.google.com/> &
Experience Ontario Place, <http://www.ontarioplace.com/>

↓ ↘ Figure 2-21 Marine City, Kikutake, K. (1963), Tokyo Bay, Japan
Source: EcoRedux, <http://www.ecoredux.com>



↑ ↗ Figure 2-22 Plan Tij, Klunder Architecten (2004), Dordrecht, Netherlands
Source: Klunder Architecten, <http://klunderarchitecten.nl/>
H2olland architecture with wet feet, <http://www.h2olland.nl/>

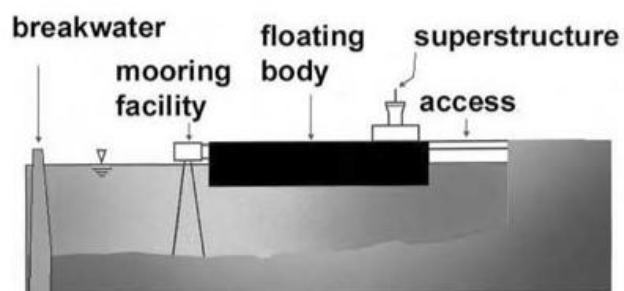
creates semi enclosed bodies of water that are safer for water recreation. The existing expressway running along the shoreline provides easy and fast access for the urban park, while the park provides attractions along the road and a pleasing variety of visual elements.

2.7 Urban style

The styles of surveyed water-based development are varied and inconsistent. However, there are two styles identified that stood out from the research, one is the interest in modularity and being different from conventional design, the other is the less ambitious design that promotes a nature oriented lifestyle. This brings out the question of: 1) should there be a style for water-based development; 2) whether or not it should look / feel / work differently because its unconventionally built on water and away from the rest of the major population; and 3) how should it be different. This section, thus this thesis, does not try to seek answers to these questions, rather to raise concerns and discuss the two approaches.

Style of the majority designs during the 1960s and 1970s were recognised as an expression of the *metabolist*²⁴ and *megastucture movement*²⁵, that is avant grade and symbolic. These designs were characterized by large-scale, flexible, and expandable structures that evoked the processes of organic growth rather than focusing on creating quality space for the occupants. So the concept of modularity was widely appreciated. For example, Kikutake's *Marine City* (figure 2-21), it is composed of concrete cylinder on saucer shaped island and prefab housing modules that is plugged into the surface of the cylinder. The resulting structure is unconventional, bold, futuristic and machine like, and it allows for ease of constructability. It made a point of different and stood out from conventional developments. However, it creates unfavoured, uninviting and inhuman urban environment.

On the other hand, there is also development that is less ambitious in architectural innovation and aimed to promote a suburban or rural lifestyle, which is consistent with pragmatism and commercial motives. For example, Klunder Architecten's *Plan Tij* (figure 2-22), where the box-like houses along the former riverbanks are raised on pylons and are organised in the form of a row of compact terraced housing, jutting into the open water like a jetty. Characteristics of the development includes, large outdoor space opened out to water and glazing on at least one side to allow for uninterrupted view of the river, which aim to enhance the multi-sensory experience with nature. From both architectural and urban perspectives, the development mimics the conventional design approach, so it is less symbolic. Nevertheless, it values experiences of the occupants and creates spaces that are much more enjoyable and relaxing.



↑ Figure 2-23 Components of VLFS

Source: Utsunomiya, T., Wang, C., & Watanabe, E. *Very Large Floating Structure*, (London, New York: Taylor & Francis, 2008), pp. 4

2.8 Building technology

The one and only literature that offers the most comprehensive information on VLFS structure is *Very Large Floating Structure*²⁶ published by Spon Research. Yet the technologies are not described in detail nor are they made available for academic use, nevertheless there are still issues in need of resolving, which make the research later on difficult.

Section 2.8 gives an overview of VLFS and then it provides the basic dimension of the two main components of pontoon type VLFS and the construction process. All of these are discussed with reference to *The Float @ Marina Bay* in Singapore (figure 1-1) and the Phase 2 of TRAM projects of *Kansai International Airport*, Tokyo Bay (figure 1-8). It is assumed here that the task of designing the 'top-layer' of the 'island' will be much similar to building and maintaining a similar complex on-shore. So it will not be examined here.

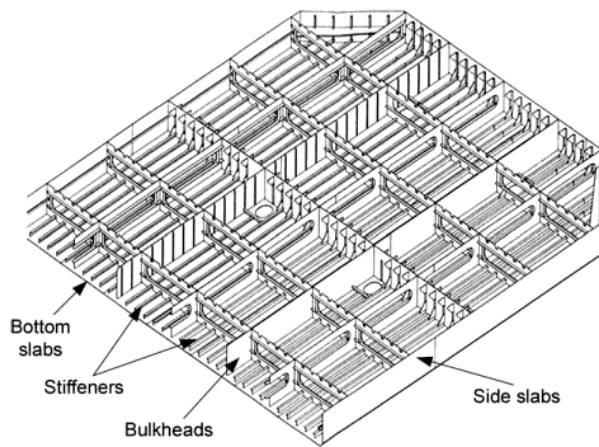
2.8.1 Overview of VLFS

VLFS in general is a simple box structure made of steel, concrete (prestressed or reinforced hybrid) or steel-concrete composite floating on the sea-surface. Currently, VLFS has a lifespan of 100 years. There are two types of VLFS, pontoon-type (also known as MegaFloat²⁷) and semi-submersible type²⁸. While the semi-submersible type are more complex structures, that are raised above the sea level using column tubes or ballast structural element for high seas environment with large waves. Pontoon-type VLFS is a more desired type to be used as a replacement for land reclamation as a form of urban expansion, because it is suitable for use in calm water, such as near the shoreline. Therefore the focus will be on pontoon-type.

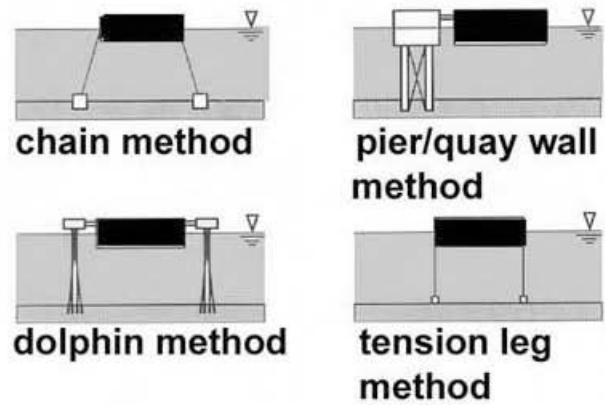
VLFS has the advantages of being exceptionally suitable for locations that are prone to earthquake because it is inherently base isolated. As a result, it has reduced requirement for foundation system, compared to conventional building method, so less drilling to seabed is involved. It also enjoys the benefits of ease of expansion and removal because of the modular nature, which means it supports phasing development that is common in urban expansion. However, due to that VLFS is not yet a mainstream practice, it is currently more expensive than conventional piling method.

2.8.2 Pontoon-type VLFS

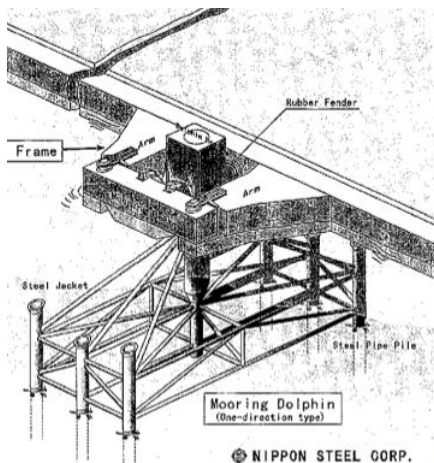
First of all, basic component of pontoon-type VLFS are (figure 2-23):



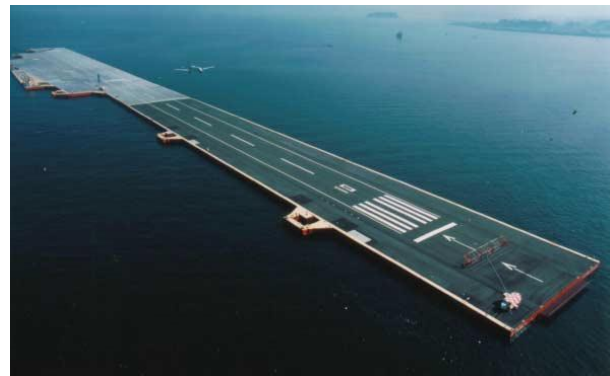
↑ Figure 2-24 Elements of pontoon
Source: Bungartz, et al. *Fluid Structure Interaction II*, Lecture Notes in Computational Science and Engineering, Vol. 73, (New York: Springer-Verlag, 2010), pp. 115.



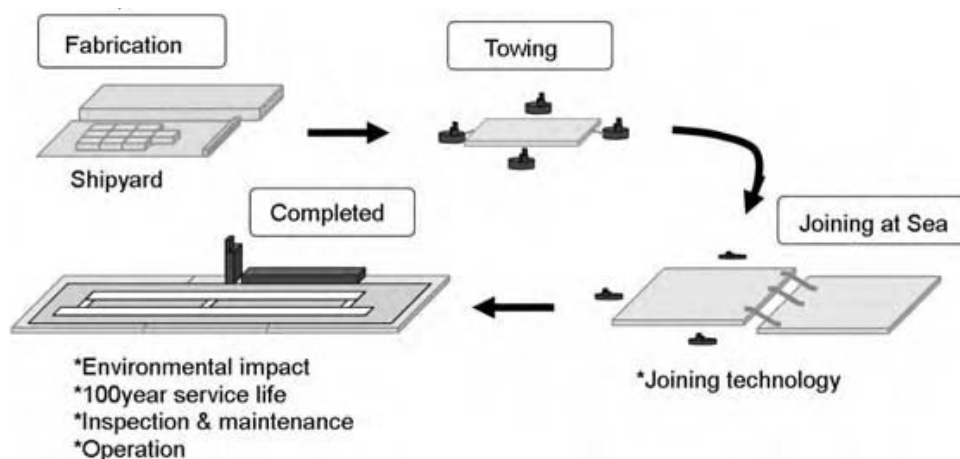
↑ Figure 2-25 four types of mooring facility
Source: Utsunomiya, T., Wang, C., & Watanabe, E. *Very Large Floating Structure*, (London, New York: Taylor & Francis, 2008), pp. 8.



↑ Figure 2-26 demonstration model for mooring
Source: Tori, T., *Development of a Very Large Floating Structure*, Nippon Steel Technical Report, No. 82, (2005), pp. 26



↑ Figure 2-27 general view showing mooring on one side
Source: Horiba, S., et al. *Overview of Mega-Float and its Utilisation*, Mitsubishi Heavy Industries, Ltd. Technical Review, Vol 38, No. 2, (2001), pp. 40.



↑ Figure 2-28 construction process
Source: Utsunomiya, T., Wang, C., & Watanabe, E. *Very Large Floating Structure*, (London, New York: Taylor & Francis, 2008), pp. 211.

- a very large pontoon floating structure.
- mooring facility to keep the floating structure in place.
- an access bridge or floating road to get to the floating structure from shore.
- a breakwater for reducing wave forces impacting the floating structure.
- superstructure on top

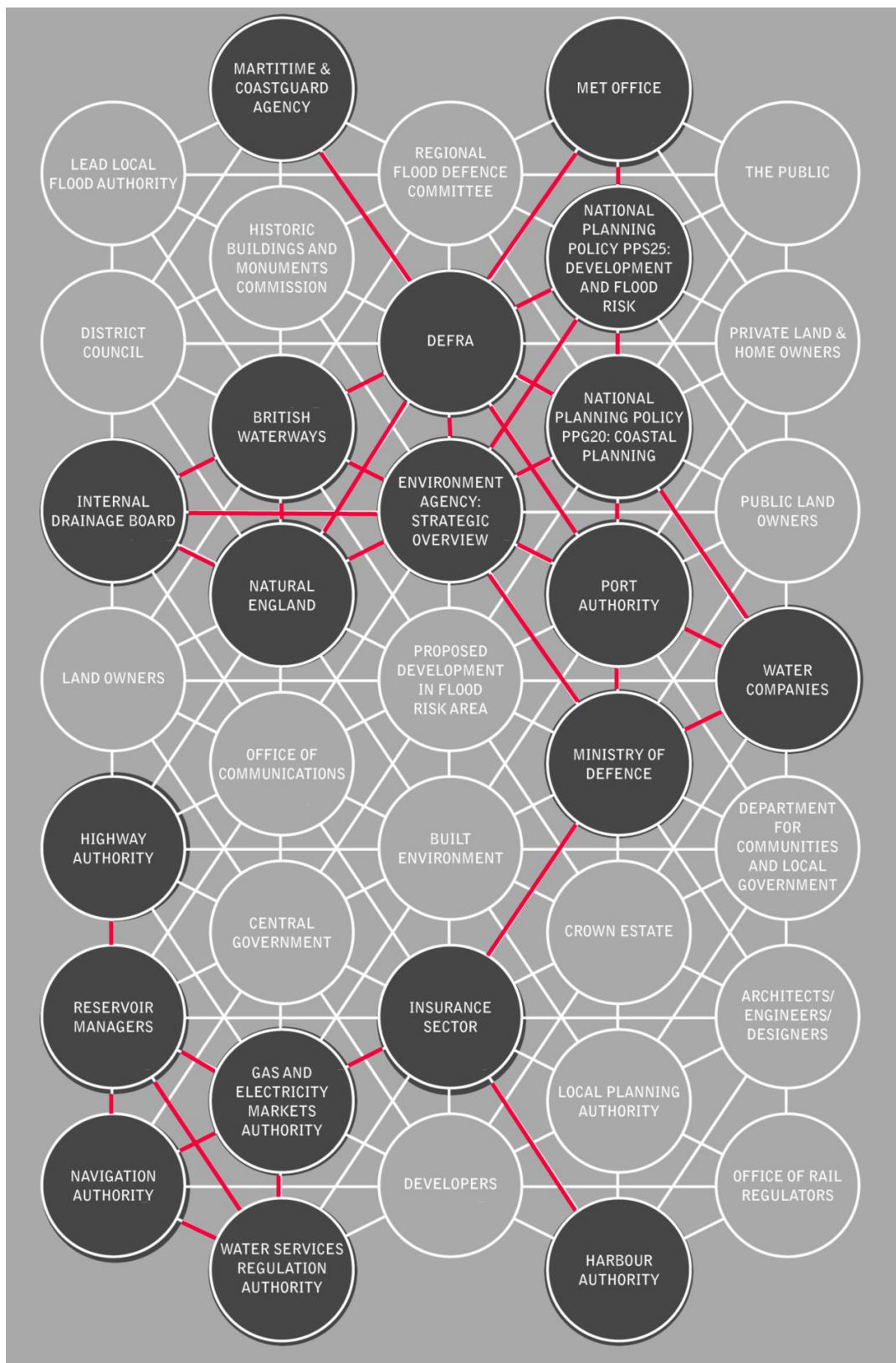
Pontoon -- The floating performance stage²⁹ in Singapore consists of 15 steel pontoons of 40m x 16.6m laid out in a 5 by 3 configuration to produce a large platform measuring 120m x 83m x 1.2m. The thickness of the top surface slab is 12mm and all the side and bottom slab are 8mm. The pontoon has a system of stiffeners to strengthen the structure as shown figure 2-23. On the other hand, in the Phase 2 research of TRAM, the steel floating airport model³⁰, largest ever built, is 1,000m x 121m x 2m, each unit is approximately between 100m to 300m in length and 60m in width.

Mooring facility -- The selection and design of the mooring system depends on the conditions the VLFS has to withstand, and what purpose it will serve. There are a number of mooring systems (figure 2-24), such as the mooring by cable and chain, tension leg method, Dolphin-guideframe system and pier/quay wall method, the last two of which may be adopted in the rougher sea situation where a greater restraint against horizontal movement is required³¹.

For the Phase 2 of the TRAM project, the mooring equipment consists of 6 mooring dolphins, guide frames for connecting the floating body with the dolphins and fenders. The dolphin-guide frame system is estimated to be 24m x 10m x H 21.9-23.9m for one-direction type, and has 6 legs with a diameter of 1400mm³², shown in figure 2-25. On the other hand, the mooring system of the smaller project in Singapore includes six pylons fixed into the seabed act as the structure's foundation and heavy-duty rubber rollers to allow vertical displacement³³. The images of both of these project reveals that the mooring facilities have significant bulk and thickness and have a huge visual impact on the overall appearance of the project (see figure 2-26 and figure 1-1).

