City of Flux

Liberating the Concrete Terrain

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ABSTRACT

In recent decades the world has increasingly become aware of our role in the continual degradation of our planet's natural environment. One of the most influential and controversial issues of the Twenty First Century is climate change and a subsequent rise in global sea-levels. The implications of the most recent scientific predictions will play out over the following century and beyond, significantly affecting millions of people and thousands of coastal cities around the world. Accelerated sea-level rise globally will demand urban, landscape and architectural solutions for low-lying regions to respond over the coming decades to the extensive changes that will occur.

New Zealand has a vast coastline and therefore will be particularly vulnerable to the predicted one-half, to two meter rise in sea-level during the following century (Evans, Milfont, and Lawrence 3). As occupants of an island nation, New Zealanders' share a strong affinity to water. The earliest Maori settlements to the most recent developments in New Zealand have occurred predominantly in coastal regions, taking advantage of both land and marine resources. In order to envision a vital future for New Zealand's coastal cities, the temporality of the relationship between these urban centres and the sea forces us to confront the transitory quality of our place within it. Simultaneously, the design proposal presented in this thesis recognises that Wellington has historically reclaimed large areas of land to form the majority of the central city seen today, and that in order to flourish in the coming century of climate change will require urban design more responsive than we know today.

The imminent threat of the encroaching ocean within the high value precinct of Wellington's central business district provides an opportunity to engage with the dynamic transition from land based activities to those functions that engage with incremental flooding. Using a critical transect of Wellington's central city this thesis proposes a system of intervention to modify a section of the existing urban fabric to accommodate, prepare and adapt for flooding. The aim of this design investigation will be to place the programme as a hinge between land and sea.

Figure 3.35
(opposite page): Visualisation of
design proposition in the year 2100,
with a predicted 1.5-2 meter rise in sea
level, author's own

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“Our deep-seated anxieties associated with losing the artificial ground that we have so painstakingly built, and being submerged below a liquid landscape, have been heightened by our awareness of the devastation brought about by recent floods in Europe, Asia and America”

- Ila Berman [AD] Journal, 2008

Figure 1.1
Photograph showing the city of New Orleans Flooded, 2005

CHP.

01

*A CALL TO
RESPOND*

1.1 Introduction To Research

In light of the most recent scientific predictions sea level rise is arguably one of the most controversial global issues of the Twenty First Century. In 2007 the Fourth intergovernmental Panel on Climate Change (IPCC) identified in their report, *Projections of Global Average Sea Level Change for the 21st Century*, that sea levels could rise by as much as six hundred millimetres by the end of the century (IPCC 45). Since then significant advances in technology have increased the accuracy of predictions, with the most recent IPCC report published in October 2013 adjusting the global rise in sea level to be upwards of one and one-half meters by the year 2100 (IPCC 2007, 258). In a publication released by the Royal Society of New Zealand entitled *Sea Level Rise: Emerging Issues*, previous evidence of a rise in global sea level is discussed; "geological records show that warmer climates have always been linked with higher seas because glaciers and ice sheets melt and add their water to the oceans." (Beavan et al. 1) There is clear evidence that sea levels will be higher than they are at present if geological information from the last Interglacial period is compared to what is expected in the Twenty First Century. Limited recorded information about the rates of sea-level rise for the inter-glacial period are available; however in a study released by the National Geoscience Institute of America, it was found that the rate could exceed one and one-

half meters per century. From this scientific data Wellington City Council undertook a series of simulations, the findings of which were published in the 2012 report "*Perceptions of Sea-Level in Wellington City and Kapiti Coast Districts.*" The simulations identified the areas of Wellington's City which will be inundated by a one and one-half meter rise by 2100, with an allowance of a two meter rise during storm surge. Refer to Figures 1.4 - 1.6. (Evans, Milfont, and Lawrence 5)

A global rise in sea level will displace hundreds of millions of people dwelling in coastal settlements and cause destruction and cities will incur a loss of trillions of dollars' worth of assets within this century. (FitzGerald et al. 607) Although current predictions identify a dire situation, there is also an opportunity to respond and adapt our behaviour over the coming century to invest in a sustainable future within our coastal towns and cities. Evidence of widespread concern of global climate change and a push towards re-thinking urban development can be seen in the number and variety of design conferences and competitions carried out in the past decade that positively engage with sea level rise. In an exhibition at the Museum of Modern Art, New York in 2011, *Rising Currents: Projects for New York's Waterfront*, a range of professional proposals were showcased in order to educate and provoke

Figure 1.2
Map showing location of Wellington
within New Zealand's North Island.

discussion. Other design forums have been held in the United Kingdom, such as the Building Futures design charrette, initiated to establish leadership for policy making on approaches to prepare for coastal flooding and living with water in the city. (Robinson et. al) The aim of these design practice steered publications is to promote an international awareness, discussing the reality of global rising sea-level, in turn seeking to alleviate the perceived risks by alternatively promoting development incentives by showcasing a proposition of a more inviting, liveable and resilient coastal urban centre.

However while the design community is poised to tackle this creative opportunity, changes in policy making are required in order to establish national strategies that cohesively will prepare for coastal flooding.

In his book, *Requiem for a Species* (leading academic on public ethics) Clive Hamilton discusses why we have struggled to understand the importance of our changing climate and react appropriately.

There is no denying the chilling effects and impacts affecting the planet today as droughts, heat waves, floods, hurricanes and ensuing disasters are ravaging the planet. So why have we not reacted?190)

Hamilton believes, to many this global issue still remains an abstract notion which has not yet directly affected daily life.(It is now apparent from overwhelming scientific evidence that global warming is having a widespread effect on the planet due to the melting of the polar ice caps. The results of which will cause an increase in global sea level inundating low-lying coastal regions globally. It is clear that in order to prepare and adapt our coastal cities for flooding strategic planning is required to be undertaken immediately.

Challenges Wellington City Faces

Among New Zealand's many low-lying coastal cities is the nation's capital, Wellington. Refer to Figure 1.2. As such, Wellington will be looked to for leadership in terms of strategies for preparing for coastal flooding as the encroaching water begins to engage with the city's vital waterfront infrastructure. Wellington City has a very close proximity to the ocean, with the region of the central business district lying one-half meter to three meters above the current high tide datum,. Refer to Figure 1.3. The most recent scientific projections estimate an overall sea level rise between 0.5 - 0.7 meters by 2050, and 1.5 - 2 meters by 2100 (Beavan et al., 1). With this data it is now possible to map the areas of Wellington's reclaimed region that will be inundated by the ocean during the following 90 year period. Refer to Figures 1.4 - 1.6 .

Similar to the Netherlands, Wellington's waterfront is settled on land which has previously been reclaimed from the harbour front. This low-lying region will be among the first coastal areas to flood. Within this region lies vital infrastructure and historically significant architecture. Therefore in order to ensure the longevity of Wellington's existing central business district, local council and national government legislation will need to prepare for flooding by re-appropriating and developing infrastructure that is prepared for a direct engagement with the rising water. This will most likely be achieved through establishing a multi-layered strategy, with a combination of adaption approaches implemented in the appropriate locations around the city over the following century.

Figure 1.3
Map showing the proximity of
Wellington's central business district
to the waterfront public trail, scale
1:25,000, author's own.

In order to facilitate new policy for urban development to prepare the city for adaption to sea-level rise throughout the course of the century, an extended timescale will be required with planned stages - to implement strategies where and when appropriate. A city wide masterplan will need to be forecast. The plan will need to reconcile the disjointed series of cycles within which local councils in New Zealand currently operate. Instead working towards an extended framework that ensures proactive preparation is continued with any change in government. A much needed change of legislation and policy-making protocols have been made evident following the recent series of earthquakes that caused widespread damage and consequential loss of life in the Christchurch region. In reaction to this natural disaster, local and national governments were given cause to re-examine the requirements of the Resource Management Act 1991 (RMA) which governs the sustainable management of New Zealand's natural and physical resources. Vicki Toan, a solicitor involved with local resource management laws, identifies that the problems in Christchurch have illustrated a shortcoming in the government's capacity to identify the risks of natural hazards and to respond to these through public education and prudent decision-making. (1) Therefore it is evident that within the current 10-15 year local spatial planning framework, Wellington City and the nation will be ill-equipped to prepare for long-term climate change. The effects of sea-level rise will present themselves in incremental stages over the following hundred years, which conflicts with the current inconsistent rate of urban development

present in the city. By the middle of the century Wellington City will be forced to respond to the inundation of vital infrastructure and architecture within its central business district. In doing so new urban development will need to be considered as a citywide scheme and an integrated management of public and private projects will be required.