2.8.3 Construction process

Floating structure are fabricated at shipbuilding docks or structure fabrication yard as one complete unit and then launched to the sea by introducing water into the dock or using cranes, floating docks or semi-submerged barges. However, it is important to insure that units size does not exceed the size of existing fabrication facilities, otherwise the whole project could become uneconomical and unrealistic. Hence, the proposed construction method of Phase 2 of TRAM project is that the floating units each 100-300m long are made at fabrication facilities on the land, transported to the site, and



↑ Figure 2-29 communication diagram for water-based development
Source: Building Future, <http://www.buildingfutures.org.uk/>

then jointed into one large unit³⁴, as illustrated in figure 2-27. This is a relatively fast process, for example, construction of the *Float @ Marina Bay* only took 13 months to make at the fabrication facilities and a month to assemble³⁵.

2.9 Legal and governance

Recent TRAM projects in Japan and the *Floating Amphibious homes* in Netherlands have demonstrated consideration of legal issues, but these issues have not been discussed in detail in the existing research, and there are still a lot of uncertainties. Section 2.9 discusses how water-based development is regulated currently and what are the affect on the legal documents.

In the floating airport project, the literature suggested that floating body in the offshore area would not be considered as a building and would be regulated by the Ship Safety Law, while the superstructure would be regulated by both the Building Standard Law and the Fire Defences Law³⁶. On the other hand, the amphibious houses in Netherlands although are regulated as a building, but involve a much more complicated, direct and indirect relationship between numerous parties³⁷. The key difference to conventional building development is the closer involvement with the regional coastal authority, harbour and port authority, and environmental authority, as well as the strong impact on the insurance sector (figure 2-28 on next page).

Furthermore, in Netherlands, current building code has been amended to adapt to new standard and requirement of water-based development, in particular important changes are made in sections of Health, Safety and Usability. *Netherlands's Guideline for building in wet areas*³⁸ gives a more detail description of the changes involved for construction-related laws and regulations, water safety and water management, shipping traffic, insurance, mortgage, building warranty standards, flooding preparation, prevention and remediation for infrastructure due to environmental damage, and waterproof performance during construction and flood events.

2.10 Cost analysis

Cost analysis on floating development, especially VLFS, is difficult, especially since there have not been many precedents in this area. Although not directly comparable, examples of *Floating Amphibious Homes*, *The Float @ Marina Bay* and Phase 2 of TRAM project are discussed below to give a general idea of the cost of floating development compared to building on land, also with an estimation of the cost of VLFS per cubic metre.

2.10.1 Cost comparison

The floating amphibious homes with Hull structure is predicted to be more costly in the current market in the mean time, but price should drop dramatically when the floating construction model becomes more mainstream, as explained by architect, Olthuis³⁹. He explained that house itself is exactly the same as the traditional [terrestrial] home, the foundation is essentially a concrete box filled with foam so it is almost the same as for a normal house with a cellar. Therefore, the amount of construction and the extent of the techniques involved in hull structure are comparable to method of building a conventional house, and technically the cost of amphibious house would be merely a bit higher due to a slight more complex foundation.

For example, currently, an amphibious buildings cost approximately €260,000 (NZD\$460,000) for a small 120 square metre home⁴⁰. According to the Census⁴¹, the average purchase price of a single family dwelling for the year 2010 is close to €260,000, keep in mind this figure includes houses of all sizes, as well as cost of land. However, existing research has not addressed if building on water includes a 'land' price, much like the conventional way of building on land. It is a significant part in the overall feasibility of the project as the 'land' could cost anything from zero to prices comparable with waterfront land.

2.10.2 Cost per cubic metre

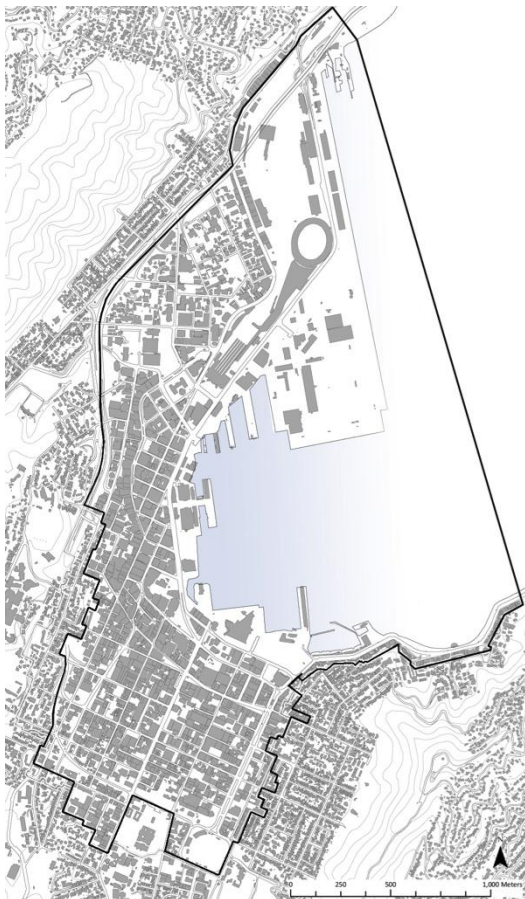
There are two large scale VLFS that have been constructed recently with known dimension and cost. *The Float @ Marina Bay* is a SGD\$226 million (NZD\$237 million) project, while Phase 2 of TRAM project includes a total of USD\$103.6 million (NZD\$139 million), note this figure also includes research allowance. The latter is used to give an estimate for the cost of VLFS per cubic metre and as a guide for future VLFS development.

- Length: 1,000m
- Area: 84,000sq ms
- Height: 2m
- Volumn: 25,000cu ms
- Budget NZD\$139 million (incl. research allowance)⁴²

Therefore, an estimation is $139,000,000 / 252,000 = \text{NZD\$}540/\text{cu ms}$, actually cost would not include cost of research, so it should be lower than this figure.

2.11 Summery of literature review

Literature research results in overwhelming amount of projects, especially during more contemporary times. Most importantly, the survey finds that very few of the water-based development, both precedents and prototypes, deal successfully with the relationship to existing urban fabric. It also explains that good waterfront design is pedestrian oriented. It delivers enhanced benefit to the wider community by ways of integrating with the overall transportation network, and improving quality of surrounding urban spaces. Furthermore, the survey also indicates that neither technical, legal nor cost aspects have been extensively dealt with or entirely resolved. Nevertheless, the materials presented proved the soundness of floating development.



↑ Figure 3-1 Studay area

Chapter Three: Wellington Condition

A case study of building VLFS structure in Central Wellington City to further expand the city is provided in the following Chapters Three and Four. The purpose of the case study is to test the urban implications of floating VLFS development, specifically the impact on the urban environment of Central Wellington, and technical, political and financial consideration. In order to answer this question, existing conditions of Wellington needs to be examined.

Chapter Three is aimed to focus on the urban condition and briefly discuss natural condition of the site, laws and regulation, and technical and financial capability in order to identify opportunities and threats of VLFS development specific to Wellington context. The chapter identifies the case study limitation, analyses under seven sections. It concludes by identifying three opportunities brought by floating development for the urban environment of Central Wellington and four constraints relates to technical, political and economy aspects.

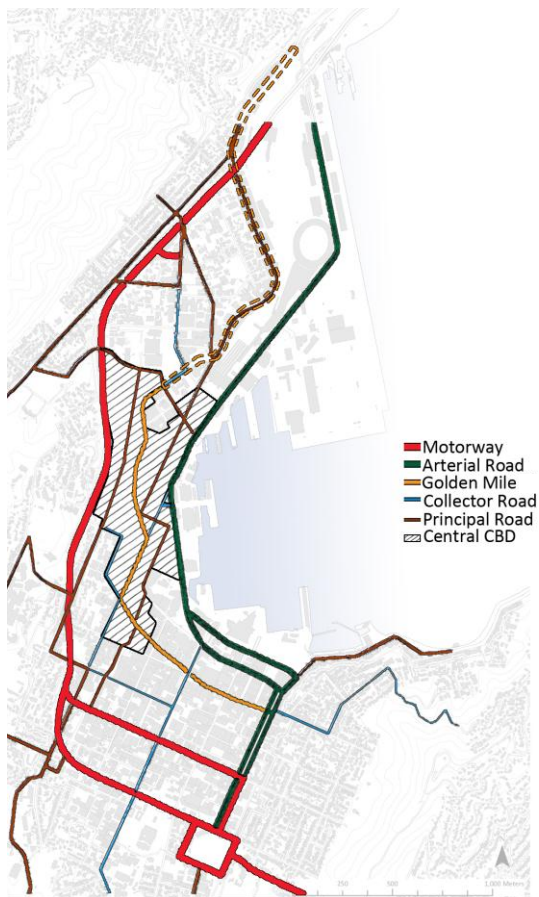
3.1 Study area

Chapter three is not aimed to give an extensive overview of Central Wellington⁴³, rather to present informative and selective discussions around the five keys identified in Chapter two. The case study looks at the onshore areas of Central Wellington City as identified in the Wellington City Council⁴⁴ and areas of Lambton Harbour, as seen in figure 3-1.

3.2 Natural environment

Analysis of earthquake, harbour depth, wave and wind indicates that Lambton Harbour is relatively shallow and experience small wave because it is near the shoreline. Therefore, it is the ideal environment for building a pontoon type VLFS structure. In addition, VLFS is protected from seismic shocks, which makes it even more desirable for Wellington. It is also worth mentioning that the Central Wellington experiences strong wind that would increase salt spray and corrosion damages to oceanic structures.

- **Earthquake** - There are three major fault-lines running either through or very close to Central Wellington, so the city is prone to earthquakes

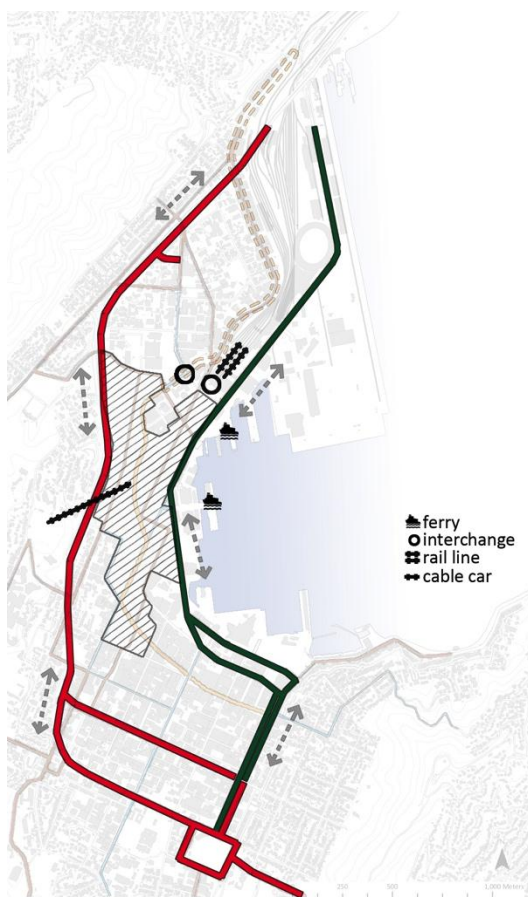


↑ Figure 3-2 hierarchy of traffic network

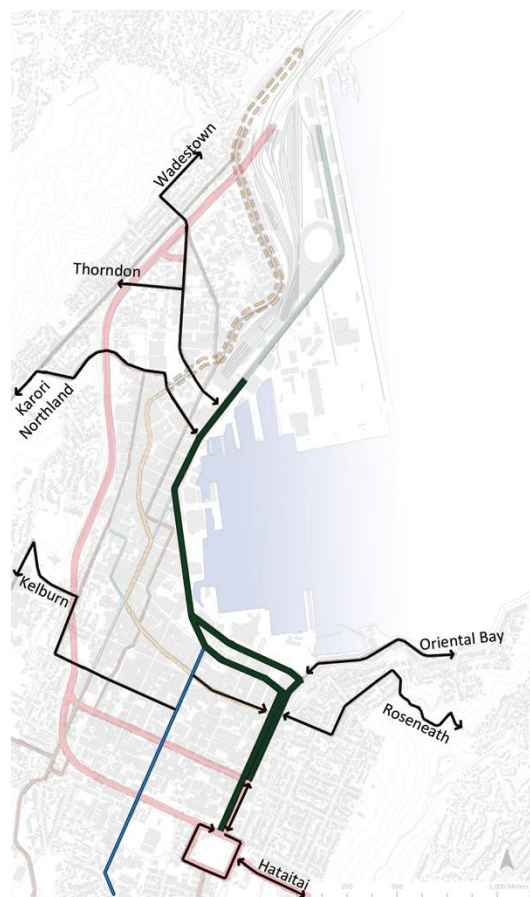


↑ Figure 3-3 the Quays

↓ Figure 3.4 through traffics



↓ Figure 3-5 east-west traffic



- **Harbour depth** -- The depth of the study area, Lambton Harbour, is ranged from 5-18m⁴⁵.
- **Wave** - Wellington City is located quite far in, from the narrow entrance of a large sheltered embayment, so the city experiences small and calm tidal range under 2m.⁴⁶
- **Wind** – the city is exposed to strong wind all year around. Most days gusts exceed average wind speeds of 7.5m/s⁴⁷,

3.3 Transportation system

Section 3.3 identify three major problems with the transportation system, the overall hierarchy is shown figure 3-2. Floating development on the harbour area would create opportunities for additional transportation routes to ease the over-burdened traffic on the existing major routes, as well as to achieve better local connection.

- There are two major north-south route so traffic becomes concentrated and congested. As a result, Jervois Quay and Customhouse Quay, separate the Central CBD from the waterfront due to the wide width of the six lanes and its high usage (figure 3-3). However, as the urban centre has a 350 metre width at its narrowest, which means that the city is unable to provide another north-south route in the central CBD to ease the growing traffic congestion. But this is achievable on the sea.
- Wellington CBD gets a lot of through traffic, which are journeys that don't stop in the central city and it is in conflict with traffic with destinations which are within the CBD. These through traffic is dependent on just two through routes, motorway SH1 and the Quays in the Wellington Central CBD to travel to railway station, bus interchange, cable car and ferry terminal located on the perimeter of the Central CBD (figure 3-4). The Quays in particular are also used for short local trips.
- East-west traffic is also directed to the north-south routes via collector roads or principle roads, which further increases the burden of the north-south traffic, in particular Jervois Quay, Cambridge and Kent Terrace and Taranaki Street (figure 3-5).

3.4 City's Buildings

In general, with very few empty lands left for developing, and a small grid pattern, the CBD is unable to further provide for new development, especially those with large plan area. Floating structure

↓ Figure 3-6 TSB Bank Arena
Source: Wellington Convention Centre, <http://wellingtonconventioncentre.com/>.



↑ Figure 3-7 One Featherston Street
Source: Fletcher Construction Company, <http://www.fletcherconstruction.co.nz/>



↑ Figure 3-9 Maritime House
Source: Warren and Mahoney, <http://www.warrenandmahoney.com/>



← Figure 3-9 Interisland ferries terminal

create additional buildable land so it opens up more opportunities for the developments of arena and office building that the city needs. Detailed reasons are provided below:

- The city lacks adequate facilities to hold bigger events, such as conferences, gala events, indoor sports games, tradeshows and performing arts. The biggest venue, TSB Bank Arena on Queens Wharf (figure 3-6) with a maximum seating capacity of 4,430, still inadequate and incomparable to Auckland's Vector Arena and Christchurch's CBS Canterbury Area, seats 12,000 and 9,000 respectively. As a result, the council is considering to demolish the 15 years old TSB Bank Arena and to introduce a purpose-built indoor concert venue with 8000 to 10,000 seats to stop big acts bypassing the city⁴⁸. Even if the existing event centre is rebuilt, the question still remains about whether such a large structure can be squeezed onto the existing site and the negative impact on the urban environment because it would be unproportionate compared to the surrounding buildings.
- There is increasing demand for large floor plates office buildings in the CBD location to house department headquarters due to recent expansion, yet this type of offering in a quality prime building has limited availability in Central Wellington City⁴⁹. Current example includes relocation of IRD to 1 Featherston Street in 2010/2011, where the building has an office plate of 300sq ms, and it is one of New Zealand's largest office floor plate buildings (figure 3-7). This is more than twice larger than the more conventional CBD building such as the recently completed Maritime House (figure 3-8) on 10 Customehouse Quay, with an estimated plan size of 1350sq ms.