Opportunity for Research

Sea-level rise due to climate change is a relatively contentious issue within present discourse. Therefore it is imperative this design research take the fear associated with the perceived 'threat' of our changing environment, and offer a proposition whereby the city is not only prepared to adapt to a rise in global sea level, but improve the quality of life shared by users of the city. Wellington City is the nation's capital, and as such will be required to demonstrate leadership within this framework.

The research seeks to offer a design proposition that reconciles the perceived 'threat' of sea-level rise with opportunities for 'productive' and creative design initiatives. Successful design strategy will need to be incremental, popular, pre-planned, and desirable for civic use. It is vital to the success of the design research that society's acceptance for a response to sea-level rise is evident in New Zealand and specifically Wellington City.

2025 Sea-Level

Water level overflows harbourfront

2050 Sea-Level

Water level overflows Waterloo Quay

2100 Sea-Level

Water level overflows Lambton Quay

Scope of Research

This thesis deals with architecture's role in the design of a dynamic infrastructure to aid in preparing coastal cities for flooding due to a rise in global sea level. Recent international predictions published by the IPCC on sea-level rise are projected to 2100, within a 90 year framework. This data sets up the period 2013 - 2050 in which the design research will focus within the larger hypothetical timeline: till 2100. The resulting architecture will become a pre-emptive landscape allowing the public to visually monitor and engage with the changing environment. Considering the high land and capital value of urban infrastructure situated in Wellington's commercial centre, it seems appropriate through design, to investigate programmatic scenarios within a framework that maintains this investment.

Site Selection

It will be vital to test the scenario of a new infrastructural intervention within the Central City for adaption to sea-level rise in a location of existing vital infrastructure and amenity - a location that occupies overlapping users and functions in the city. In order to set an example for other low-lying cities around New Zealand, the study site will need to demonstrate leadership in regards to an adaption strategy that engages directly with commercial and recreational spaces that are vital to maintaining a high quality of lifestyle.

*Figure 1.4
Illustration showing the virtual
simulation of predicted sea-level rise
in Wellington Harbour by the year
2025, author's own*

*Figure 1.5
Illustration showing the virtual
simulation of predicted sea-level rise
in Wellington Harbour by the year
2050, author's own*

*Figure 1.6
Illustration showing the virtual
simulation of predicted sea-level rise
in Wellington Harbour by the year
2100, author's own*

Research Method

This thesis approaches the design research through a collaborative framework establishing a design-led process that moves between urban, landscape and architectural design. The research sought a synthesis between the design processes practice in all three of these disciplines in order to collapse the scales of the broader discursive argument: implications of sea-level rise at the scale of the city towards design experimentation at the reduced intimate scale of site-specific architecture. To ensure urban and landscape design practices were carried out appropriately within the framework of the thesis, local and international academics were brought in to collaborate and provide critical feedback.

The design research is situated in the current gap between theoretical projects and experimental test scenarios that engage directly with a transition from current practices on land towards functions during aquatic fluctuation. Refer to Figure 1.7. The design proposition seeks to help fill the gap in the current discourse of public architecture and urban infrastructure in New Zealand, therefore positioning itself as a test scenario by modifying a section of Wellington's existing central business district to accommodate, prepare and adapt for flooding. The objective of the design investigation will be to place the agendas of the occupants (program), as a hinge between land and sea.

The research is presented in two key stages: the first focuses on master-planning and the design of infrastructure; the second deals with the design of site-specific architecture. Although this thesis is presented in chronological order, the two stages of design were intrinsically linked, as the design-led process sought frequent critical reflection between each to inform a cohesive design outcome. Figure 1.9 illustrates the design research structure, with the associated review schedule that provided critical feedback.

Figure 1.7
Diagram showing the 'real' and 'disciplinary' components that form the basis of the research proposition for this thesis, author's own.

Research Question and Aims

How can the design of an urban infrastructure modify a Wellington CBD site to engage with sea-level rise during a 90 year period, through transition from land-based functions towards amphibious operations?

In relation to this question, three main aims were formulated:

- To respond to the impending water within Wellington City, designing within the framework of a study site that engages with vital urban infrastructure. (Vital Infrastructure)
- To investigate how current strategies for adaption to sea-level rise can play an instrumental role in preparing coastal cities for climate change. (Adaption Strategies)
- To critically reflect upon the design of dynamic infrastructure and architecture against current (design) discourse on architecture's role in preparing coastal cities for sea-level rise. (Discourse)

DIAGRAM OF RESEARCH AIMS

Figure 1.8
Diagram showing the three key aims
of the design research, author's own.

Figure 1.9
Diagram of thesis structure, showing
the design research method, author's
own.

1.2 Social Perception

"Urban waterfronts have become fertile areas for urban planning and redevelopment as a key part of rebuilding healthy cities. "(Ryan 8) Historically cities have often been founded in locations with close proximity to the ocean for trade, transport, industry and recreation; Wellington is one such case. "Wellington's waterfront is a special place that welcomes all people to live, work and play in the beautiful and inspiring spaces and architecture that connect our city to the sea, and protect our heritage for future generations." (Wellington City Council 11) Guidelines published in the design brief for the North Kumutoto region in 2012 dictate that development in this area at the terminus of Bunny Street must support safe twenty-four hour activity. (Wellington City Council 7) Refer to Figures 1.12 and 1.13.

Recent scientific predictions forecast a global sea-level rise upwards of one and one-half meters over the coming century. A sea-level rise of this nature within Wellington harbour has the potential to sever this attractive connection between the central business district and the recreational spaces at the waterfront. Refer to Figure 1.10 - Figure 1.13. It is therefore of vital importance to immediately commence with long-term planning to avoid being forced into short-term expensive fixes due to insufficient preparation. Furthermore the longevity of new design initiatives should

be promoted within the planning framework to maintain the symbiosis between live, work and play which is so important to Wellingtonians. The design of a built intervention within the city must conform to social and cultural tendencies if design longevity is to be established beyond the ninety year timeframe. Therefore it is important to assess the current perspective of Wellington's residents on the threat of sea-level rise and which actions they would prefer to have undertaken.

Perception of Wellingtonians

In a study jointly funded by local governmental bodies, academics from Victoria University's School of Psychology surveyed 2,519 residents to establish the local perception of sea-level rise. The results of this reflect a growing concern towards the threat that a rise in sea level will have on the inner city, with all residents surveyed considering sea level rise as a very serious threat to their daily lives at both national and global scales. With respect to the imminent threat, respondents reported that a "rise in sea level is going to be a serious issue in the next 25 to 45 years' time" (Evans, Milfont, and Lawrence 12). The second section of the survey assessed the preferences of residents on the adaption strategies that local councils might take. The participants were asked to create an adaption strategy based on three types of categories: retreat, accommodate, protect.

They were asked to indicate which option(s) they preferred and an estimated year when each should begin. The results created a layered strategy, whereby all three categories are used in combination to provide an adaption timeline. "In total, 62 percent chose accommodation, 53 percent chose retreat, and 37 percent chose protection" (Evans, Milfont, and Lawrence 15). Significantly the results from this questionnaire identified a shift in thinking towards an adaption timeframe:

Although respondents earlier indicated a perception of multiple decades until sea-level rise becomes a serious threat, responses to this strategy question show that they prefer immediate steps towards a solution. The median preferences for beginning action were 2015 for both accommodation and protection and 2030 for retreat. (15)

The outcome of the survey provides a clear direction for local councils, upon considering how to respond to the predicted rise in sea-level. It further sets out a forecast timeframe in which to begin applying design through new infrastructural and architectural projects in and around the city. Resulting statistics indicated that the residents of Wellington prefer action to be undertaken within the next fifty years in order to accommodate the rising sea level within the low-lying region of the city.