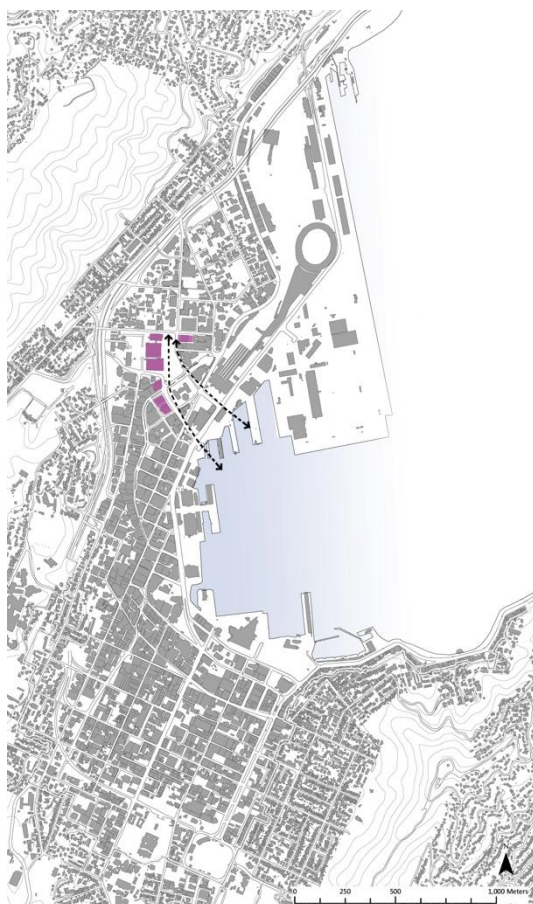
3.5 City's Spaces

Section 3.5 identifies four urban problems around the Lambton Harbour. Proposal of floating structure would allow for, support, and benefits surrounding development such as relocation of ferry terminal, redevelopment of operational port area, locating public building on to the waterfront. However, by doing that, it may cause negative impact on the existing waterfront developments.

- Interislander Ferries Terminal, located in the less commercially developed Pipitea Precinct beside the unattractive motorway SH1, is distant from central CBD. As a result, the terminal has poor amenity, unpleasing pedestrian experience and fewer choice of public transportation between the terminal and CBD (figure 3-9). Relocate the terminals closer to central CBD would be desirable but currently unachievable because of the difficulties regarding having enough spaces for cars, trucks and trains.



↑ Figure 3-10 Overlooking centreport operational port in the centre of the image, bottom right corner is the CBD
Source: CentrePort Wellington, <http://www.centreport.co.nz>



↑ Figure 3-11 government centre extension



↑ Figure 3-12 waterfront front row



↖↑ Figure 3-13 Queens Wharf
Source: Wellington City Council, <http://www.wellington.govt.nz/>.
A hard road for Hilton, Capital Times, Wellington, (28/06/06),
<http://www.capitaltimes.co.nz/article/789/AhardroadfortheHilton.html>, accessed on 25/02/11.

- There is an increasing focus on integrating the currently poorly developed operational port area, shown in figure 3-10, into a new urban precinct⁵⁰. The reason is that the land of the current operational port is supporting lower value activities, containerisation, and it is disruptive to existing waterfront urban fabric as a public amenity. The operational port area urgently needs to be redeveloped into a better waterfront area. And existing container shipping service can be discharged and loaded in nearby Port of Napier or New Plymouth instead to support the redevelopment.
- Political power and public buildings are not represented on the waterfront, which weakens city and sea relationship that is important to the city's identity. Majority of the government buildings are currently located at an inland site. During the recent years, as Supreme Court and IRD are finding their new site along Whitmore Street, a trend of the public buildings growing towards the harbour is recognised (figure 3-11). The City Council has always been more committed to express Wellington's role as capital, yet no firm plan has been made.
- Wellington City is characterised by its natural single amphitheatre setting, but this results in privileged 'front row' with the best view out in harbour and the high land value (figure 3-12). This situation means that placing floating structure further out into the harbour would have a negative impact on the existing 'front row buildings', such as decreased land value and disrupted sea view.

3.6 Physical Profile

One of the major concerns is that floating structure added on Lambton Harbour would have an adverse effect on the existing physical profile, especially to significant features of the Double T and Curving in harbour. This section argues that the changes to the physical profile could further enhance Wellingtonness.

- Queens Wharf (or outer T), is recognised by its distinct profile double T that is different to other over water wharf structures. Furthermore, it also has historical significance being the earliest land reclamation project of 1865 represented on the present waterfront area, hence it is the oldest finger wharf (figure 3-13). There has been attempts of locating Hilton Hotel on Queens Wharf during the recent years, but this was turned down by the Environmental Court



Figure 3-14 Wellington Harbour
Source: Wellington City Council, <http://www.wellington.govt.nz/>.



Figure 3-15 concept diagram of road pattern



Figure 3-16 roads with potential for extension

because the design affects the area's amenities values⁵¹. Currently the outer piers of Queens Wharf is used as a ferry terminal without any significant improvement, and with appropriate public-oriented developments, Queens Wharf could become more economically prosperous and culturally successful.

- Curving in nature of the overall urban physical profile (figure 3-14) is important to Wellington's sense of place⁵², but results in single relationship between waterfront and the sea. A floating development in the harbour would have a huge visual impact on the physical profile of the city. Nevertheless it creates additional waterfront land and various possibilities between the shores, which further enhance the well-favoured city / sea relationship.

3.7 Street Grid

Street grid analysis helps to give a guideline and identify potential for design of the floating structure, which is explained in detail below:

- Main characteristics of the street grid of Central Wellington include two most recognisable city grid: Te Aro and Central CBD grids, and a separated waterfront grid, in which the two different city grid patterns are interconnected by less gridded, curving streets (figure 3-15). The important waterfront grid is created by the finger wharves oriented north-south that goes around the waterfront area and extends onto the Thorndon container port reclamation. Therefore, there is a potential to replicate the waterfront grid for the floating structure on Lambton Harbour and join it with the main city grids.
- Waterfront street bends and curves along the harbour and acts as the boundary of the main urban street network resulting in different street patterns collide with the waterfront grid. Figure 3-16 identifies trends of existing streets pointing towards the harbour area that have potential for extension.

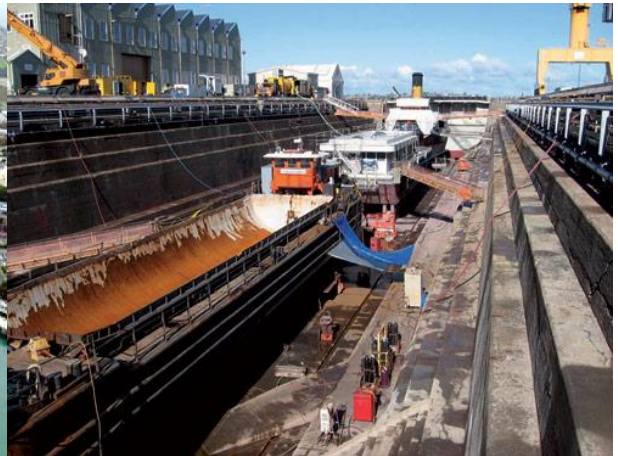
3.8 Technical Feasibility

Heading 3.9 presents materials about technical logistical capacity in New Zealand and practical limitations on construction, as well as factors that might influence design and construction of the VLFS structure in Wellington context. It focuses on floating pontoon of the VLFS.

↓ Figure 3-17 Auckland Harbour Bridge under construction, 11/29/58,
Source: Alexander Turnbull Library



↑ Figure 3-17 support structure under the bridge



↖↑ Figure 3-18 Devenport dockyard
Source: Babcock Fitzroy,
<http://www.babcockfitzroy.co.nz/index.html>



← Figure 3-19 Three tug boats
Source: CentrePort Wellington,
[http:// www.centreport.co.nz/](http://www.centreport.co.nz/)

3.8.1 Expertise

New Zealand has had very few experiences in designing and constructing large marine structure but it has the basic skills required by constructing a VLFS. It is demonstrated by the construction of Auckland Harbour Bridge (figure 3-17) that the building industry here would be capable of carrying out general fabrication, standard concrete and steel work, and advanced constructions on the sea. The project involves on-site assembling and working with steel girder, steel pontoon and 'Nippon clip-ons', as well as towing and joining at sea. But the facts that it was designed by UK designer Freeman Fox & Partners, clip-ons components (figure 3-17) were prefabricated in Japan, and England has sent out expertise / labour to help with the construction are also acknowledged⁵³. The case study of building a VLFS is likely to be the first in New Zealand; therefore, overseas expertise would be employed to help to complete the project.

3.8.2 Fabrication yard

Wellington city does not have the fabrication facility that is required for the construction of the pontoon. The current largest in the country is Babcock Fitzroy based at the Devonport dockyard in Auckland (figure 3-18), with the capacity to create unit size of approximately 180m x 24m, but it is uneconomical because completed units are too skinny and would have to be transported to Wellington via other means. Therefore it is better and necessary to prepare part of the current centre port as a temporary fabrication yard which it is capable of fabricating units of 200m x 200m⁵⁴. When the unit is completed, the yard is filled with water to allow the unit to be floated out to sea. However, the temporary facility would result in a significant cost added to the overall development.

3.8.3 Tugboats

Centre Port Wellington currently owns three red tugboats (figure 3-19) with maximum pull capacity of 68, 34, 28 tonnes for small operations, which is incapable of towing a 200m x 200m x 3m pontoon unit weights thousands of tonnes. Therefore, a VLFS project in Central Wellington would further require four to five tugboats each with a total pull capacity that is comparable to the weight of pontoon unit on water to complete the 'float in' process.

3.9 Legal feasibility

In general, floating development is likely to be high-risk from a political and statutory point of view. Current New Zealand plans and policies do not cover floating development because floating

structure is still novel to the building industry here. Moreover, further city extension out into the harbour fell into disfavour with the councils. Section 3.7 puts forward concerns and suggestion for Wellington City Council (WCC), Greater Wellington Regional Council (WRC) and Department of Building and Housing (DBH)⁵⁵ and discusses the opportunities it brings and the effect on current plans and policies.

3.9.1 Waterfront management

Past reclamation works on the waterfront have been overseen by Wellington Harbour Board on behalf of the WCC since the year 1880⁵⁶. Therefore, if Wellington harbour board is to continue to take in charge, there would be many challenges to the changes brought by floating development. Nevertheless, transparency and public engagement⁵⁷ in the process of waterfront development would be the emphasis and remained as the key concern for floating development on the waterfront.

3.9.2 WCC

The site of the floating VLFS development falls under the WRC's Regional Coastal Plan area⁵⁸. If the WCC is to be the controlling authority for floating development based on that it is a way for city expansion, then the inner harbour will need to be taken out of the WRC's Regional Coastal Plan and placed into the WCC's District Plan⁵⁹. Furthermore, in keeping with the structure of the District Plan, the new added area created by the floating development will be put forward as a Plan Change (or Variation) to the District Plan. For example, the new floating development would be created as Lambton Harbour precinct with its own set of 'Objectives, Policies & Rules' and 'Design Guideline' similar to the current established precinct in the central city.

WCC is developing a long-term strategic framework, called Wellington 2040⁶⁰, looking at how the central city might evolve to further enhance its centralness over the next 30 years, though it has not yet been finalised. So, the case study of this thesis takes this opportunity to present VLFS development, as the speculation on Wellington City beyond 2040. The speculation could further look for development to enhance the centralness because currently, Central CBD poses a linear relationship with the two subordinate precincts, Te Aro and Thorndon.

3.9.3 WRC

The environmental impact underlined by the WRC's Regional Coastal Plan⁶¹ is one of the main concerns for activities and developments on the study area. Therefore, floating VLFS would need to

consider these issues during the design stage, as well as to carry out Environmental Impact Study after completion of construction. The two most important points to be dealt with are, onsite sewage treatment and stormwater management before being discharge into sea⁶², and influence on the ecosystem due to a possible block of low and a large shaded space created below the floating structure, the latter of which is not mentioned in the plan but is highly important.

3.9.4 DBH

The pontoon of the VLFS will be regulated by Maritime and Maritime Protection Rule while the superstructure will be regulated by the New Zealand Building Code. This would results in amendment of Building Code and the weather-tightness guideline of DBH because they are currently not designed for floating building at an on-shore location. The amendment would include specification for VLFS engineering, especially solution to cope with higher weather-tightness risk, and higher requirement for services and maintenance for VLFS development.

3.10 Financial Feasibility

This section 3.8 looks at how floating VLFS development on water is compared to conventional development on existing waterfront land and analyses factors to be taken into account to ensure it is financially feasible in the Wellington context.

3.10.1 Leasing development

Concept of ownership and leasehold for floating development is a similar to development on reclaimed land. The additional land created is owned by the Crown and then it is subdivided into separate parcels and leased for development to second parties. This would probably be called 'pontoon' lease, which enables to build on the pontoon of VLFS to a certain height. VLFS pontoon is currently designed to withstand 100 years, which just allows the leasing period of the 'pontoon' to match up with land lease on existing waterfront with a maximum of 99 years.

Nevertheless, due to the 'pontoon' is not being long lasting, it would raise questions about the readiness of banks, investors and also insurers to invest in this kind of development. So it is important that people would have to be convinced of its long-term viability.

3.10.2 Project phasing

A large urban scale like this means that the floating development would take tens of years to complete, or it may result in partial completion. Thus, it is essential that design and construction of the floating development is carried out by phases, each adds a specific urban function to the city and it is independent. So in case of an early termination of a particular phase, the overall development is still visually pleasing and fully functioning.

3.10.3 Cost comparison

The table 3-1 shows a comparison between cost of a conventional building development and VLFS development. It compares the cost of a section of development for three basic six-storey office building of 3000sq ms on a land area of 200m x 200m x 3m, a total of 120,000cu ms. The cost of infrastructure and services, and the cost for 'using' the seabed/sea currently inexistent, are excluded here, but they are essential to the overall construction cost.

Conventional building	VLFS
Land value:	Cost of the VLFS pontoon:
Waterfront @ \$4500/sq ms ⁶³ = \$180 million	\$ 540/cu ms (refer to 2.10)
Te Aro Precinct @ \$2000/sq ms ⁶⁴ = \$80 million	= \$65 million
Overall building cost:	Overall cost of superstructure on pontoon:
\$2600/metre square ⁶⁵	= \$7.4 million ⁶⁶ for each
= \$7.8 million for each	= \$22.2 million for three
= \$23.4 million for three	

Table 3-1 Cost comparison

The calculation shows that the a section of VLFS development for three six-storey office building requires a significant amount of money for setting up the pontoon land because any building work starts. There is not a significant cost saving for building on pontoon. On the other hand, the pontoon land covers nearly 90% of the overall cost. Nevertheless, the overall higher cost is justified by that the 'pontoon land' is more affordable than lands on Te Aro precinct, and a third of the cost of waterfront land.

Nevertheless it is still doubtful whether the City Council will be capable of providing funding for the pontoon land. Therefore, the project would require a substantial amount of private investment from foreign interests. Furthermore, from a realistic point of view, VLFS will be more at risk to stall development as a result of competition with development on existing waterfront land.

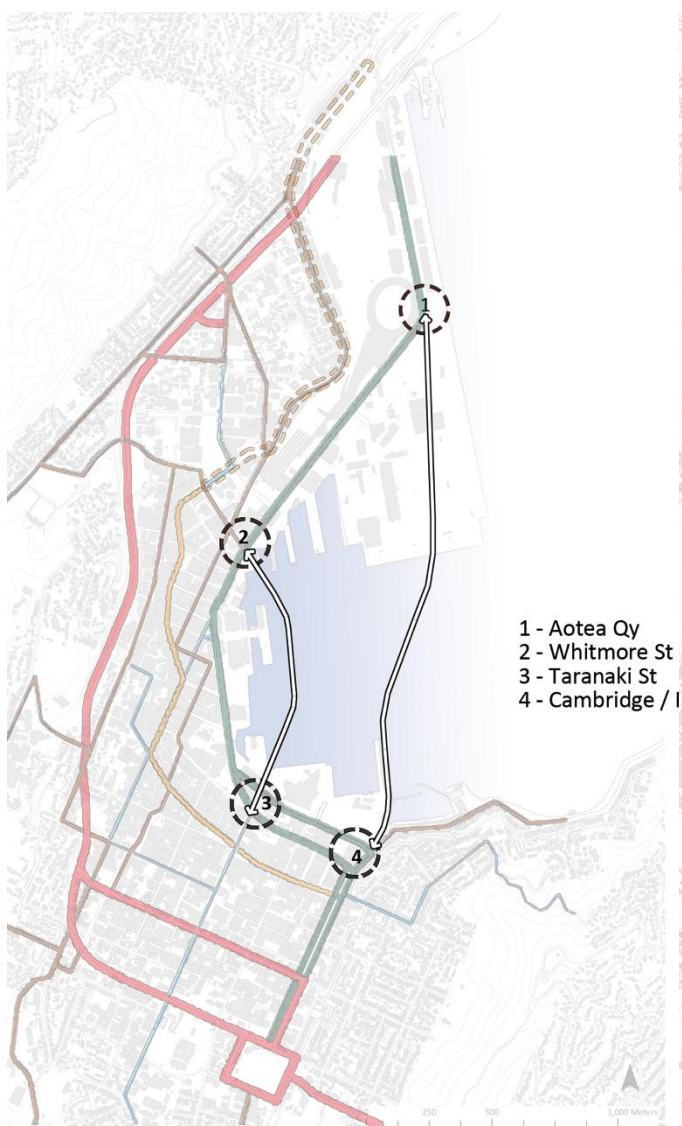
3.11 Final evaluation of Wellington conditions

This chapter determines the major opportunities and threats of incorporating VLFS to Wellington urban environment, see table 3-2 below. In conclusion, despite of the huge price tag, from an urban design point of view the idea of a pontoon land is still an attractive and promising, because land reclamation is unlikely to happen in the future, and the opportunity to have additional waterfront land at a central location that benefits and supports development of the city is precious.

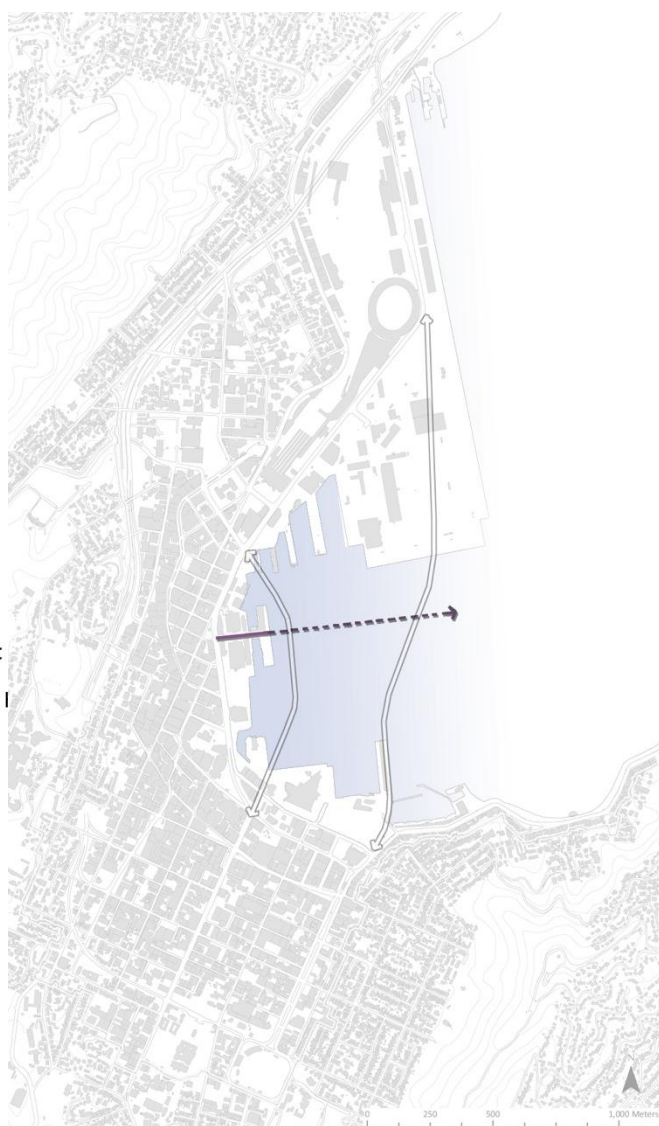
Opportunities	Threats
<ul style="list-style-type: none"> • Provide additional transportation route and 10,000 people arena, office blocks with plan size over 3000 sq ms that the city currently needs. • Beneficial to the surroundings by improving the amenity value of the existing waterfront land and supporting developments for the operational port and extension of government centre • Create additional precincts further enhance the centralness of the CBD 	<ul style="list-style-type: none"> • Social acceptability and environmental concerns influence government approval of the project. • Multi phasing approach might result in partial completion • Pontoon land has a high construction cost and it requires temporary fabrication yard that puts it under increased financial pressure. • Competition with existing waterfront development.

Table 3-2 Opportunities and treats

↓ Figure 4-1



↓ Figure 4-2



Chapter Four: Design

Chapter four is the design part of the case study, it presents a speculation of the future for Wellington City beyond 2040, that continues to expand its waterfront through building VLFS development. The chapter aims to guide through the design process and evaluate the success of building VLFS development as a form of urban expansion, focusing on the urban dimension.

The chapter firstly illustrates and describes the ten design objectives and how the objectives are met that leads to a concept design. Secondly, it evaluates how well the proposed design meets the objective, looking at its plan and three aerial perspectives. Thirdly it moves on to discuss in detail and evaluate the selected areas, Queens Wharf extension and Whitmore and Taranaki Street extension. Lastly, Project phasing and Detail designs are explained. This chapter is then concluded by a section on evaluation summary of the final outcome, which takes into account comments made by the reviewers.

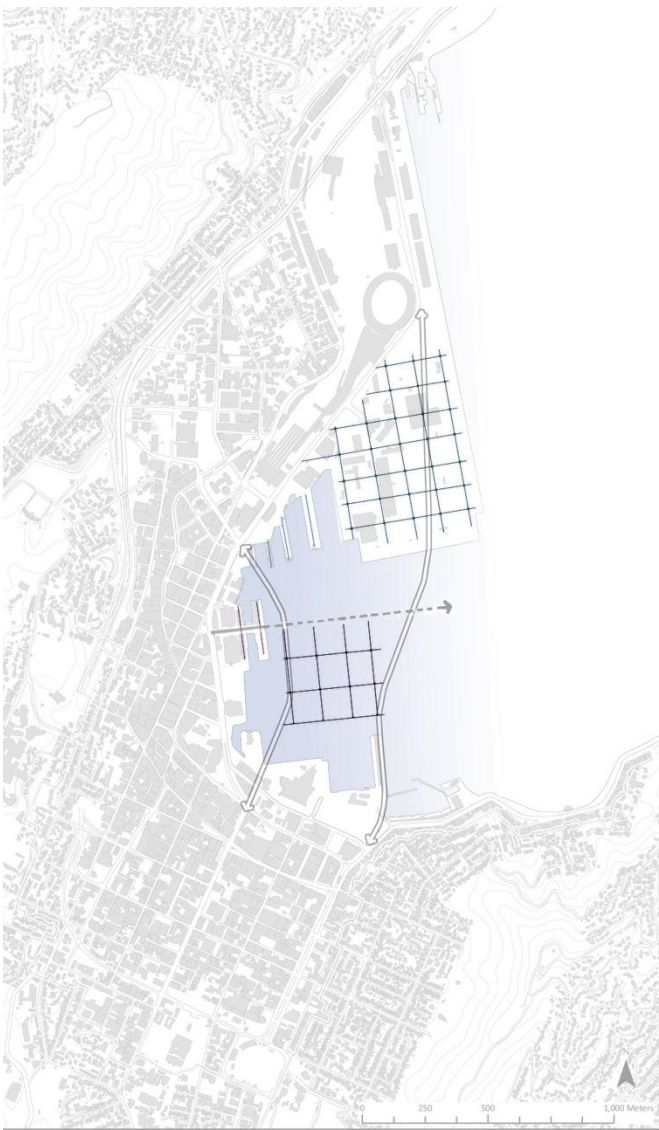
4.1 Design Objectives

4.1.1 Making north-south connections (figure 4-1)

The starts with satisfying the city's need for additional north-south road infrastructures: one is connecting Whitmore Street and Taranki Street to form inner route, the resulting traffic lane aims to provide an alternative for traffic between one of the biggest residential district Karori and eastern suburbs, Island Bay and Miramar for example. The other one is connecting Aotea Quay and Cambridge/Kent Terrace to form outer route. As a result, the traffic on Jervios Quay and Customhouse Quay can be reduced to two lanes in each direction. This further creates the opportunity for tree lined boulevard or light rail system.

4.1.2 Queens Wharf extension (figure 4-2)

The wharf is extended out onto the harbour creates strong east-west axial connection with CBD to encourages pedestrian traffic as well as to allow for further public building development along side the extension to emphases significance of Queens Wharf.



↑ Figure 4-3

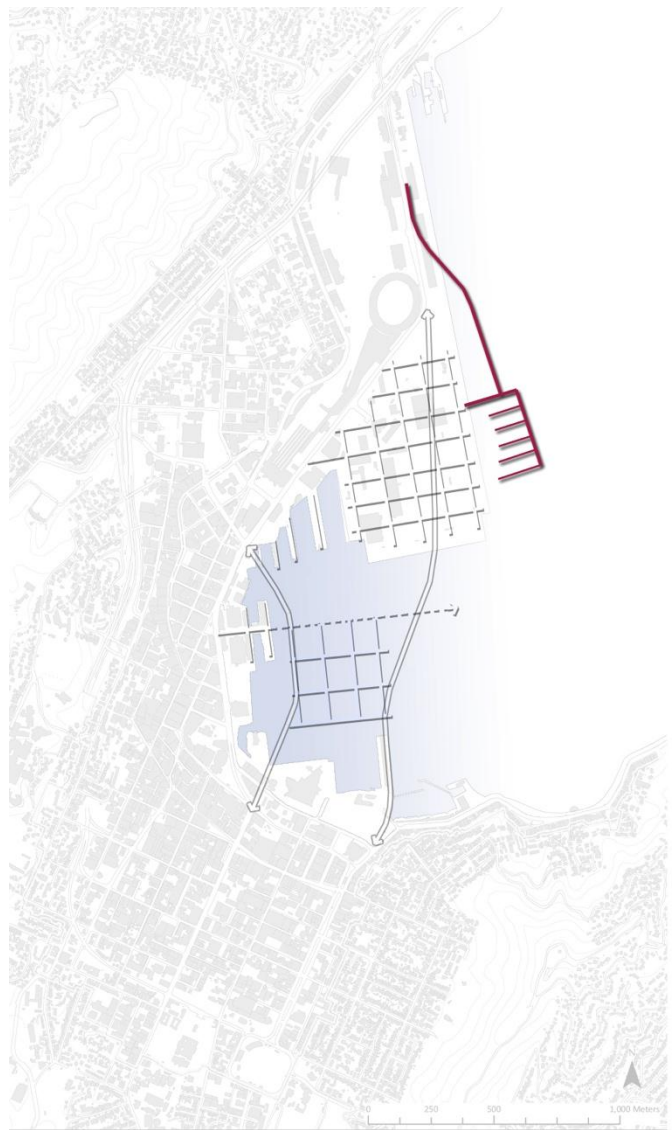
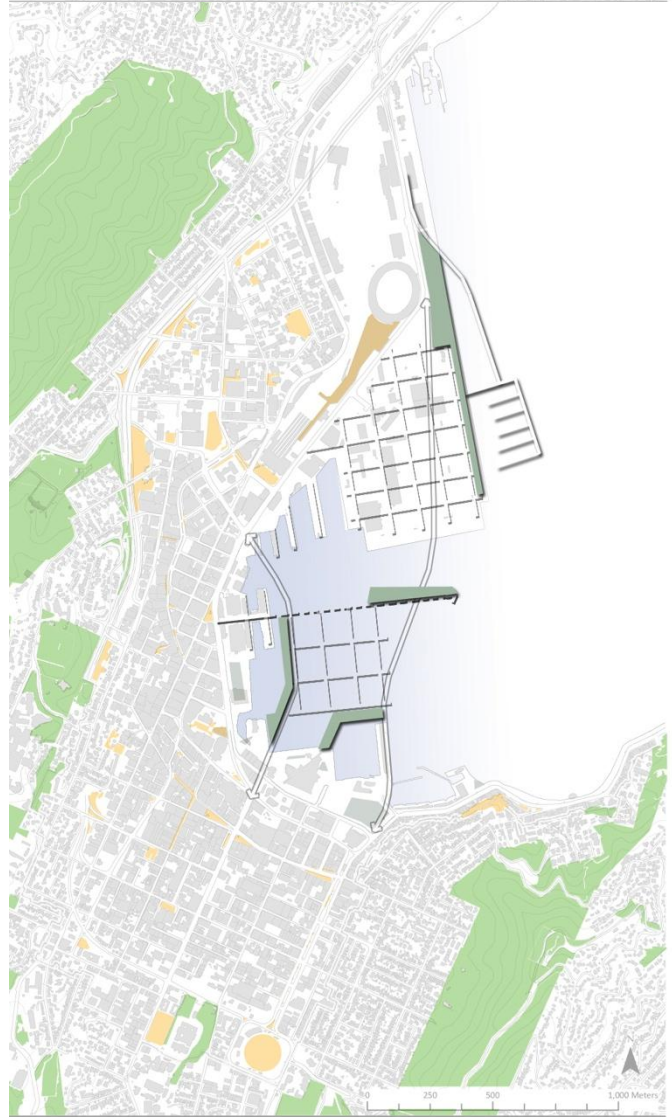


Figure 4-4 ↗
Figure 4-5 →



4.1.3 Continue the existing waterfront grid (figure 4-3)

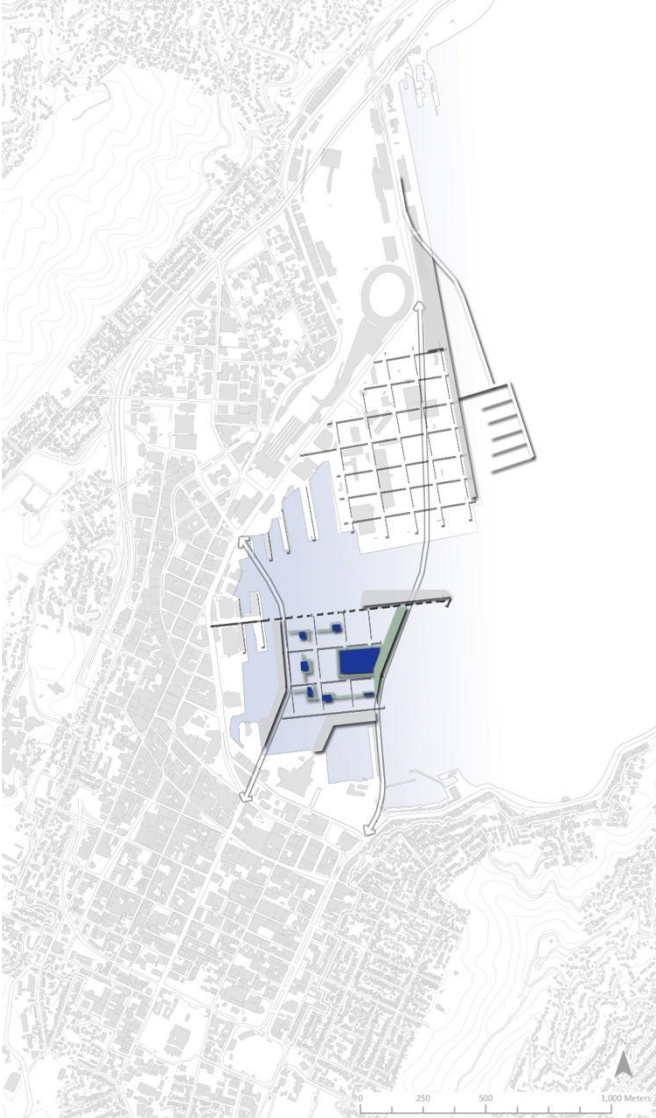
Because much of the existing waterfront edge already conforms to waterfront grid created by the finger wharves, the fact that continuation of the waterfront grid means that open spaces between on-water fabric and the existing waterfront take on more regular coherent shapes. The resulting waterfront grid has an adequate size to provide for development of large plan area. Each grid is sized at 150m x 180m, which is between Te Aro's larger 350m x 450m grid and CBD's smaller 70m x 90m grid.

4.1.4 Relocation of Interislander Ferry Terminal (figure 4-4)

Relocate Interislander Ferries Terminal to the east of the current operational port to enable a better pedestrian and vehicle connection between the terminal and the central CBD. This is provided by a grid that is slightly tilted and still closely connected to SH1. Inner harbour ferry terminal remains at its current location to allow for direct and quick trip from / to the heart of the city.

4.1.5 Incorporate peripheral green space (figure 4-5)

The new waterfront development provides opportunities for these peripheral green spaces that the existing Wellington central city is unable to provide due to its high built-up density. They also act as a transitional space between built forms and sea.