Photography along Wellington Waterfront boulevard, author's own

Figure 1.10 (top): Looking southwest towards the lagoon

Figure 1.11 (middle, left): Looking north along Te Papa pier

Figure 1.12 (middle, right): Looking west along steps, Kumutoto

Figure 1.13 (bottom): Looking north towards Kumutoto wharf

1.3 Literature Review

Global sea-level will render the ground condition of Wellington City as amphibious, fluctuating between flooded and dried regions during tidal cycles. Wellington City will be challenged to prepare and adapt the operations of the city in low-lying areas to engage with this fluctuating environment. This review examines previous approaches and design practices that have dealt with flood management, critiquing these in comparison to contemporary practices of modern flood management being developed internationally. This review will then analyse and reflect on the formal implications that these modern practices could have on the future of infrastructural and architectural design discourse.

Approaches

A wide range of adaption strategies already exist in urban design discourse on preparing for flooding. The international Panel on Climate Change identified that the challenge for a coastal city is to implement strategies that allow for timely reactions to the impacts of sea level rise before major costs are incurred that could have been avoided with proactive planning. (IPCC 2007) Therefore the important task for Wellington City Council and National Government will be to select a range of adaption approaches that are appropriate to be implemented and adjusted over time, in light of on-going information.

These strategies have been grouped into three categories in recent discourse: Robinson et al. of Building Futures identified them as: retreat, defend, and attack. The examined approaches have been developed in accordance with specific issues surrounding the implications of sea-level rise in recent discourse. In order to establish the appropriateness of each strategy the criteria for evaluating their successfulness is set out by Nekooie et al. as the following: time, cost and construction difficulty, adaptability and flexibility to provide for different stages of inundation, and ability to coexist within the current natural and built environment. (6)

RETREAT

Retreat –

This scenario calls for action to be undertaken by stepping back from the problem, to reduce the potential risk of damage that flooding would cause to critical infrastructure and housing within low lying areas of the city. Refer to Figure 1.14. By

Figure 1.14
Plan and section diagrams illustrating
the adaption strategy: Retreat,
author's own.

retreating, investment in existing building stock and infrastructure is lost. Extensive investment will be required to relocate and establish new infrastructure. A wide scale retreat in developed urban regions is not desirable or viable in accordance with the findings in the fourth report released by the IPCC in 2007, due to extensive financial burden.

To avoid large scale damage to buildings and disruption to activities within Wellington's central business district an alternative approach was established in the Institute of Civil Engineers (ICE): "Building Futures" report. The outcome of the design charrette discussed in this publication identified a method of retreat that gives hierarchy to spaces of civic significance, in turn sacrifices areas of low significance within the low-lying region of the city. This method of retreat involves retreating upwards, abandoning lower floors for occupation. This approach shifts the functions on the ground floor upwards. It requires residents of ground floor spaces within buildings predicted to be affected by inundation to relocate to the first floor and allow the ground floor to flood. This approach would reduce the useable space of affected buildings; however the cost incurred is affordable in comparison to alternately relocating further inland later. In the short-term costs would be incurred to strip the ground floor façades in order to re-appropriate the space as an open pavilion for flooding (essentially extending the structural function of the building, as columns become piers).

Current examples of this alternate approach have not been extensively tested and therefore this option carries a risk. In the long-term, by

relocating functions and current ground access upwards to the first floor the ground plane is made available and activities can continue to be maintained at an elevated level. Due to practically, in response to the extreme cold and the discomforts and inconvenience of street level pedestrian movement in the winter, the city of Calgary in Canada has developed an elevated street system. The Calgary +15 network established over forty years ago is a successful example of such an approach. The network of pedestrian bridges, walkways and indoor parks form elevated connections around downtown Calgary, fifteen feet above the ground. This approach requires large expenditure at the scale of the inner city masterplan to develop links at elevated levels around Wellington's central district. However it provides the opportunity for the development of new infrastructure that creates vital links between inner city amenities and increases pedestrian activity around the city in inclement weather.

DEFEND

Defend-

The main purpose of a defensive scenario is to ensure the sea water does not enter vital infrastructure and cause costly damage to the built environment. Refer to Figure 1.15. Many

Figure 1.15
Plan and section diagrams illustrating
the adaption strategy: Defend,
author's own.

of the 'hard' engineering solutions of the 20th Century adopted this strategy, restricting the connection between the city and the water. As a result, urban design discourse has provided a positive push in redeveloping urban waterfronts around the world. In their report "San Francisco Bay: Preparing for the next level" Raalten et al. identify an opportunity to strategically develop defensive systems that integrate the design of flood mitigation with opportunities for urban growth. An example of this would be the combination of a seawall network with a new public transport system. (107) A defensive approach such as this would require large financial investment to appropriately defend vital infrastructure from being compromised. In order to offset the cost incurred for construction, the cross-function of the defence system would be required to provide space for commercial development and public amenity.

ATTACK

Attack-

This strategy calls for action to be taken by constructing new infrastructure that advances out into the harbour, braced for rising water and more extreme meteorological conditions. Refer to Figure 1.16. An attack strategy would

consist of land reclamation, floating structures or stilted wharfs, which could create space for urban expansion and commercial development. A recent example of this is the Palm Island development in Dubai, where two large artificial islands have been developed connecting to the shoreline to accommodate large-scale urban development. This approach to land reclamation has been employed in the context of Wellington City in the past during three stages of reclamation from 1850 to present day. During which period the motivation for reclaiming large areas of the harbour was for commercial opportunism, rather than a method of adapting the city to prepare for a rising sea-level. Therefore methods of attack would need to integrate opportunities for commercial development to offset the high expenditure of the new useable land created.

Recent design discourse has established that it is more appropriate to develop flexible methods of construction within the harbour that are less costly and relatively quick and easy to adapt as the water datum changes (Berman 66). The key aim in the Twenty First Century is that coastal development will ensure any further reclamation is only sought to maintain a link between the waterfront and the central city. This departs from the majority of the Twentieth Century where urban development neglected waterfronts.

It appears that one of the most flexible options for a coastal region to prepare and adapt for flooding has not been considered in the IPCC and Building Futures literature - the capacity for cities to accommodate inundation. A fourth option for addressing rising sea levels, involves

Figure 1.16
Plan and section diagrams illustrating
the adaption strategy: Attack,
author's own.

re-appropriating regions of the city for sacrificial flooding. This mixed mode strategy integrates a measure of control by channelling the rising water coming into the city towards sacrificial zones for flood alleviation. This latest strategy is to accommodate, Refer to Figure 1.17.

ACCOMMODATE

Accommodate-

Current examples of accommodation are evidenced in the Room for the River scheme in the Netherlands, while in the United Kingdom BACA Architects have been awarded international recognition for their Life project (long-term initiatives for flood risk environment). The common concern for such projects is to disseminate a set of principles for an approach to modern flood risk management and to increase society's ability to cope with the effects of a flooded future. According to Robert Baker, founding partner of BACA Architects, modern flood management is not about blocking the water out, but rather utilising the fluctuations in a site condition to generate areas of extraordinary character and quality through innovative architecture and environmental planning (Lynch). Accommodation measures taken in the city of Nijmegen, Netherlands as part of the Room

for the River project have received an award of excellence for integrating the construction of a riverside park with civil engineering flood safety measures. The aim of this project is to step back from the immediate banks of the current river course and allow space for flooding to occur at its edges, while elevating an area of the inundated land to operate as a park, connecting the city to its waterfront.

In the USA, leading academics Martyn Hook and Richard Black have compiled project-based research and architecture projects from RMIT, originally exhibited in the Mobility: 1st International Architecture Biennale in 2003 on ecological and architectural implications of living on floodplains through concepts of mobility and change. Their book *Mobile Landscapes* identifies a framework for combining all four of the discussed approaches to inform, an integrated urban strategy which "allows ideas to move back and forth from large scale to small scale," from site strategy, zooming into applications of resilience at a detailed level. (Black and Hook 35)

A key advantage of the accommodate strategy is that it allows new design initiatives to be introduced into the urban fabric of the city at an incremental and affordable rate, with staged development over time. This approach heightens public awareness, educating them visually by monitoring the level of the water as it rises.