↑ Figure 4-6

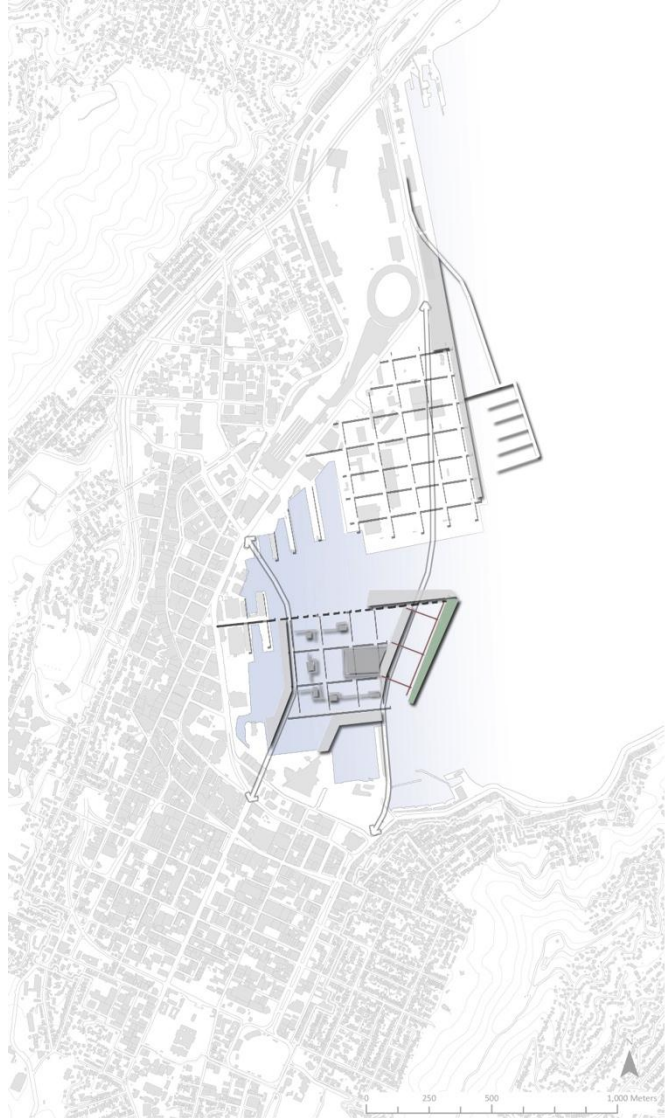
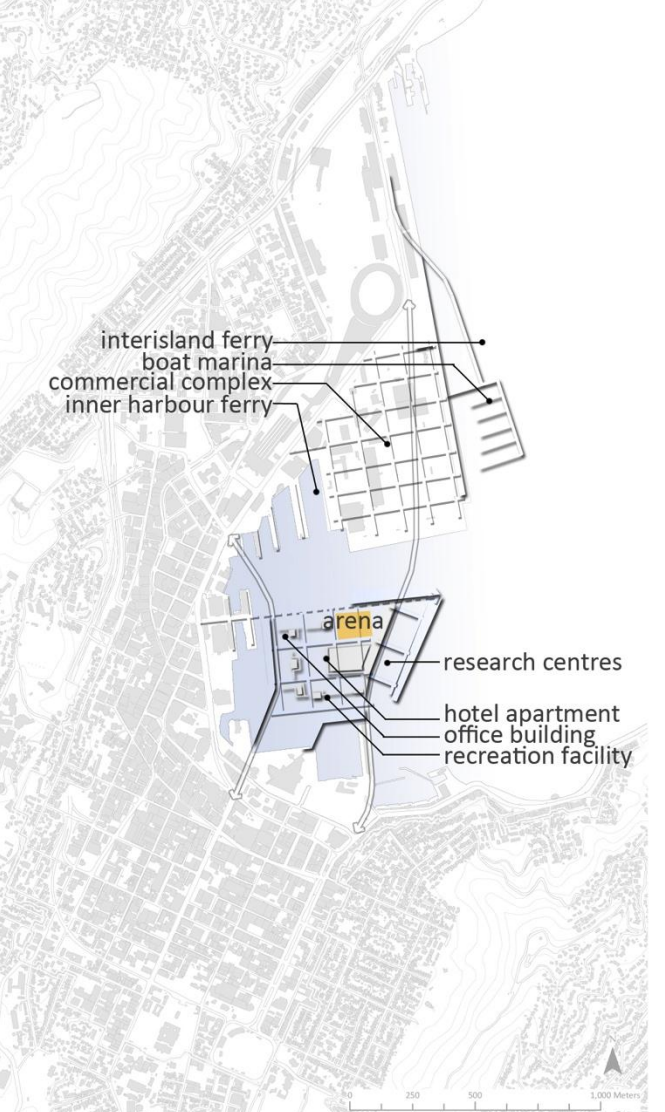


Figure 4-7 ↗
Figure 4-8 →



4.1.6 Adding internal water bodies (figure 4-6)

To take full advantage of the modularity and flexibility of the floating VLFS structure, internal water space is created to give a character to the design and further enhance the distinctness from being on land. These are open space, or 'blue' space, shared by the surrounding development on the new land.

4.1.7 Create new waterfront edge (figure 4-7)

New waterfront edge is created to replicate the existing waterfront condition. So firstly the floating component does not end with a busy traffic thoroughfare; secondly it make the development public oriented and not restricted to private use only; thirdly, it provide opportunity and models for continuous growth.

4.1.8 New arena and other large footprint buildings (figure 4-8)

Programme wise, it provides space for a 10,000 seats purpose-built indoor concert venue to match up with the venues in Auckland and Christchurch, and office with large floor plates approximately 3000sq ms that the city desperately needs. As a result of the floating development, current marina in front of Waitangi Park is moved to east of the proposed Pipitea Precinct (existing operational port). The development also provides amenity of recreational facilities, hotel apartments and general retail spaces, as well as research centres to help of monitor the environmental impact of VLFS on the marine environment.

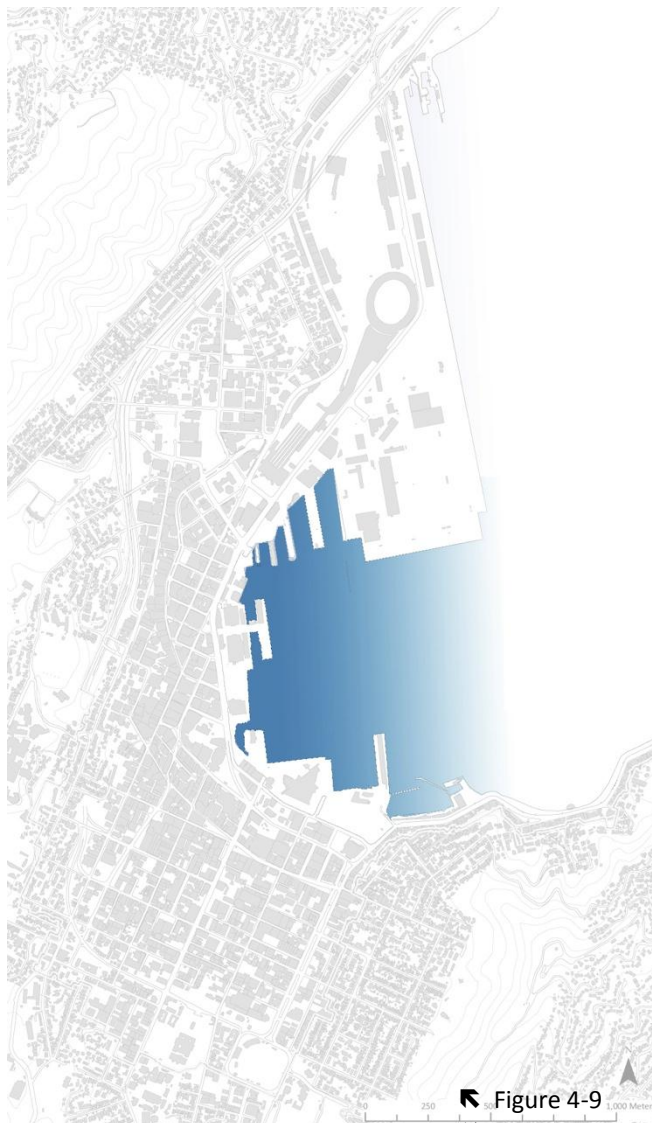


Figure 4-9
Figure 4-11

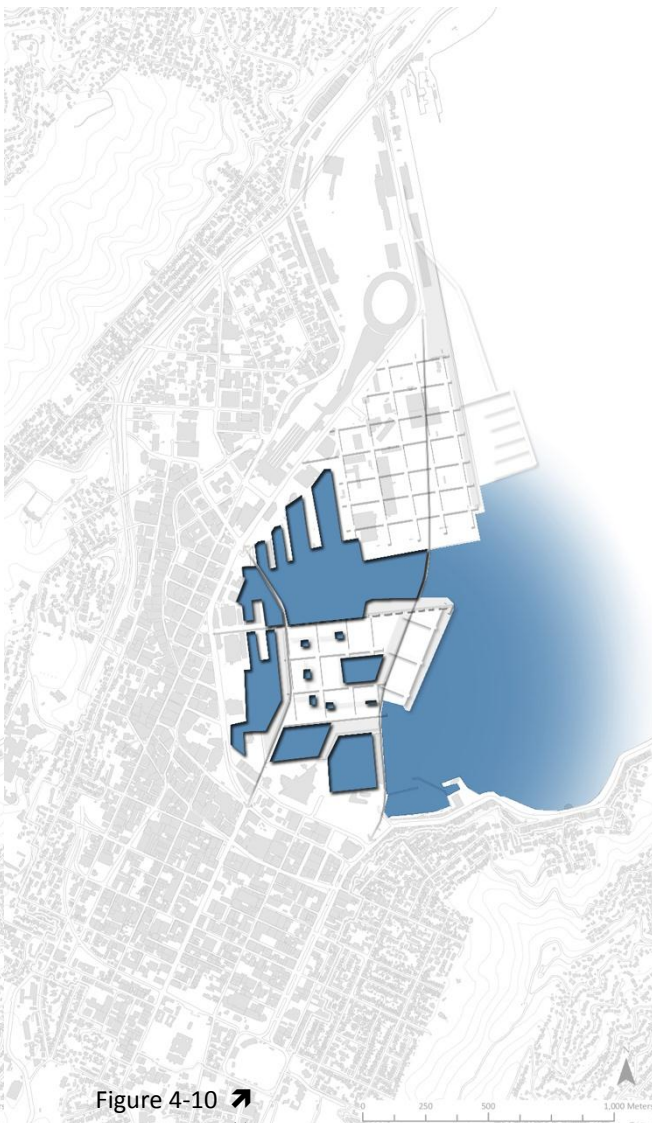
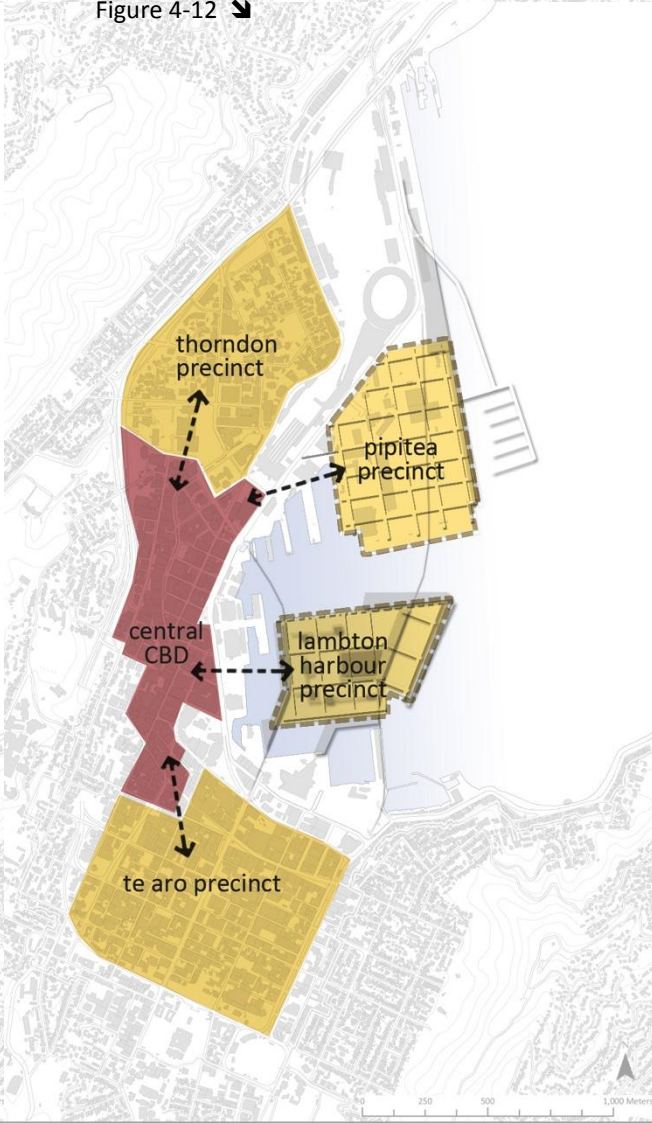
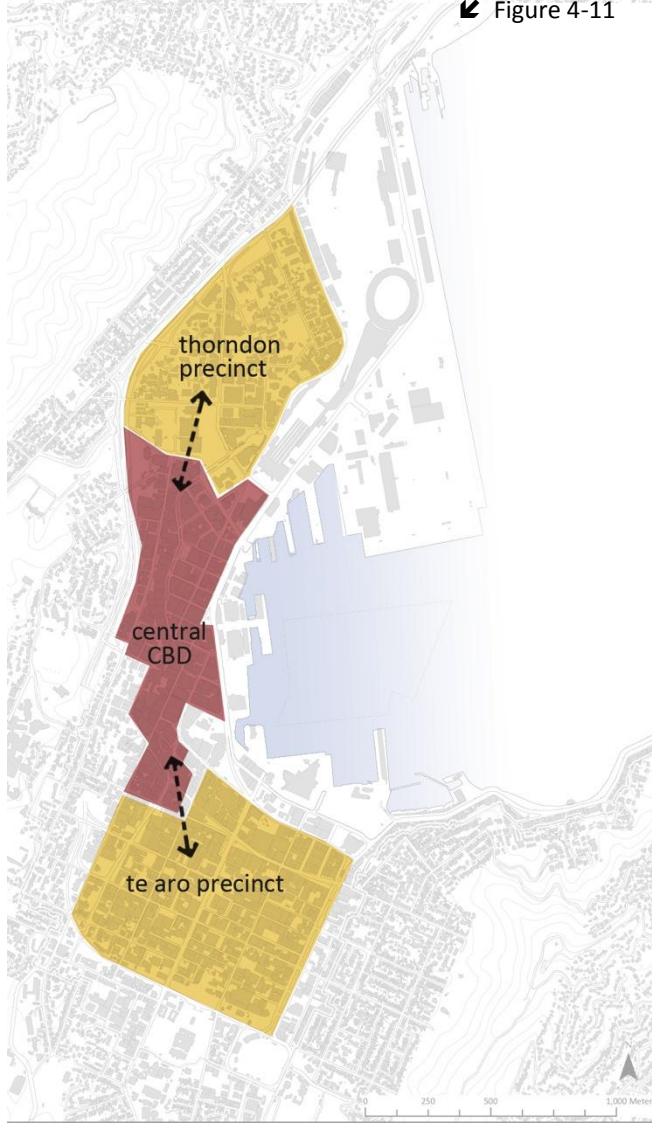


Figure 4-10
Figure 4-12



4.1.9 Varied relationship with water

The existing single relationship between built-form and water results in privileged 'front-row' buildings along the waterfront (figure 4-9). The proposed design divides the harbour into a few enclosed bodies of water with buildings on either side (figure 4-10). These water bodies are of a variety of size and importance, this hierarchy helps to create a varied experience, and the implicit hierarchy of spaces assists a clear idea about urban structure. As a result, the length of the coastline is extended considerably and the amenity value along the waterfront improves as well.

4.1.10 'Core' relationship with Central CBD

Currently, CBD and the two subordinate precincts, Te Aro and Thorndon have a linear relationship (figure 4-11). The proposed design suggests a model that further emphasise the compactness and centralness of the CBD. The operational port area would be redeveloped as a precinct to support higher-value office complexes and small industries to support Interislander Ferry and Freight services. As a result, current operational port is downsized and relocated near SH1. While the floating development would be developed as Lambton Harbour precinct. Together, the two new and the two existing precinct form a ring relationship with the CBD and together they play a subordinate role in serving the CBD (figure 4-12).

The existing precincts, Te Aro and Thorndon, each has a population of 4521⁶⁷ and 3840⁶⁸ respectively, and CBD is the home to 4776⁶⁹ people. According to these figures and the size of the area, it is estimated that the proposed would has a similar density to Te Aro and Thorndon combined with the capacity for approximately 8000 people.



Figure 4-13 ↗
Master Plan

4.2 Design analysis

The proposed design transforms Lambton Harbour and the operational port into two new areas of developments and aims at accommodating approximately 8,000 - 10,000 people (figure 4-13). It would provide various urban figures and grounds that are much more beneficial and needed by the city. This section 4.2 analyses and evaluate the design focuses solely on the overall picture, in particular the floating development on the harbour.



Figure 4-14 ↗
Location plan showing traffic network

4.2.1 Road network

Most key accomplishment made by the floating design is that it completes the city's overall transportation system (figure 4- 14). These five north-south routes are spaced 200-500m apart. Inner north-south route connected Whitmore and Taranki Street helps with the local trip. While the outer north-south route, connected Aotea Quay and the Cambridge/Kent Terrace, activates the proposed Pipitea Precinct by adding new routes from the south to make the precinct more accessible. The outer route has 4 lanes, 2 in each direction to provide an effective alternative shorter and faster connection from one side to the other side of the harbour for public transportation, bus, and private vehicles. Reaching to the proposed development is relied on these two north-south routes so they are the primary routes. The green parks provided aims to reduce the impact on the adjacent built forms and the activities on the waterfront.