The results of the ICE – 'Building Futures' report identified that a combination of the four examined approaches is required to provide a multi-dimensional framework for coastal cities

Figure 1.17
Plan and section diagrams illustrating
the adaption strategy: Accommodate,
author's own.

preparing to engage with sea-level rise. This is significant as it reveals opportunities to test various combinations of the adaption approaches within the research to inform design. In accordance with the evaluating criteria set out by Nekooie, an accommodation approach is desirable for implementation in combination with the other three approaches. (6) By integrating the accommodation approach the research will test unprecedented design scenarios against the established criteria.

*Figure 1.18
(top): The Delta Works, storm surge
barriers as part of the
Delta Project, Netherlands.*

*Figure 1.19
(bottom): Folding Water - designed
by Kuth/Ranieri Architects for the 'City
of the Future' competition for San
Francisco, 2008*

Transition from Static to Dynamic Infrastructure

There has been a recent shift within the discourse of urban ecology towards an understanding that water management practices can play an active role in the future direction of urban design and land use re-appropriation in coastal cities. The most obvious example of this has been the development of projects that deal with 'soft infrastructure'. Ila Berman explains how our polarised perception of land and water has been shifted by the failure of statically designed infrastructural systems in the recent years during natural disasters. (67) The failure of static levee flood control systems in New Orleans during Hurricane Katrina and the destruction of the ten meter high sea walls stretching along forty percent of Japan's coastline are both recent examples that have triggered international practices of flood management to change. While 'hard' engineering solutions were sought to design defensive structures during the Twentieth Century, the turn of the century has seen a re-interpretation of infrastructure's role in the city from discreet systems of utility towards opportunities for place making. Refer to Figure 1.18 and 1.19. This is evident in the New York Highline project, where an abandoned railway infrastructure has been renewed as a Public Park. D'Hooghe suggests that infrastructure may be read not as "systems of engineering and transportation," but as "objects of cultural production." (85) By approaching the design of future infrastructure for flood defence through practices of place-making, Allen suggests that there is a need to reassert architecture's role in the design of "large-scale systems and structures." (38)

The major challenge for Wellington City over the coming decades will be to plan for adaption throughout the entire city. This will be of vital importance as seawater will be rising at a constant level, and therefore the effects of inundation will be seen across the entire stretch of coastline. It will be important for designers to consider new infrastructure as networks spreading throughout the city implemented within an extended timeframe. Each localised project should be considered in relation to the city masterplan and therefore a process of zooming in from site strategy towards architectural detailing will be required. New infrastructure will need to be scaled appropriately in order to maintain the vital connection Wellington City shares with its'waterfront.

Resilience: A Formal Language

Given architectural tradition that has been historically engendered by the values of firmness, stability and permanence, these modern infrastructural artefacts have promoted static, discreet and formal systems. (Berman 67)

Modern and historic infrastructural projects within New Zealand cities have focused on increasing the stability of structural systems and the amount of service that can be provided at the least expense to the tax payer. What has yet to be made evident are design initiatives at an infrastructural scale which promote the use of mobile, flexible materials. The predicted transition of Wellington's central business district from terra firma to a fluctuating territory provides an opportunity to re-programme our understanding of dwelling at the water's edge. Luca Galofaro of lan+ Studio suggests we should begin to perceive our streetscapes as cause and effect of each spatial event (2). Therefore infrastructural design could reveal a shift in reading of the city during incremental stages of inundation. If the formal design of new infrastructure was to promote a dialogue between the occupied buildings of the city and its fluctuating geography, a more enriched urban context could be created. This would increase public awareness on sea-level rise and encourage a willingness to engage with the changing environment. It also offers an opportunity to positively engage in a design dialogue with the amphibious zone between land and water, previously perceived as threatening due to its unpredictability.

At present only experimental projects working within this 'amphibious' framework at an urban scale have been documented. These recent projects seek to address the changes occurring in coastal cities globally due to climate change as positive opportunities to incorporate new building processes and materials into urban centres. The propositional designs exhibited in the *City of the Future* competition in San Francisco in 2008 treats water as a building material in its own right, "incorporating mixtures of flow and stasis into their design parameters." (Berman 69) This formal design process encourages a sympathetic relationship between "architecture's artificial containment and the flux of its natural fluid environment," in comparison to the discreet containment of undesired natural environmental changes produced by current civil engineering solutions (69). Refer to Figure 1.20 and 1.21. The significance of this knowledge encourages designers to exploit the material properties of water. Water is more fluid in its continuous morphology than conventional building materials and therefore can be utilised to test new methods of designing flexibility.

Ultimately the design of infrastructure to prepare cities for future flooding needs to reconcile pure utilitarian infrastructural systems with spaces for social connectivity. This will entail a transition of current urban discourse from permanent static boundaries, such as the current arrangement of the city grid with separate land holdings towards collaboration between the state and the private sector to encourage the integration of citywide projects.

Permanence

Over the following century there will be dramatic changes to coastal cities with the development of modern flood management systems; this will change the perception of people's relationship to their city. In order to address the fear associated with the threat that sea-level rise poses and to remove the "deep-seated anxieties associated with losing the artificial ground that we have so painstakingly built," new creative opportunities will be required from the design sector, in order to propose future development that maintains the current function of the central business district—simultaneously developing spaces of recreation within the city that directly engage with water as a vital resource. (Berman 68) Ultimately as a society we need to accept that we cannot control nature, but we can learn to adapt; but to encourage change we must first acknowledge and accept the problem. Refer to Figure 1.22.

Conclusion

This literature review identifies the main approaches operating internationally in low-lying regions already preparing for coastal flooding due to an increase in global sea-level. The examined approaches form a body of knowledge that promotes contemporary methods of design offering an alternative to the proliferation of high sea walls that run the length of the coast, which during recent natural events have failed to protect and prepare urban centres for flooding. The combination of the four approaches presents a strategy towards tackling the financial burden associated with the displacement of a city's vital infrastructure, which could be economically crippling.

Disparities between the static strategies of current urban design widely employed in New Zealand and the transitory quality of our future fluctuating city context presents an opportunity to confront the existing impermanent infrastructure of our coastal cities. Current modes of construction will be challenged within the design of new architecture that alternatively permits continuous fluctuations to occur within the built environment.

*Figure 1.20
(top): Hydroelectric station,
designed by Becker Architekten in
Kempten, Germany, 2010.*

*Figure 1.21
(bottom): Conduit designed for the
Shahe Aqueduct Project, part of the
South-North Water Transfer Project, in
China's Henan.*

*Figure 1.22
Photograph showing people loading
their boats with sandbags on a
flooded street, in Datchet, England,
Monday, Feb. 10, 2014, due to the
breach of the Thames River recently.*

1.4 Case Studies

Recent history has reminded us that our natural weather systems are constantly in a state of flux, making it clear how dramatic the reality of living next to water is in coastal communities. As occupants of an island nation New Zealanders share a strong affinity to water; in order to envision a vital urban future we must reconsider our methods of urban development in our coastal cities. In order to progress often architects and urban planners look to the past to extract helpful lessons. Significantly traditional Maori settlement patterns can be looked upon to provide examples of resilience living at the water's edge.

Coastal development in New Zealand over the past century reveals a disparity between the way European settlements occupy the coastline, as opposed to the more resilient strategy of early Maori settlements that were arranged perpendicular to and terraced away from the harbour. Refer to Figures 1.25 and 1.26. Traditional Maori settlements are characterised by two distinct forms: the Pa – defensive settlement, and the Kainga – unfortified settlement. The steep natural topography of headlands, spurs and hills surrounding coastal sites was often used to locate the Pa, as this would assist the construction of defensive earthworks in the form of rampart and trench. Refer to Figure 1.24. Awatere et al. identified that in “some instance the residential population lived outside the pa and retreated only in times of insecurity” (4). It is also noted by anthropologists that “Maori

occupied a number of different settlement types during any one year” (4). The Maori were largely nomadic but when they did settle for an extended period of time they often strategically positioned themselves in the landscape to secure and protect their people, food stocks and natural resources. Therefore the “ecological footprint of Maori settlement was restricted to what was available and accessible within the surrounding environment” (6). Traditional Maori settlement patterns illustrate the capacity to readily adapt and relocate providing a strategy of resilience for unpredictable changes in the environment or in some case due to European invasion. Significantly the Maori people “lived in a state of balance with the environment,” and as such were able to respond to the change in natural seasons and shift their settlement location during periods of flooding (6). While this largely flexible lifestyle would be neither desirable nor viable within New Zealand's coastal cities today, there appears to be relevant lessons to be learnt from Maori settlement design. Of most relevance is the ability for settlements to engage with changes in the natural environment through methods of adaption that prepare the settlement and protect its vital resources.

Recent design solutions that respond to the fluctuation of tides within low-lying seaside regions are amphibious in nature. The term amphibious within the research refers to design that can move

to accommodate the variation in terrain (land – aquatic). Existing amphibious architecture can be characterised within the framework of small-scale buildings; these are constructed within a concrete caisson (basement severed from its foundations), and so as the seawater fills the caisson the entire building rises upwards on guideposts. The current lack of design solutions that deal with amphibious construction on an urban scale provides the potential for new design exploration.

To date an increasing number of architects and designers have proposed designs to address the problems of a global rising sea-level and subsequent issues of inundation. Although some projects remain untested or in the early stages of operation, lessons from each can be gained. The following four contemporary case studies have been examined to assess their appropriateness to fulfilling the framework set out by the research. The research objectives seek to test approaches to design at both the scale of the site and the scale of architectural intervention. The first and second case studies reveal approaches to adapting a city site to engage with a rising sea-level. The third and fourth case studies identify an infrastructural and architectural approach towards design that accommodates public transport in a site of multiple functions. These case studies are examined to identify the implications that each design outcome has in light of the three main research aims. Refer Figure 1.23.

Figure 1.23
Diagram of research aims,
implemented as evaluation criteria for
each case study, author's own.

Traditional Pa

Figure 1.24
Sectional diagram showing
perpendicular arrangement of a
traditional Maori Pa, author's own.

Coastal Resilience

Traditional European

Traditional Maori

Figure 1.25
Diagram showing the arrangement
of traditional European settlement in
New Zealand parallel to the coastline,
author's own

Figure 1.26
Diagram showing the arrangement
of traditional Maori settlements
perpendicular to the harbour, author's
own.

Cap Gemini Campus /CIE

This large scale project completed in 2003 for the new head office of Cap Gemini Ernst & Young is located on the west side of the Amsterdam-Rhine Canal, Netherlands. It features five separate high-rise buildings connected by a central plaza. Refer to Figure 1.28. It is designed with concave ceilings and flared columns creating a central hall underneath that appears to mimic the spatial image of a cathedral. On top of the plaza an undulated parkland forms a canopy over the square to connect the adjoining sites to the newly uplifted landform. Refer to Figure 1.28. The landformation provides shelter by covering the carpark and individual entrances to the five buildings at ground level. Refer to Figure 1.31. Constructed voids into the landscape have been made to provide for natural daylight and vistas. Refer to Figure 1.29.

The new landscape that stretches out between the five buildings onsite allows for multiple programs to occupy a singular footprint. Refer to Figure 1.29. The plaza space underneath can accommodate functions requiring shelter, while the parkland on top encourages recreational activities. The introduction of this new landscape between the five key buildings not only extends the usable area of each high-rise, but also provides an armature around each providing security and shelter. This armature has been specifically contoured to meander from topographical heights at one end of the site to the other, allowing for a consistent formal transition increasing pedestrian access around the complex. The park creates legibility of the overall site scheme, while allowing users to casually navigate their way around the large-scale campus.

Design Application

The design of the Cap Gemini Campus responds to the need for protecting the vital infrastructure of the five key high-rise office buildings in which Ernst and Young extensively has invested. The design of the landscape/plaza between the surrounding buildings protects the entrances to each while providing space for additional program. The strategic contouring of the new landscape to form an accessible transition from topographical heights on both sides of the site can be discussed as an adaption strategy to link up site conditions while providing a defence barrier for a rising water datum. This new landscape,^t while fluid in its transition from one side of the site to the other, sits statically in the site and its only capacity for flexibility is a shifting of functions below in the central hall space or a resurfacing of the parkland on top.

Figure 1.27
Diagram showing the evaluation
of the case study in relation to the
research aims, author's own.

Figure 1.28 (opposite page, top):
Photography of the Cap Gemini
Campus - looking at the rooftop park.

Figure 1.29 (opposite page, left):
Axonometric diagram of campus
design showing terraced levels.

Figure 1.30 (middle):
Photograph of park level at
night, area artificially lit.

Figure 1.31 (bottom):
Section through campus
showing spatial relationships at
terraced levels.

Room for the River project/ Netherlands

This large scale national project across the Netherlands is an integrated new approach to flood risk management, involving thirty separate locations along the IJssel, Rhine, Lek and Waal Rivers moving dikes back to make room for these swelling rivers. The overall project with a total budget of 2.2 billion Euros has been designed with two main goals to increase safety and to add public facilities in areas close to the rivers, reconnecting the country to its natural resources. Breaking the long established flood risk management tradition of building dikes higher, the various governing Water Boards from across the Netherlands have formed the 'Room for the River' project in order to rethink the traditional approaches that saw 250,000 people evacuated in 1993 and 1995 during periods of high water. These events have convinced authorities that climate change requires additional measures. Design methods undertaken so far have been successful, with the city of Nijmegen's *Room for the River* plan receiving the Excellence for the Waterfront Honour Award 2011 from Washington, D.C.-based Waterfront Centre for integrating the construction of a riverside park with flood safety measures. (Haskoning UK Ltd)

This Nijmegen project involves pushing a dike three hundred and fifty meters inland and digging a new channel for the River Waal. The design outcome is to create a new island and an urban river park in the heart of Nijmegen. Refer to Figure 1.32. The dike island and new channel are expected to be completed by 2016, with future development planned for a further rise in river and sea levels. The channel will also be used for rowing and sailing, and the island is intended for recreational, cultural and natural use.

After eight hundred years of building dikes and making them taller to keep flood waters from inundating half the country, endangering the lives of ten million people living in areas below the benchmark NAP (Amsterdam constant level) the government decided in 1990 to no longer raise the dikes but move them back. To remain flexible to future implications of climate change it was imperative to remove the bottlenecks identified. Gert-Jan Meulepas, project manager of Royal Haskoning, an engineering and environmental consultancy who developed the project.

The *Room for the River* project at Nijmegen responds to the need to protect the vital infrastructure of the city, lying on low land behind the dike. After critically reflecting upon traditional construction methods by raising dikes to provide protection from the rising waters, the Netherlands government has established this project to create an opportunity for new design methods to be considered and implemented. Refer to Figure 1.33. The adaption strategies of retreat, accommodate and defend implemented previously for projects along the Thames River in the United Kingdom were adopted to design for current flood conditions presented in this project, with provision for a future rise in water level. By combining these strategies a sustainable design approach will improve the connections between cities across the Netherlands and their urban waterfronts by investing in the social and economic benefit of the country's inland waterways. Flood protection in the Netherlands is seen as a major contributor to the country's aim to double foreign profits from the water sector by 2020. In return the development along waterways in the Netherlands is contributing to an increase in international awareness on new approaches to flood risk management.

Design Application

Key strategies for coastal preparation have been employed within the *Room for the River* framework to ensure a multi-layered approach was planned with the contingency for current construction methods to be adapted in the future, in light of further environmental changes. Shifting the line of defence by moving the dikes inland allows room for flood alleviation as high rainfall causes rivers to swell, while accommodation of the swelling rivers has been implemented by digging wider channels for diversion during periods of high water. A new line of defence is created inland where future construction will create an increase in capacity to divert river water. By combining these adaption strategies, an opportunity to create a new sustainable riverside park with future urban development was created. Significantly the connection between the cities' community and their river is increased, with more opportunities for commercial and recreational development to engage directly with the water.

Figure 1.32
(top): Artist impression of new riverside park and canal at Nijmegen.

Figure 1.33
(middle): The Nieuwe Waterweg storm surge barrier prevents flooding from the sea but restricts river overflow.

Figure 1.34
(bottom): Diagram showing the evaluation of the case study in relation to the research aims, author's own.