However, the proposed design is not able to provide much traffic routes in the east-west direction, only one is through Queens wharf and its extension. Nevertheless it is pedestrian oriented. A logical place for the additional east-west connection to achieve evenly spaced street network would be cutting through Frank Kitts Park. But since the negative impact outweighs the gains by doing so, i.e. destroying one of two large, popular and quality public green space well established on the waterfront, it would be better not to provide more routes in the east-west direction.

4.2.2 Green space

Significant amount of green spaces are provided at the central location and are accessible within 10 minutes walking distance (800m) from the surrounding precincts. However, the spaces facing the outer harbour might not be as popular as anticipated because it is less sheltered and requires significant amount of walking from inland. On the other hand, spaces along the existing waterfront are sheltered from the exposed weather and closer to CBD therefore it is likely to be more populated, this would be further analysed in 4.3.2.



Figure 4-15 ↗ Mt Victoria Lookout

Figure 4-16 ↘ Botanic Garden and Cable Car Lookout



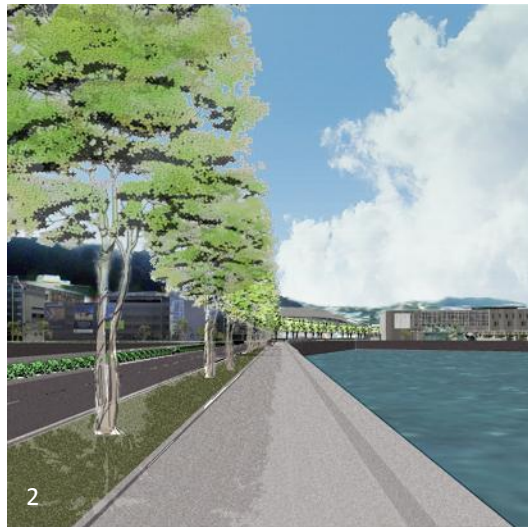
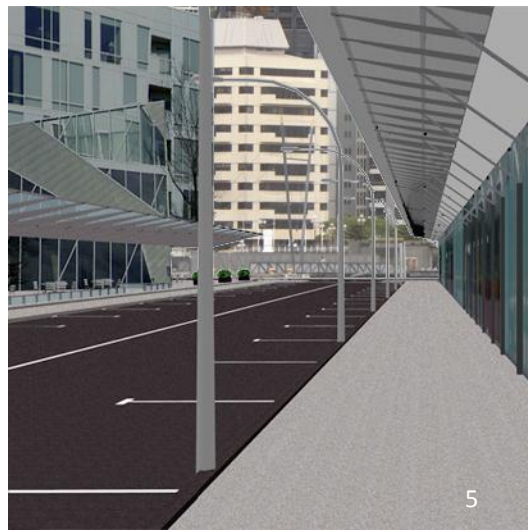
4.2.3 Visual appearance of the city

Arguably the major concern is the visual impact on the overall appearance of the city due to floating development on the inner harbour. The distant perspectives show a promising result, the area created is much richer and porous urban space compared to in land reclamation project where the inner harbour would be filled.

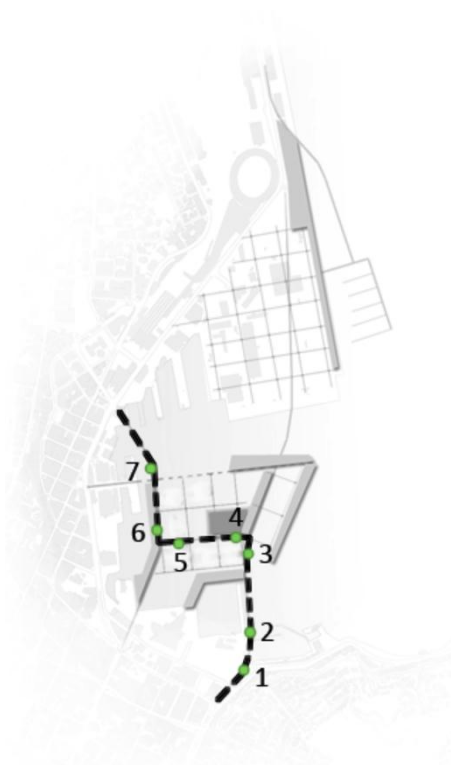
The Mt Victoria lookout (figure 4-15) shows that the floating development is set in the middle of the inner harbour and is lightly tied to the edge of the existing city. As a result, the curing-in profile, that contributes to Wellingtonness, is unobstructed and remains visually apparent.

The Botanic Garden lookout (figure 4-16) on the other hand shows that the proposed floating development on the inner harbour is incorporated into the cityscape whereas in the current situation, waterfront area is blocked by high rise buildings of the CBD. The resulting cityscape has these intricate bodies of water feeding into the central city to further enhance the relationship between city and sea. In addition, the entire Wellington Harbour and the Eastbourne hills will not be obstructed in the view as a result of the development. Thus, the outcome is still very much a harbour city, although it would appear quite different with the floating structure.

The proposed development would change the image of the Central Wellington City for the better, the image that celebrates the growth of the city due to VLFS application while making connections with past reclamation project and future opportunities for continuous floating development.



←↶↷→ Figure 4-17 Seven walk through scenes



Keys:

1. chaffers dock looking to proposed development
2. pontoon bridge of the outer route
3. research centres on the outer route
4. apartments and offices by the central park
5. retail shops and outdoor café
6. office block on inner route
7. pontoon bridge of the inner route looking to NZ Post

4.2.4 Quality of space

The proposed development emphasises an out-of-town park quality that has a lesser density than the compact and built-up Central Wellington. The floating development is designed for ease of walking. The continuous pedestrian pathway is maintained throughout, with a width of 3m. Street planting runs continuously along at least one side of the major streets to provide a zone of separation between pedestrian and vehicle traffics. These qualities are unachievable in existing Central Wellington, for example areas around Taranaki Street only have 2m wide pedestrian path and a few spots of trees. The resulting design offers an urban environment that is un-Wellington but it is better and more like Melbourne.

The seven walkthrough scenes in figure 4-17, also shows that these urban spaces have a varied degree of enclosure and exposure created by the different edge treatment. In Scene 3, the entrance of a research centre is set back from the site boundary to create a wide entrance space. Being adjacent to busier arterials, the set-back also provides a more substantial buffer for these properties. Car parking spaces are hidden at the back of these buildings to avoid creating a divisive barrier between building and street.

Scene 4 show a more open and permeable space. It is integrated into the existing urban form and the natural environment that does not change the existing skyline. Streets are running towards the existing city like a view-shaft and buildings are constructed lower with the city skyline visible behind



↑ Figure 4-18 Cental park and arena on the right.

it. There is also a variety of buildings, that are residential apartments (right) or commercial offices (left), and new or existing. These characteristics make an encounter a rich experience, and also helps to make the new place legible by providing a sense of orientation relative to CBD.

Also in scene 4, 3m semi-private strip between commercial building fronts and public pavement provides amenity space for small garden, bicycle stand or seating and 'spill-out area' for pavement cafes or shops. It puts an emphasis on social and outdoor experience. On the contrary, in scene 5, building line adjacent to pavement edge creates direct commercial frontage areas and a sense of enclosure.

4.2.5 Access bridge

Not much attention has been paid to the design of the access bridge. Scene 2 and 7 shows that the bridge is long and filled up with vehicle traffic with no built forms or attractions along the way. Therefore, it is unpleasant and potentially dangerous to walk on. Although access bridge is an essential part of the VLFS, and it is an effective and functional transportation route for vehicles but it is not suitable for pedestrian traffic.

4.2.6 Central park

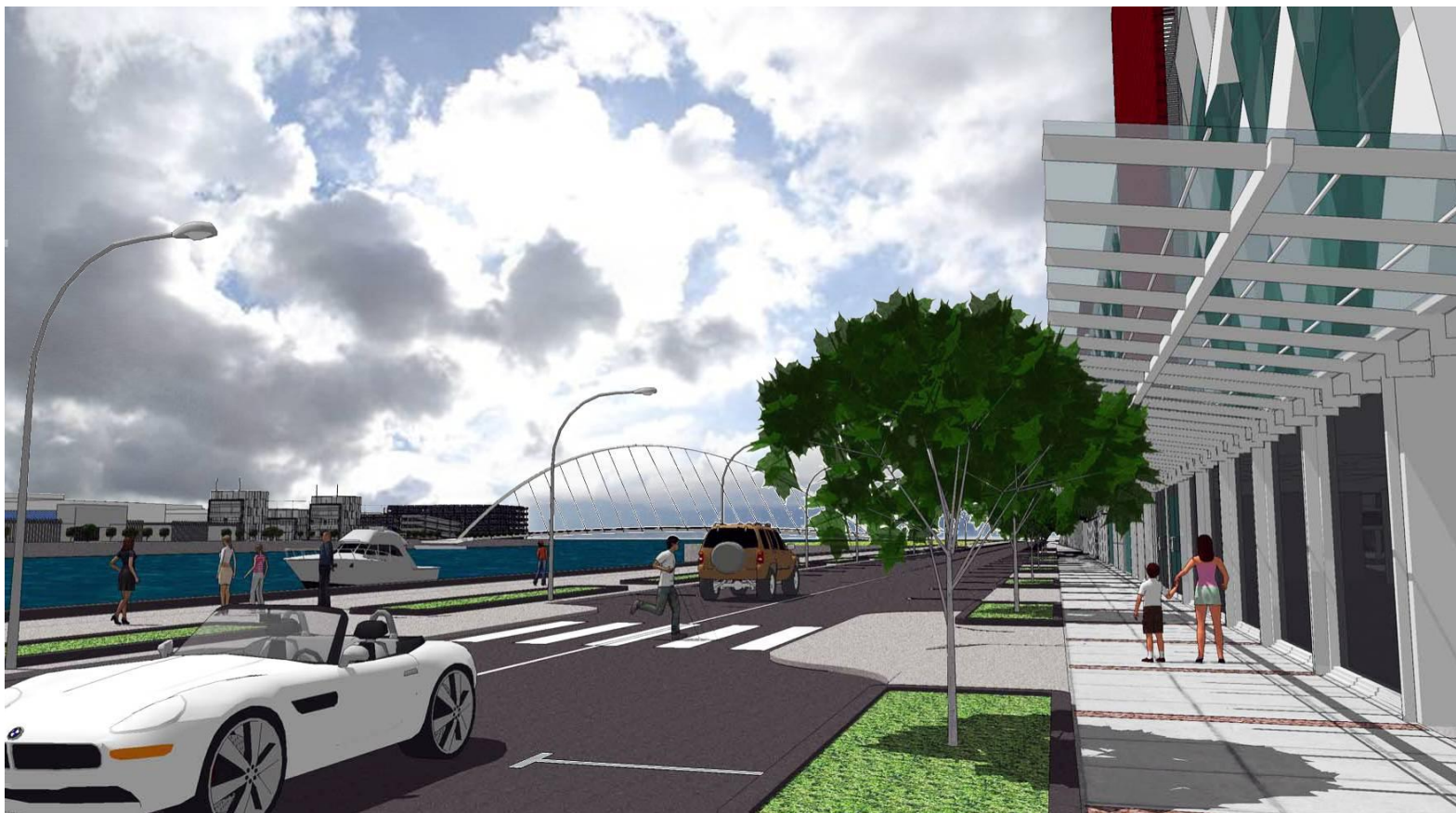
Figure 4-18 shows area around large enclosed water at the centre of the development with size close to Waitangi Park. The topography steps down so the eyes are drawn to the large bodies of water. Furthermore, the linear element provides the definition that contributes to a sense of place. The large blue and green park also provides an open space that helps to cope with high people density during an event in the proposed arena (on the right of the figure 4-18), as well as to reduce the effect of noise pollution on surrounding residential livings.

Moreover, the open space helps to absorb the massive and unproportionate 'big box' – arena. The bulkiness of the arena is also concealed by retail spaces wrapping around the main perimeter of the 'big box' so it become compatible with the surrounding urban setting.



↗ Figure 4-19 indication plans (left: Queens Wharf extension; right: Whitmore and Taranaki connector)

↓ Figure 4-20 Queens Wharf extension looking out to east



4.3 Design features of selected areas

Section 4.3 moves on to evaluate and give suggestion to urban function, architecture quality and pedestrian experience of Queens Wharf extension and the Whitmore and Taranaki connector (figure 4-19). These two areas are modelled in 3D modelling computer software Sketchup to produce accurate representations of real-life scenario.

4.3.1 Queens Wharf extension

Queens wharf extension is north facing so it receives sunshine through out most of the day. It also has the scale and importance of a major street/route within the city, and convenient accessibility from central CBD. These make it a high quality pedestrian route. Overall, the proposed urban space is compatible with any setting. In order to associate it with the existing Queens wharf, features such as pavement and sails will be utilised in the extension area.

The proposed extension has potential for development of government buildings to continue to expand further throughout Whitmore Street, and along Queens Wharf extension out into the Lambton Harbour. In order to make the extension work, it requires making a link between Queens Wharf extension and the existing government centre, to create continuous street edge all the way along. This can be achieved by having building along the Whitmore access bridge and build up the site on the corner of Whitmore and Jervois Quay, which is currently the Shell service station.

On one side, the buildings' straight facade contributes a strong street edge to the public realm and creates a sense of space (figure 4-20). The façade treatment is compatible to the sea surrounding. A light, glassy envelope, that is projected towards the sea to expresses an openness and airiness, is chosen. Although a step in façade would create balcony spaces on the upper levels and encourage contact with the natural environment, but it would not be a strong street edge.

On the other side by the water, continuous vegetation separates the 5m wide footpath from the traffic. The simple footpath provides a more open ground for pedestrians to experience openness and closeness to nature. There is the concern that the length of the path, nearly doubles the one in front of Frank Kitts Park, that it may need to have various attractions on the way to make the journey worthwhile.



➤ Figure 4-21 looking back to the existing waterfront

➤ Figure 4-22 looking out to the north (inner route on the right)



4.3.2 Whitmore Taranaki connector

The proposed change to the Frank Kitts Park area is beneficial to the city's infrastructure, as well as, it improves amenity value of the spaces along the shoreline without the 'front-row' building making a big sacrifice. So the 'front-rows' are still able to enjoy the distant view and large area of blue space. The peripheral green space together with the water bodies create a pocket park, offers calmer and safer recreational water for dragon boating and kayaking, and a more pleasant peripheral green space sheltered from the wind for waterfront recreation. This creates intimate space as linkage between the shores, and it is intensified between front-row buildings to create a sensation of enclosure.

The change involves placing a through route connecting Whitmore and Taranaki Street on the water edge essentially replicating the condition found on the Customhouse / Jervois quay side. The advantage is that the lane on the quay can be reduced by half to allow for other mode of transportation, such as light rail. The disadvantage is that the edge is dominated by traffic, 2 lanes. Alternatively attempts have been made to design the edge so it is dominated by people rather than cars. This is achieved by creating topography stepping down to reach the water, as illustrated in figure 4-23, so people on the other side of the waterfront are able to make sense of the activities involved on the green park and relate to it.

Nevertheless, through route also has implication on the connection within the new lands. Pedestrian access from the blocks on the east to the green park is reliant on the east-west streets, thus through route becomes the barrier to get across.

Another major connection problem of the proposed is the lack of direct pedestrian access to the new land from the existing waterfront, especially evident in this part of the design. The green space by the waterfront forms a continuous walking loop and the primary access, but the pedestrians would have to walk to Queens Wharf or Te Papa to get across to the new land (figure 4-23). Though the length of the walk would be much longer than the distance between two shores makes the trip uneasy. Even then, Pedestrians would find themselves on a busy through-route. Providing alternative path for pedestrians, such as a bridge, to reaching the floating development from existing waterfront may not be effective and desirable because the bridges will need to be located on the sides to minimise the visual impact on the scenery.