Navigable Aqueduct over A4 Highway/ Netherlands

Along the Ringvaart near Roelofarendsveen (a town in Western Netherlands) the newest portion of the loop canal was completed in 2006 with the construction of a navigable aqueduct to bridge over the north bound lanes of the A4 Highway. Refer to Figure 1.36. This new aqueduct is 1.8 kilometres long and 2.4 meters deep. The aqueduct is used for commercial and recreational traffic travelling around the Ringvaart. The conduits of the aqueduct bridge separately over the two sets of traffic lanes, with a third conduit bridging over the HSL-Zuid high speed railway. Both sides of the aqueduct are flanked with an access road and pedestrian paths, and have extensive green areas, forming informal parks that contour down to the road level. The aqueduct operates as a high-line canal that allows boats to pass over the highway below. This juxtaposition of various types of transport creates an opportunity for unique recreational engagement between water, park and commuters. Constructed of cast-in-place concrete, a small dredger was used to precisely remove the earth below the reinforcing pits. Refer to Figure 1.37.

Design Application

The design of the navigable aqueduct over the A4 Highway allows for an extension of the Ringvaart (loop canal.) The aqueduct itself implements a combination of adaption strategies. Firstly it accommodates the water within the canal and extends the usable canal area; secondly it protects the key transport routes that run below, vehicular and rail. Excavation was required either side to elevate the aqueduct and to sink the highway below, resulting in a protected armature of Parkland that contours from road height upwards. The Ringvaart is a vital urban infrastructure within the region and has been used by commuters since 1845. The new aqueduct extension engages with this existing infrastructure while providing room for future urban expansion. The aqueduct affords an exciting visual image, capturing the capacity of modern construction. The method of construction applied within this case study provides an example for contemporary infrastructural development in coastal cities.

Figure 1.35

(opposite page): Diagram showing the evaluation of the case study in relation to the research aims, author's own.

Figure 1.36

(top): Aerial photograph of navigable aqueduct over the A4 Highway near Roelofarendsveen, Netherlands.

Figure 1.37

(bottom): Photograph looking towards the conduit for the navigable aqueduct over the A4 Highway near Roelofarendsveen, Netherlands.

The High Line/ New York

The design for the re-appropriation of the once vital urban infrastructure of the New York *High line* was a collaboration between landscape architecture firm James Corner Field Operations and Diller Scofidio and Renfro, with a variety of expert collaborators. This on-going project features various stages of implementation with each stage considered to provide a variety of site specific microclimates including sunny, wet, windy and sheltered spaces along its length. Refer to Figure 1.40. The ruin of the High Line is reinvented through biodiversity that is translated from the inherited vegetation that took root on the infrastructure after it fell into disrepair. Refer to Figure 1.39. A fluid transition between the various segments of planting is created with opportunities for recreational use throughout by providing spaces to rest, sit and lie in the sun. Refer to Figure 1.41. The design team sought to retool the industrial structure that had been left to dilapidate and be overgrown with vegetation into a post-industrial space of leisure, life and growth. Refer to Figure 1.42. The design strategy is described as 'agri-tecture', combining organic and building materials into a blend that accommodates experiences of wild, intimate and social. The High Line is designed as a linear experience of slowness and distraction, where occupants are immersed in a new condition once foreign to the urban context. Along the length of the High Line are various vistas where tailored viewing facilities provide an opportunity for navigation. Refer to Figure 1.42.

Figure 1.38
Diagram showing the evaluation
of the case study in relation to the
research aims, author's own.

Figure 1.39

(Opposite page, top-left): Aerial
photograph of the New York High Line
in disrepair prior to the year 2006.

Design Application

This rejuvenation project has heightened an international awareness towards reusing old, abandoned industrial infrastructure by introducing soft building materials back into the hard context of the urban centre. The High line project has set the benchmark for other urban rejuvenation projects taking place across America, such as the *Highway 101* in Los Angeles and rooftop park in San Francisco's Transbay Centre. The High line project engages directly with vital urban infrastructure and re-appropriates its use to increase its value and to ensure longevity. The design team have carefully considered the adaption of this large expanse of infrastructure in accordance with two key strategies for adaption. Firstly the re-appropriation of the railway infrastructure accommodates the need for a recreation facility in Manhattan. The proliferations of the existing infrastructure with vegetation will deliver many benefits to the city, from improving air quality to cooling streets and reducing rainwater runoff during heavy storms. Secondly the extensive financial investment required to re-appropriate the abandoned infrastructure has protected the structure and ensured continued use of the railway infrastructure.

Figure 1.40
(top, right): Aerial photograph of the New York Highline after being re-purposed as a public recreational boulevard and vegetation restoration begun in the year 2006.

Figure 1.43
(bottom): Photograph looking towards the elevated highline infrastructure terminus.

Figure 1.41

(middle, left): Photograph of public seating area and restored garden.

Figure 1.42

(middle, right): Photograph showing one of the viewing decks looking down the adjoining avenue.

Conclusion

Design response to sea level fluctuation has a long history. Early settlement patterns of the Maori people reveal methods of adaption that protect vital human and natural resources. Significantly their settlement patterns allow for an expansion and contraction of the settlement (footprint) as low-lying areas were flooded or dried up. The Maori people have shown the capacity for flexible patterns of living by arranging their settlements to protect their habitats and increase the connectivity to vital natural resources.

The four contemporary case studies examined identified a variety of design responses for preparing a city site for inhabitation at an elevated ground level. The first two contemporary case studies discussed design approaches that ensured key functions within the current site are maintained, while ensuring that past and future financial expenditure is protected. The second case study specifically identifies a method of adaption that engages with flooding by integrating recreational and commercial development with the design of infrastructure for flood mitigation. The third reveals an approach to the design of public transportation infrastructure that engages with an increase in water volume, while providing public amenity within the site. The final case study presents a combination of urban and landscape design that deals directly with the public's relationship to a new recreational urban space to rejuvenate the city's once vital infrastructure. The design approaches used within these projects reveal ways to transition from design relationships at a wider infrastructural scale, towards designing more intimate relationships between buildings at the scale of individual architecture.

Figure 2.1
View of Aotea Quay looking south,
Reclaimed land stage three,
Wellington Reclamation

CHP.

02

*LIBERATING THE
CONCRETE TERRAIN*

2.1 Site Analysis

Liberate- *To set free, as from oppression, confinement, or foreign control.*

Terrain- *defined as all surfaces between built entities*

Test Site as Urban Mediator

The pivotal Central City site of Bunny Street which runs adjacent to the existing waterfront from Glasgow Wharf, north to Parliament Hill has been chosen as the study site for the design research. Refer to Figure 2.2. This site significantly sits at the intersection of the commercial and government precincts, with direct access to public transport infrastructure. Refer to Figure 2.3

In order to develop a sympathetic design response to the relatively contentious global issue of climate change, the research undertook an in-depth analysis of the historic and current characteristics inherent to the study site. Through the lens of site analysis the research followed a framework attuned with the landscape architecture discipline. It was important that the research revealed the underlying site morphology in order to map the continual topographical and social transformations of the site and its wider context – the city. Historic photography and government plans revealed the stages of growth the city has undertaken to present day. Refer Figure 2.4. Rapid land reclamation took place from 1850 to the end of the Twentieth Century, adding more than

one hundred and fifty-five hectares to Wellington City. During this period social spaces were born and disappeared in a continually transforming environment. The research has established links between past and future predicted phenomena. The reclamation stages that occurred within the site can be directly mapped over the zones of incremental sea-level rise that are predicted over the following century. This poetic reading of the site reveals an opportunity to empathise with the laws and rhythms of nature when conceiving a design response.

The design methodology will involve researching how the site can merge the heavily populated central business district and the adjacent government precinct with the waterfront to create a new dialogue that visibly monitors the environmental changes that are occurring. It is envisaged that this will encourage the users of the city to understand and accept the vital role that water plays within the urban built environment.

Figure 2.2
Location map of study site, Pipitea
precinct, Bunny Street, scale 1: 20,000

scale

Figure 2.3
Locating study site at overlap
between commercial and government
precincts, author's own.

1

2

3

4

Precincts	A	Commercial district
	B	Governmental district
	Scale	1 : 5000
1	Willis Street - goods distribution	
2	Lambton Quay- shoreline	
3	Aotea Quay- Thorndon baths	
4	Oriental Bay- trestle railway	

Figure 2.4
Photography illustrating the history of
development in Wellington's harbour
region.