Figure 4-23 looking out to the floating development from Frank Kitts Park



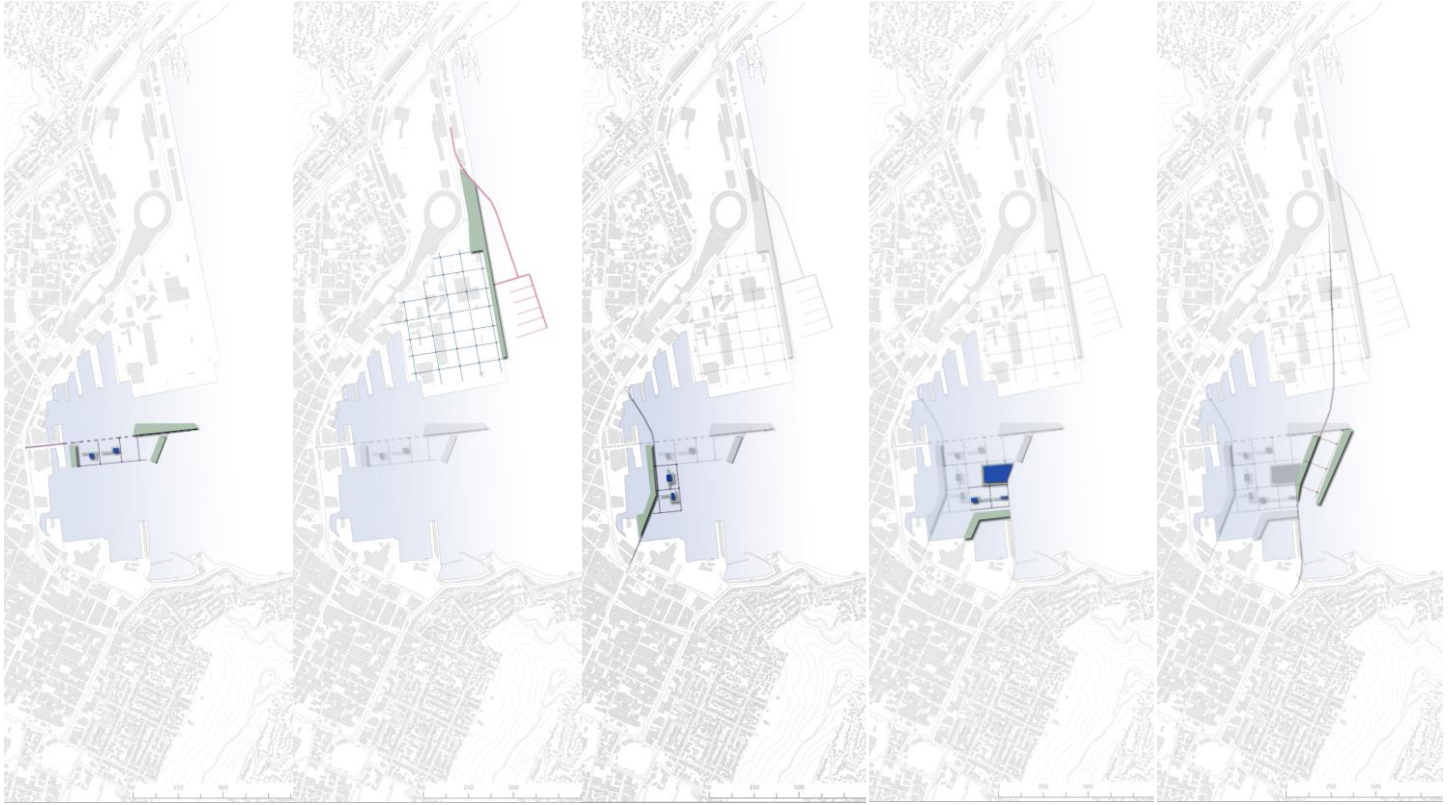
Buildings are concentrated on one side of the through route. The design is contemporary with facade of varied depth, so as to be different and stand out from design on the other side of the city. The buildings are ranged from 4-7 stories; therefore, they are still in scale with the existing buildings on the waterfront (figure 4-22). It is also able to incorporate large outdoor spaces, which is impossible to achieve in CBD because land is prioritised for building developments (figure 4-21)

As a consequence, there would be less activity in the park because it doesn't have a building edge directed in the open space (figure 4-22). On the contrary, if there is building on the green park side then the open space may be privatised.

The view of Frank Kitts Park lookout below (figure 4-23) is probably the most problematic. Though the structure acknowledges the east-west streets as shown by the nice built up street edge. Nevertheless the proposed design creates a harsh urban-scape, i.e. a wall of building blocking the expansive view of the harbour, and only allows glimpses of the Eastbourne hill. Though the wide open view would be available at the new waterfront on the west of the proposed development.



Figure 4-24 Five project phases



Keys:

- 1: Queens Wharf extension and new arena
- 2: Pipitea Precinct redevelopment and relocation of Interislander Ferry terminal
- 3: inner north-south route extension
- 4: central park development
- 5: outer north-south route extension including harbour bridge

4.4 Project Information

4.4.1 Project phasing

Project phasing is based on the logical pattern of growth, which means development is from closer to shoreline to further out on to the sea. The proposed project will be broken up into five phases so that finance and resource are more manageable (figure 4-24). Timeframe for each phase is around five years including the building of the base platform and the superstructures above⁷⁰. The whole project will begin in 2040 and takes approximately 25 years, so it will end in 2065. This project is likely to be the first in New Zealand, so it is important to establish and maintain trust and public confidence by showing that the project is feasible and beneficial to Wellingtonians throughout every step.

Preparation for the development would include construction of a temporary fabrication yard on the south-west corner of the operation port, which is closest to the developing site. Phases 1 is one of the most representative part of the whole project. It represents political power on the waterfront and introduces the significance and scale of the project. This is followed by 'inner north-south route extension'. These phases are happening first due to the reason that developments are closer to the CBD and easier to access and populate. The outermost portion of the site could be built once the others are operating and will help to 'bridge' out to the more distant location. The temporary fabrication yard is removed or can be turned into a museum for the VLFS application in post-completion.

4.4.2 Overall cost

Approximate estimate of overall cost: \$1050 million

10 of the 200m x 200m pontoon unit: $65 \times 10 = \$650$ million

50 of the 3000sq ms building: $7.8 \times 50 = \$390$ million

4.4.3 Relatives measurements

The proposed design transforms Lambton Harbour and the operational port into Pipitea and Lambton Harbour Precinct to a medium density development that accommodates approximately 8,000 - 10,000 people. Table 4-1 shows that the amount of offices of the two proposed precincts

combined would be 40% of the total amount of office in CBD location. The proposed development proposes around 85% of the office with large floor area of over 3000sq ms to meet the long term future need. The central city will further benefit from an increase of 1800 apartment units, 154,000sq ms of new green park, and additional 3km of shoreline.

	Proposed development	Existing condition
Office Space (area, sq ms)	Total amount of office proposed 650,000 sq ms under 2000 sq ms -> 100,000 sq ms around 3000 sq ms -> 320,000 sq ms around 4000 sq ms -> 230,000 sq ms	Total office floor area in CBD 1,570,000 sq ms ⁷¹ (by the end of 2011) Amount of office added to CBD in 2011 88,000 sq ms ⁷²
Apartment (units)	Total units proposed 1800 units	Number of unit added to CBD in 01-06 1937 units ⁷³
New park (area sq ms)	Total area of green park proposed 154,000 sq ms	Total area of park in Central Wellington 50,000 sq ms (for major parks ⁷⁴)
Waterfront (perimeter, km)	Length added 3 km	Length of inner harbour ⁷⁵ 4.5 km

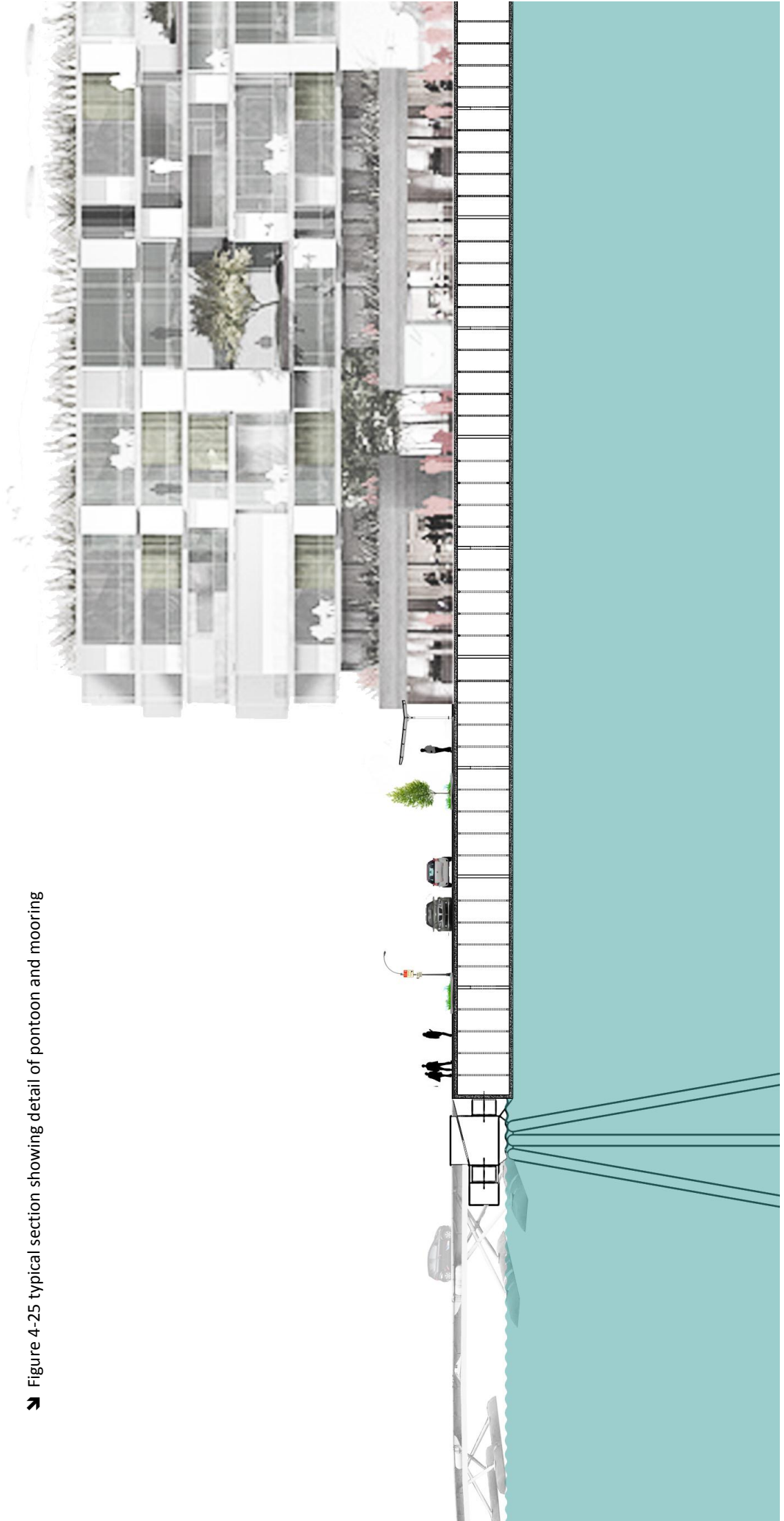
Table 4-1 comparison of measurements

4.4.4 Post completion and occupancy

To answer the question of the amount of time Wellington must take to absorb these new developments. The current rates of growth for the apartment units and offices per year are compared with to justify this growth. As a result, the total amount of proposed office is possibly equivalent to seven years of growth, and apartment units would possibly take approximately six years to reach, if development in the other area of central city is not taken into account.

The proposed apartments and offices are also likely to be more attractive because of its prime location closest to CBD and sea front and a potential uninterrupted view. But undoubtedly, current front row development will be put at some sorts of disadvantages and prices would lower due to competition.

➡ Figure 4-25 typical section showing detail of pontoon and mooring



4.5 Structural design

Section 4.5 focuses on the detailed design of floating pontoon of VLFS. It is aimed to give a general sizing of the main component, steel pontoon and dolphin-fender mooring facility, a description of the construction method proposed, and additional issues found during the detail design. Figure 2-25 are close estimation based on the studies of previous VLFS projects and consultation advice from structural engineer Peter Johnstone. The other components, such as steel floating access bridge and steel/concrete composite superstructure is relatively standard and well documented are also illustrated on a typical detail section, but they won't be explained in this thesis.

4.5.1 Steel pontoon

Each unit is sized 200m x 200m x 3m. It is simple cellular steel structures, each cell is 10m x 10m. Entire platform is roughly 800m x 800m. It sinks down 800mm when live load and dead load are spread on the pontoon. As a result, 2.2m of the pontoon appears above the water, which is in scale with the current waterfront ground that is around 2m above the sea level. Each unit is fabricated in temporary fabrication yard west-south of the proposed Pipitea Precinct, and float to site by four to five tugboats. These units are joined onsite and then connected to the offshore mooring facility prepared early on.

4.5.2 Dolphin-fender mooring facility

Overall size of the dolphin-fender system with rubber fender is 5m by 5m. It is supported by 6 steel pipe piles each is 900mm in diameter. 15 mooring dolphins are provided evenly on three sides of the pontoon structure⁷⁶. As a result, the mooring facilities have minimal interaction with seawater and seabed, and cause little underwater pollution and have negligible effect on tidal currents.

4.5.3 Issues and technology gap

- the building weight and other loads need to be evenly distributed to the pontoon in case of a tip over.
- fastening system for superstructure on pontoon platform to provide hold-down strength.
- how is 'cut outs' achieved in the pontoon platform?
- how to use pontoon platform in combination with other structural system, such as stilt / pile or hull structure?

4.6 Evaluation summary of design

The design chapter presents a speculation on the future of Wellington City beyond 2040 and illustrate with plans, perspectives and one detailed section, and provides analysis from distant to close up views.

The proposal overall makes a positive contribution to the Wellington's urban development, these three areas are described below, but is still somewhat skeptical at the moment for Wellington because of the huge price tag of 1050 million and numerous technological gaps and uncertainties. In addition, as pointed out in the external review, the proposal is likely to have a low social acceptance. Because as it challenges to further expand beyond the current coastline that is controversial in the current Wellington context and the scale of the proposed design is large and disproportionate that would change the look and feel of the city that has accompanied Wellingtonians for a long time⁷⁷.

- There is an overall improvement of traffic network for local and regional traveling. In the north-south direction, 2 additional primary routes - 6 more lanes, are provided for the city to allow for a mix of transport, both private vehicle, bus and light rail (on Jervois Quay). It is a well spaced and dispersed traffic system. Roads in the east-west direction are minor routes but still lacking and awaiting solution as sacrificing Frank Kitts Park is undesirable. On the other hand, the pedestrian traffic to/from the open space by Whitmore/Taranaki connector is most problematic, because it is lacking direct access and disrupted by primary through route.
- The proposed design provides a total of 550,000 sq ms office space with large plan size of over 3000 sq ms for public buildings and other commercial needs, as well as 1800 more apartment units, which subordinate to the CBD. An arena for 10,000 at a harbour location is also provided. The arena has been wrapped with smaller units and surrounded by large area of open space to become compatible with the neighbouring settings.
- The proposed design creates a series pocket park with blue and green space that the Central Wellington is unable to provide. It will add three times more greens park than what the central city currently has, and nearly doubles the length of the waterfront. The pocket park creates intimate yet porous spaces within the broader context. These spaces help to improve amenity value of the waterfront and 'front row' development and build more desired relationship between different uses of building.

Chapter Five: Conclusion

Chapter five is the conclusion chapter for this thesis. This chapter reminds the reader the aim of the project, discusses how the project has achieved its aim, and reviews the research process. Then it describes findings and recommendation of the project, and concludes with a final remark.

5.1 Review of research aim

To recap, the aim of the thesis is to find out what would be possible if floating structures were available instead. The research focuses on urban aspects, as well as technological, economic, and political aspects at lesser level of detail. A case study is used, of Very Large Floating Structure (VLFS) on Lambton Harbour for Wellington City beyond 2040 to test the feasibility.

The main component of the thesis includes a literature review, an assessment of Wellington condition, and design. The thesis starts with analysing a selective number of projects and found a majority of the water-based developments have poor urban connection with existing land-based city. Then, it examines various existing conditions of Wellington and prepares an urban planning for the future of Central Wellington that integrates well with existing land-based city.

The evaluation of design (Chapter 4) indicates that from an urban design perspective, floating development is very beneficial to the urban environment because it creates floating land for additional transportation routes and various buildings and green spaces that the city is lacking and unable to provide. Moreover, the proposal results in less seabed and tidal current disturbance. Existing waterfront areas also gain benefit from having pocket parks that existing Wellington reclamation is unable to achieve. However, the project significantly increases financial pressure for Wellington council that it is more at risk of becoming unfeasible, and further research is needed to determine several technological variables and uncertainties encountered during the research.

5.2 Findings of the research

5.2.1 Urban design feasibility

Floating development is able to increase the supply of scarce waterfront land at central sites to support urban expansion. It is now more driven by commercial and market interests evident in developments in Dubai and Netherlands. But most precedents neglect urban context and fail to establish successful connections with the host city.

The major strength of floating development is that it is able to create pocket parks and internal water bodies that allow varied relationships between built-form and water. The impact on the existing waterfront development is positive, that the amenity value of the waterfront area and spatial relationship between built-form and water are improved.

Quality and accessibility of pedestrian connection is crucial to floating development because floating development at a waterfront location is public-oriented. Existing projects and research overlooks these connections. During the case study, it is found that access bridges is a successful model for providing vehicle transportation, but unacceptable for pedestrians traffic.

5.2.2 Technical feasibility and ecology

It is technically possible to realise this concept, and the technology existing now. Still future research is in need to determine several variables and uncertainties encountered. Some of which are listed in section 5.3 below. These technologies of floating structure also contribute to a sustainable development. Floating development prepares and adapts to rising sea level and provides a more favourable lifestyle of living on water. Furthermore, it has reduced foundation requirement which means it is much more environmentally friendly to the seabed and the ocean.