Figure 2.5
Photograph illustrating the study
transect in the context of Wellington
City, author's own.

Transect Study

An exploration of a transect through the site directs this thesis toward an urban infrastructure that engages with the vertical fluctuation of the encroaching ocean across a horizontal slice of the city. Refer to Figure 2.5. The transect is examined to analyse the past and present development that has shaped the condition of the site at present. The study also seeks to reveal opportunities for further site investigation. Refer to Figures 2.6 - 2.8.

KEY

TIMBER
MASONRY

scale

Figure 2.6
Hand-drawn section through the study site transect, analysing the historical morphology in the year 1850, author's own.

Pre-Reclamation

The original shoreline (1850) began along Lambton Quay. (Refer to Figure 2.6), with commercial development beginning to grow along the waterfront. Timber construction was widely used during this period.

KEY

TIMBER
MASONRY

scale

Figure 2.7
Hand-drawn section through the study site transect, analysing the historical morphology at the beginning of the 20th Century, author's own.

Reclamation Stages One, Two

During this period the development of government buildings expanded, with timber construction prevailing. Historically important buildings such as Old Government Building (known today as Victoria University's Law Campus) was constructed on the newly reclaimed land advancing towards the harbour. Refer to Figure 2.7.

KEY

TIMBER
MASONRY

scale

Figure 2.8
Hand-drawn section through the study site transect, analysing the historical morphology from 1958 to present, author's own.

Reclamation Stage three

Figure 2.8 illustrates the pattern of growth which continued to advance towards the harbour, and up into the foothills, bridging across the land currently occupied by the Wellington motorway. During this period many significant timber buildings were demolished due to fire or instability. Masonry construction replaced many of the important government buildings on Parliament Hill. Modern reinforced concrete construction produced high-rise buildings within the reclaimed region, expanding the city's central business district.

Existing Building Uses

- Infrastructure
- Institutional
- Commercial
- Government
- Residential
- Secured parking

Value of Building Stock

- High significance value
- Medium significance value
- Low significance value
- University campus link

Cross Access Distances (meters)

View Paths of Civic Significance

- 1 Bunny Street, looking towards Parliament
- 2 Parliament Hill, looking towards Harbour
- 3 Waterloo Quay, looking towards Parliament
- 4 Lambton Quay, looking towards Harbour
- 4a Feathersron Street, looking towards Parliament

Design Implications

Next, an investigation into the existing view-shafts and cross access links within the site was undertaken, refer to figure 2.10. The view-shafts mapped were presented in the Wellington City Council District Plan (Central area view-shafts 2007), refer figure 2.12. From these observations an opportunity was establish to design a primary axis to extend the existing function of the transport route: Bunny Street. Key nodes along the length of the axis were forecasted to form vital cross links.

Design Implications

An investigation of the existing building stock within the site area identified that between buildings on the north and south of Bunny Street links between similar functions could be identified. It was important to identify which buildings were of high civic importance, and therefore necessitate protection from flooding, refer to figure 2.11. Strategies of adaption are better suited to buildings of high-to medium importance, and strategies of retreat or demolition and relocation for buildings of very limited importance or value. Alternatively a retreat strategy could also be implemented by vertical retreat, reprioritising the ground floor functions of buildings within the medium to low range in order to allow low-lying areas to flood in the future with overflow. The large volume of impending water predicted to inundate the site will require large-scale water management systems to divert the flow away from vital infrastructure and architecture, subsequently forecasting which building could be retained was essential to estimate the required financial expenditure.

Figure 2.9
(Opposite page, top-left): Map diagram illustrating existing building uses, author's own.

Figure 2.10
(Opposite page, bottom-left): Map diagram illustrating existing distances between buildings flanking Bunny Street, author's own.

Figure 2.11
(Opposite page, top-right): Map diagram illustrating the value of existing buildings in the site, author's own.

Figure 2.12
(Opposite page, bottom-right): Map diagram illustrating view shafts of civic significance author's own.

Figure 2.13
Map diagram illustrating the buildings onsite that are predicted for demolition, and those that are to be retained, author's own.

Figure 2.14
Olympic Sculpture Park, Weiss
Manfredi.

*SUB-
CHP.*

2.1.1

*GEOTECHNICAL
INVESTIGATION*

scale

Figure 2.15
Transect plan through the study
site analysing topographical and
geotechnical conditions, scale 1:1000
@ A1, author's own.

Figure 2.16
 Transect section through the study
 site illustrating the shallowest depth
 to reach hard bedrock below Bunny
 Street is eighty meters down, scale
 1:1000 @ A1, author's own.

Depth to Bedrock

1 : 7,500

Design Implications

Physical modelling was undertaken to facilitate a thorough analysis of the geotechnical condition present at the site in relation to the wider city context. Refer to Figures 2.18 and 2.19. The underlying geomorphology of the study site illustrated the significant depths that were present to reach hard rock below the existing ground surface. These depths ranged from minus eighty to minus one hundred and forty meters. Refer to Figure 2.17. This geotechnical analysis revealed the extent to which the soft sediment is spread throughout Wellington's inner city region. Here an opportunity for design is created by extrapolating the geotechnical data presented in order to respond to Wellington's currently invisible dynamic context.

*Figure 2.17
(opposite page): Map of
Central Wellington showing the
Geomorphological condition of
the sites, illustrating the depths to
bedrock, refer Appendix A1, author's
own.*

Figure 2.18
Photography of physical model
illustrating the topographical
condition within Wellington City,
author's own.

Figure 2.19
Photography of physical model
illustrating the geotechnical condition
below Wellington City, in order to
analyse the implications within the
testing site, author's own.

2.2 Masterplanning

Adaption Theories

The above series of diagrams shown in Figure 2.20 illustrate the four strategies of adaption for sea-level rise. The first three categories - attack, defend and retreat - were established in a joint venture between the Royal Institute of British Architects (RIBA) and the Institute of Civil Engineers (ICE) during a design charrette 'Building Futures' in July 2009. A fourth strategy 'accommodate' has been established in the research as a flexible mediator between these three. It is the intention of the research to structure a design

response, which is multi-layered. The scope of the research directly engages with a study site, and therefore it is assumed that a combination of these strategies will be employed within adjacent sites, encouraging city wide integration. It is the intention of the research to ensure that the masterplan considers the urban context and how the solutions presented within the site can be implemented in various combinations around the city to prepare for sea-level rise as appropriate.

*Figure 2.20
Plan and section diagrams illustrating
the four key adaption theories
established earlier in the thesis,
author's own.*

*"My profession is to go
beyond boundaries"*

- J.G. Ballard (Novelist)

Figure 2.21
Conceptual Masterplan site scheme
Bunny Street Infrastructural
intervention, author's own.

Site Strategy

Waterfront extension

Length - 7km

Usable - 5km

Extension - 600 m

Total Usable - 5.6km

scale

Design Implication

The site strategy illustrated in Figure 2.22 reconciles the current disparity between the way European settlement in New Zealand closely occupies the coastline, as opposed to the more resilient approach of early Maori settlements that were arranged perpendicular to and terraced away from the harbour. Refer to Figure 1.26. The reapplication of this historical model reveals the predominant axis for the site strategy, proposing a ninety degree rotation of the current waterfront forming an extension, sculpting the water into the city.

*Figure 2.22
(Opposite page): Diagram illustrating the masterplanning site strategy as a ninety degree rotation of the existing waterfront boulevard, extending in to the site, facilitating a six hundred meter extension, author's own.*

scale

Traversing Property boundaries

The large land area that the site occupies necessitated a wide scope of initial research to be undertaken in order to investigate the condition of the existing buildings. Consent drawings of the buildings flanking Bunny Street were analysed to assess which buildings on either side of Bunny Street required links to bridge between the key functions they offer. This investigation was carried out in order to identify which current functions onsite required future investment to maintain vital connections during sea-level rise. It was established that three connections or nodes (connectors) for bridging were viable. Refer to Figure 2.23. Each location was examined to create a framework for programmatic input.