5.2.3 Social / political feasibility

Environmental, building and council regulations have major influences on the government approval process of floating development. The building code, for example, would need to be amended to adapt to new standards and requirement of floating development beforehand. Also, it is in the nature of floating development that they would have an unavoidable impact on the existing cityscape; therefore, it has higher risk of being socially unacceptable

5.2.4 Economic feasibility

High construction cost is a major constraint for floating development. In particular, sizing of the pontoon unit has a great influence on the length of construction time and overall costs of the project. As a result of the higher cost, a large scale urban project might be feasible in city of Dubai, but not for Wellington City. Furthermore, floating development would have a negative impact on the existing waterfront development. Price of existing waterfront may suffer due to competition.

5.4 Recommendations for further research

- Investigation of integration between architectural and structural design. The superstructure on top of pontoon requires holding-down mechanism that could be expressed architecturally.
- Ways in which impacts on the cityscape could be minimised or made more acceptable.
- Ways to articulate the openings in the pontoon platform to allow sunlight penetration for marine life below the pontoon of VLFS.
- Explore the flexibility of pontoon units and its application in an urban design. Floating development has a modular nature means that it can be removed or expanded and grouped, and made to take any shape as needed.
- Use a combination of pontoon, pile and hulled structure to build on or over the water for the purpose of waterfront development.
- Study the complication of living on water, including psychological effect, and safety in case of fire and flooding.
- Issues relating to design, government approval, and construction process of floating development that conflicts with political / social resistance.

5.5 Final remark

This thesis investigates floating development as an alternative to land reclamation for waterfront development. It presents a variety of valuable opportunities that opens up for urban planning of coastal cities in the future. Overall, the significance of this thesis is that it gives an overview encompassing the past six decades, and urban analysis of application of floating development, these researches have rarely been looked at before. In addition, the research process helps further design and construction of floating development elsewhere.

Although the research indicates that urban scale application of VLFS development seems unlikely to be happening any time soon for Wellington city due to economical and technical constraints. Nevertheless, the strengths and benefits of floating development make it an ideal and even better alternative for land reclamation. Furthermore, with the fast advancing expertise so cost of construction would reduce substantially in the near future, it is undoubtedly none of these constraints would preclude the concept of city expansion by floating development from realisation in the future.

Acknowledgment

This thesis represents not only my work at the keyboard, it is a milestone in 12 months of work with the Architecture School of Victoria University of Wellington. It presents the lessons learned in performing research relating to floating development in urban planning and is the result of work by dozens of people. Therefore, I wish to thank my supervisor, Christ McDonald whom has helped me grow academically, professionally, and personally that I was able to write this thesis with much confidence in my heart. I also want to thank my family especially my mum, Lanfen Qu, and my close friends, David Jiang, Jony Fang and Fulei Wang for the continuous supports.

Xin Sharyn Qu

¹ Koh, T. & Lin, J., *The Land Reclamation Case: Thoughts and Reflections*, 2006 Singapore Year Book of International Law and Contributors, (Vol.10, 2006), pp. 1-7.

² Harding, A., *Singapore seeks new sand supply*, BBC News, Singapore, (19/03/07), <http://news.bbc.co.uk/2/hi/asia-pacific/6465855.stm>, accessed 05/05/10.

³ Hansen, E., *The Water Village of Brunei*, Saudi Aramco World, Vol. 46, No. 3. (Texas: Aramco Services Company), <http://www.saudiaramcoworld.com/>, accessed on 10/12/10. Brunei's water village, called Kampong Ayer. The entire village's labyrinth of building is built on stilts and is divided into 40 smaller communities. Residents travel over the water in a speed boat / water taxi to get onto dryland for work or other urban amenities in the Central CBD. It is based on the living-on-water culture and custom.

⁴ Venice is built on an archipelago of 117 islands formed by 177 canals in a shallow lagoon, connected by 409 bridges. In the old centre, the canals serve the function of roads, and almost every form of transport is on water or on foot. The center of Venice is built on wooden thick piles which reach the underwater base of clay and sand.

⁵ More than a hundreds years ago, everything in downtown Astoria almost was made of wood-frame construction and entirely raised off the marshy ground on pilings. Water mains were also wooden, and carried water beneath the wooden streets. The town was devastated by fire twice because wood burned fast and easily.

⁶ This is based on the observation during the survey of different projects. The peak period is when the development receives greater concern, and the numbers of documented development are greater.

⁷ Raisbeck, P., *Marine and Underwater Cities 1960-1975*, Conference of SAHANZ, (2002), pp. 2-10. & Bequette, F., *Waterworlds*, The Unesco Courier, June 1996, (Paris, France: UNESCO), pp. 47. The former provides discussion around Economy, and Technology sides, the latter on Political.

⁸ Fuse, T., *Legal Framework for the Use of Oceans – Considerations from International Law of the Sea*, Proceedings of International Symposium on Ocean Space Utilisation Technology, (Tokyo, Japan: 2003), pp. 3.

⁹ *Future city: Eco City, Intelligence City, Energy City, Water City and Space City*, Diverse Possibilities section of the Harmony Plaza in Shanghai Expo '10, an animated film is shown at a 36-meter-high screen, visited on 20/07/10.

¹⁰ Ibid., "To have more space, the cities of the future should be built on the seas. The views would be great and we would play in the ocean, swimming like the fish, with artificial gills."

¹¹ Kaji-o'grady, S. & Raisbeck, P., *Prototype cities in the sea*, The Journal of Architecture, Vol, 10, No. 4, (London: E. & F.N. Spon), pp. 444

¹² Tange, K. (1960, 1986), Kurokawa, N (1961), and Maymont, P. (1965), all proposed A Plan for Tokyo for Tokyo Bay

¹³ Raisbeck, P., *Marine and Underwater Cities 1960-1975*, Conference of SAHANZ, (2002), pp. 2-10.

¹⁴ United States: Sealab I and II, Tektite 1, Edalhab, Hydrolab; France: Cousteau's Conshelf series; Japan: Seatopia, Germany: BAH, Helgoland; USSR: Sadko series, Chernomor.

¹⁵ Flesche, F. *Water house*, (London: Prestel, 2005). The book covers an extensive amount of project and raise

the concept of amphibious living areas prone to flooding, other ideas that is commercial driven, eg. precious coastal areas can be preserved; increase the number of properties along the shoreline and to extend beaches; also lifestyle choice for floating house, and challenges and adventure offered submerging architecture.

¹⁶ Kaji-o'grady, S. & Raisbeck, P., *Prototype cities in the sea*, The Journal of Architecture, Vol, 10, No. 4, (London: E. & F.N. Spon), pp. 443

¹⁷ *ibid.* pp. 449

¹⁸ Heynen, H., *Architecture and Modernity: a critique*, (Cambridge, Mass: MIT Press, 1999), pp151-173.

¹⁹ Flesche, F. *Water house*, (London: Prestel, 2005), pp. 24.

²⁰ Kuroyanagi, A., & Sasaki, R., *Exterior Composition of the Oceanic Architecture with a Plane Form*, Journal of Architecture, Planning and Environmental Engineering, No. 546, (Tokyo: AIJ), pp. 317, <http://ci.nii.ac.jp/>, accessed on 06/08/10.

²¹ Bettinotti, M., *Kenzo Tange: 1946-1996: architecture and urban design*, (Milano: Electa, 1996), pp. 88-97.

²² OMA, *Waterfront City, UAE, DUBAI, 2008*, <http://www.oma.eu/>, accessed on 26/11/10.

²³ Thomsen, C., *Eberhard Zeidler: in search of human space*, (Berlin: Ernst & Sohn, 1992), pp.152-153.

²⁴ Lin, Z., *Kenzo Tange and the Metabolist movement: urban utopias of modern japan*, (New York: Routledge, 2010). Urban planning concepts that could keep pace with social change. The idea of city as process as it continued to grow and renew itself.

²⁵ Banham, R., *Megastructure: urban futures of the recent past*, (London: Thames and Hudson, 1976). where a city could be encased in a single building, or a relatively small number of buildings interconnected together.

²⁶ Utsunomiya, T., Wang, C., & Watanabe, E. *Very Large Floating Structure*, (London, New York: Taylor & Francis, 2008).

²⁷ *Ibid.*, mega-float is floating structure with at least one of its length dimensions greater than 60 metre.

²⁸ Remmers, G., et al. *Mobile Offshore Base: A Seabasing option*. Proceedings of the third international workshop on very large floating structures, pp. 1-6. The semi-Submersible type have been researched mainly by the Americans for use as a MOB (mobile offshore base). MOB is a self-propelled, floating, prepositioned base that would help with the transportation of resources via surface vessels and aircraft.

²⁹ Bungartz, et al. *Fluid Structure Interaction II*, Lecture Notes in Computational Science and Engineering, Vol. 73, (New York: Springer-Verlag, 2010), pp. 114.

³⁰ Tori, T., *Development of a Very Large Floating Structure*, Nippon Steel Technical Report, No. 82, (2005), pp.

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³¹ Utsunomiya, T., Wang, C., & Watanabe, E. *Very Large Floating Structure*, (London, New York: Taylor & Francis, 2008), pp. 7.

³² Tori, T., *Development of a Very Large Floating Structure*, Nippon Steel Technical Report, No. 82, (2005), pp.

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³³ Goh, B. *New stage for the bay. Voices@Central Singapore*, Vol. 36, (Singapore: FLP Singapore Pte Ltd, 2007), pp. 24-25.

³⁴ Tori, T., *Development of a Very Large Floating Structure*, Nippon Steel Technical Report, No. 82, (2005), pp.

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³⁵ Goh, B. *New stage for the bay. Voices@Central Singapore*, Vol. 36, (Singapore: FLP Singapore Pte Ltd, 2007), pp. 24-25.

³⁶ Horiba, S., et al. *Overview of Mega-Float and its Utilisation*, Mitsubishi Heavy Industries, Ltd. Technical Review, Vol 38, No. 2, (2001), pp. 121.

³⁷ *Facing up the rising sea level – retreat? defend? attack?*, Building Future & ICE (London: RIBA, 2010), pp. 3. <http://www.buildingfutures.org.uk/>, accessed on 12/01/11.

³⁸ *Guideline for building in wet area*, <http://www.waterbestendigbouwen.nl/>, accessed on 30/07/10.

³⁹ Davies, G., *Amphibious Houses: Dutch answer to Flooding: Build Houses that Swim*, Spiegel Online, (09/26/2005), <http://www.spiegel.de/international/>, accessed 18/05/10.

⁴⁰ *Ibid.*

⁴¹ *House Price Index by type of dwelling, region; existing own homes*, CBS Statistics Netherlands, <http://www.cbs.nl/>, accessed on 23/01/11.

⁴² Horiba, S., et al. *Overview of Mega-Float and its Utilisation*, Mitsubishi Heavy Industries, Ltd. Technical Review, Vol 38, No. 2, (2001), pp. 116.

⁴³ For general information of Wellington, please visit Wellington City Council website or any other department officials and reference materials mentioned in this chapter.

⁴⁴ *Wellington District Plan 2006*, Wellington City Council, <http://www.wellington.govt.nz/>

⁴⁵ *Wellington Hydrographic Chart N46, 7/2000*, Land Information New Zealand, <http://www.linz.govt.nz/>

⁴⁶ *Standard Port Tidal Level*, Land Information New Zealand, <http://www.linz.govt.nz/>.

⁴⁷ *Sustainable Building Guidelines – Wellington Conditions*, Wellington City Council, <http://www.wellington.govt.nz/services/environment/sustain/wgtn.html>, accessed on 20/05/10

- ⁴⁸ Burgess, D., *Capital ideas on an arena for big acts*, The Dominion Post (17/11/10), <http://www.stuff.co.nz/dominion-post/news/wellington/4351994/Capital-ideas-on-an-arena-for-big-acts>, accessed on 18/11/10.
- ⁴⁹ *Wellington CBD office annual 2010*, Bayleys Research (2010), <http://www.bayleys.co.nz/>.
- ⁵⁰ Put forward as Plan Change 48: Central Area Review, 2007, Wellington City Council. Port redevelopment into a new pipitea precinct, includes business park that incorporates a mixture of uses, max building height increased to 40m, offices building is allowed only upon consent approval.
- ⁵¹ *Thumbs down to Hilton on Wellington*, The Dominion Post (15/03/08), <http://www.stuff.co.nz/national/318107>, accessed on 12/12/10.
- ⁵² *Wellington – our sense of place*, Wellington City Council, www.wellington.govt.nz/aboutwgtm/pdfs/senseofplace.pdf.
- ⁵³ *Auckland Harbour Bridge*, IPENZ Engineers New Zealand, <http://www.ipenz.org.nz/heritage/itemdetail.cfm?itemid=117>, accessed on 16/01/11.
- ⁵⁴ The size is estimated taking consideration of the unit sizes of previous VLFS project. Refer to 2.8.2
- ⁵⁵ *Our coast*, Auckland Regional Council, <http://www.arc.govt.nz/environment/coastal-and-marine/our-coast/managing-the-coast.cfm>, accessed on 25/08/10. Refer to the list prepared by Auckland council for coastal management as a reference, others agencies are Department of Conservation, Ministry of Conservation, Ministry of Fisheries, Ministry for the Environment, Biosecurity New Zealand, Maritime New Zealand.
- ⁵⁶ *Waterfront Reclamation*, Wellington Waterfront Ltd, http://www.wellingtonwaterfront.co.nz/history/waterfront_reclamation/, accessed on 06/06/10.
- ⁵⁷ *The Wellington Waterfront Framework*, Wellington City Council (April, 2001), pp. 10. Public participation in the form of committee meetings, formal public consultation, etc, because the waterfront area is a lovely designed public area that belongs to every Wellingtonian.
- ⁵⁸ *Wellington District Plan 2006*, Wellington City Council, <http://www.wellington.govt.nz/>
- ⁵⁹ *ibid.* Map 12, 16, 17,18.
- ⁶⁰ *Wellington 2040: The Future of Our Central City*, Wellington City Council, <http://www.wellington.govt.nz/projects/new/wellington2040.html>, accessed on 21/10/10.
- ⁶¹ *Regional Coastal Plan*, Greater Wellington Regional Council, (2000), <http://www.gw.govt.nz/guide-to-the-regional-rules-and-regulations/>, accessed on 18/05/10.
- ⁶² *Ibid.* Rule 53-77
- ⁶³ *Rate - Search Property*, Wellington City Council, <http://www.wellington.govt.nz/services/rates/search/search.html>, accessed on 07/01/11. New Zealand Post Head Office on 7 Waterloo Quay costs approximately \$4000/sq ms.
- ⁶⁴ *Ibid.*, Wesley church complex on 75 Taranaki Street costs approximately \$1600/sq ms.
- ⁶⁵ Rawlinson & Co., Rawlinson's New Zealand construction handbook, (Auckland: New Zealand, 2010), pp. 1-24, section 9.1.5, Base Building Cost.
- ⁶⁶ *Ibid.* pp. 2-53, section 8.1, Office buildings, substructure excluded
- ⁶⁷ *QuickStats About Willis Street-Cambridge Terrace*, Statistics New Zealand, (2006), <http://www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/AboutAPlace/>, accessed on 28/01/11,
- ⁶⁸ *QuickStats About Thorndon-Tinakori Road*, Statistics New Zealand (2006), <http://www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/AboutAPlace/> accessed on 28/01/11.
- ⁶⁹ *QuickStats About Lambton*, Statistics New Zealand (2006), <http://www.stats.govt.nz/Census/2006CensusHomePage/QuickStats/AboutAPlace/>, accessed on 28/01/11.
- ⁷⁰ The estimation is based on reference to the *The Float @ Marina Bay*, size 120x83m, takes 13 months to construct the platform. Soho apartment on Taranaki Street, construction of the 15 floors excluding substructure takes 21 months. Therefore each street grid, takes about a years, and each standard six floors office/apartment block can be completed around a year and a half.
- ⁷¹ *Wellington CBD Office Annual 2010*, Bayleys Research (2010), http://www.bayleys.co.nz/Our_Services/Research/Commercial/WELLINGTON_CBD_OFFICE_ANNUAL_2010.htm, accessed on 23/01/11.
- ⁷² *Ibid.*
- ⁷³ *Wellington CBD Apartmnts*, Bayleys Research (2006), http://www.bayleys.co.nz/Our_Services/Research/Residential/WELLINGTON_CBD_APARTMENTS.htm, accessed on 23/01/11.
- ⁷⁴ Major parks that have been measured are, Frank Kitts Park, area by the Boatshed, areas around Te Papa, Waitangi Park, Te Aro Park, area by Civic Square, Midland Park, Glover Park
- ⁷⁵ Distant measured from south edge of opertational port to north edge of the Waitangi park
- ⁷⁶ The size is estimated taking consideration of the unit sizes of previous VLFS project. Refer to 2.8.3
- ⁷⁷ *External Crit*, School of Architecture VS318, Prof Hunt, J., Blunt, G., Danielmeier, T., Gjerde, M., 27/10/10.

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