*Figure 2.23
(opposite page): Map showing the
locations on-site for architectural
intervention, three nodes selected,
scale 1:200, author's own.*

Programmatic Considerations

The design proposition for each connector was established to operate as a mediator between functions on land and operations during aquatic fluctuations. Therefore it was important to propose site-specific programmatic criteria within the conceived masterplan. The first connector has been designed to function as the entry point for the extension of the existing ferry transport network into the site via a canal infrastructure. Auxiliary functions consist of a tidal pools complex with public recreational amenities offered at the harbour entrance. The second connector was development to operate as a pedestrian link between the current train station to the north and the large commercial office block (Asteron Centre) to the south in the middle portion of the study site. The second connector plays a pivotal role in the site's infrastructural network, housing a transport interchange for ferries commuting back and forth. The transportation interchange, mediates between the split level of the first and second stages of the high-line canal designed to travel at elevated levels of fifteen to twelve meters above the existing ground level. The third connector operates as an extension of the existing commerce and law school facilities located at the intersection of Bunny Street and Lambton Quay. The extension was envisaged to operate as a collaborative hub for education, with entertainment facilities to increase activity at the site during day and night. The site proposition provoked the need to think beyond artificial property lines and work within a collaborative framework between crown and commercial owners.

scale

- A Excavated Sector : Remediate Soil
 - B Amphibious Retrofit
 - C Intuitive Landscape
 - D Terraced Edge
-
- Tidal Pool : Bathing Reservoir
 - ||||||| Extend Existing Wharf frames
 - Demolition
 - Thresholds
 - First Zone of Defence

Conceptual Site Design - 2025

The design proposition for the masterplan began by applying the appropriate adaption strategies within the three land holdings across the length of Bunny Street. These are: the waterfront parcel (Glasgow Wharf), commercial parcel (between the commercial block and the train station) and the private parcel (North section between the university campuses). Firstly, the research established that the previously reclaimed wharf area needed to include defensive infrastructure that would provide the first line of protection between the harbour and the new development that was conceived for the study site by the year 2025. Refer to Figure 2.24. The defensive strategy was employed at the entrance of the site to attenuate the rising sea-water and channel large volumes into the water management network planned to traverse the site. The design of infrastructure for flood mitigation was combined with the accommodation strategy in order to appropriately develop an infrastructural system to move large volumes of channelled sea-water around the water management network. This action was envisaged to be facilitated by a series of hydraulic locks. Refer to Figure 2.30.

Figure 2.24
 (Opposite page): Map showing the conceptual master-planning, illustrating the site strategies for the operation of the wider site water-management network by the year 2025, scale 1:5,000, author’s own.

Design Implication

To further test the strategy of accommodation, Shed 21 a recently refurbished historical brick building within the waterfront portion of the study site was adapted in accordance to BACA Architects amphibious house design, published as part of the LIFE project (Long-term Initiatives for flood-risk Environment). Refer to Figure 3.8. The conceptual design tested the ability to protect the historically important infrastructure from the impending sea-water that would flood the ground level and render it unusable. Here the concrete caisson (basement severed from its foundations) was allowed to flood and the building to eventually rise, aided by buoyancy material installed below the ground floor. Refer Figure 2.25. This design approach maintains the operation of the ground floor through elevation; however it would require a large financial investment, and therefore would need to be offset by the return of investment sought from future lease of the ground floor.

*Figure 2.25
(Opposite page): Section illustrating
the conceptual design of retrofitting
Shed 21 to protect it from damage
caused by predicted flooding of the site
by the year 2025, author's own.*

scale

- E Reuse Existing Ferry Terminal
- F Establish Canal + Lock System
Along Bunny Street
- G Retreat Ground Floors -
Shift Function Upward
- Build Up Resilient Reservoir
- Channel Fills
- — — — Thresholds

Conceptual Site Design - 2050

The second stage of planning looked at responding to the predicted 2050 sea-level (0.7 –1 meter) by reprioritising the use of ground floor spaces within the buildings located within the first two portions of the study site. Figure 2.26 shows the implementation of the adaption strategy 'retreat'. This approach sacrifices less important spaces to aid the protection of critical adjoining spaces. Ground floor functions within the commercial block (Asteron Centre) to the south of Bunny Street are shifted upwards to the first floor, between 2025 and 2050. Refer Figure 2.27.

Figure 2.26
(Opposite page): Map showing the conceptual master-planning, illustrating the site strategies for implementation by the year 2050, scale 1:5,000, author's own.

Design Implication

The ground floor is stripped of valuable claddings for recycling and the structural columns remain, essentially forming an open pavilion. Refer to Figure 2.26. The impending water is then allowed to overflow into these spaces in order to alleviate a buildup within the conceived canal infrastructure. Therefore the ground floor will experience wetting and drying during the first fifty years; following this, the flooded spaces will be utilised for recreation, operating as a visual indicator to monitor the rising sea-level.

Figure 2.27
(Opposite page): Section illustrating the conceptual design for removing an external facade on the ground floor and shifting functions to the first floor, author's own.

scale

- H Establish Architecture Intervention,
Expansion For Commercial Block
- I Establish Architecture Intervention,
Expansion for University Campuses
- Build Up Resilient Reservoir
- Intuitive landscape Fills + Drains
- Functional Platforms in
Inundation Zone
- — — · Thresholds

Conceptual Site Design - 2100

By the turn of century the third stage of construction is predicted for the land parcel at the termination of Bunny Street where it intersects Lambton Quay (the original shoreline.) Development within this third portion will involve the construction of a connector to bridge between the commerce and law campus on either side of Bunny Street. Refer to Figure 2.28. The new architecture conceived for this site operates as an extension of both campuses (institutional hub).

Figure 2.28
(Opposite page): Map showing the conceptual master-planning, illustrating the site strategies for implementation by the year 2100, scale 1:5,000, author's own.

Design Implication

After consulting hydraulic engineers it was established that in order for the high-line and low-line water management network to be in full operation, a series of hydraulic locks were required. Refer to figure 2.30. These would pump the water and move commuting ferries up and down the site to establish drop off points within the connectors. Design investigation was undertaken to assess how the construction of a typical lock could be modified towards an appropriate scale to operate with regard to adjoining architecture. The research established the need to manipulate the traditional structure of the lock to create a conduit that allows for pedestrians to move over and underneath the lock itself. Refer to figure 2.67.

*Figure 2.30
(opposite page): Section illustrating the conceptual design of building water infrastructure within the study site; programmes are moved around the building via hydraulic locks, utilising the flood water predicted by the year 2100, author's own.*

*Figure 2.29
(opposite page): Plan and section diagrams illustrating the basic mechanics of an operational hydraulic lock, author's own.*

3-Month Review - Critical Feedback

This intermediary review provided a critical design reflection and subsequent direction to develop the masterplan. The initial concepts were examined by international academics and practitioners from the disciplines of architecture, landscape and urban planning. The three-month review identified the strategic strength of the project, necessitating the development of the water management network by integrating it with the development of new architecture. The design of new architecture to link directly into existing buildings was envisaged to allow for forecasted programmatic requirements. Landscape critics suggested a further investigation of the site by documenting the existing patterns of movement in order to encourage further design experimentation. Refer to figure 2.32 and 2.33.

Figure 2.31
An illustration showing the spatial quality of the envisioned boulevard High line and urban rooftop park, author's own.

Predicted Traffic Volumes within Study Site - 2030

A	Existing Seatoun ferry link	1	Recreational hub
B	Existing Bluebridge ferry link	2	Public transport exchange
C	Waterloo Quay	3	Institutional hub
D	Thorndon Quay		
E	Lambton Quay		

Figure 2.32
Map illustrating the predicted traffic volumes within the study site, established from statistics supplied by Wellington City Council for the year 2030, scale 1:2500, author's own.

Direction of Itinerary

Traffic Volume : [p/d] people per day
 [c/d] cars per day

1	170 p/d
2	1,250 p/d
3	950 p/d
C	500 c/d
D	290 c/d
E	350 c/d

NB:

Based on 17.8% projected increase in traffic volume 2030, in accordance with 'Wellington Regional population and population projections', refer to Appendix A2

scale

Figure 2.33
String parti diagram showing the conceptual analysis of flows at major intersections along Bunny Street, used to establish axis of significance for infrastructural intervention in the site, author's own.

Figure 2.34
Parti sketch diagrams showing
the trajectories of flows at major
intersections along Bunny Street,
author's own.

Construction - 2025

PHASE ONE

- Public boardwalk, bridge link
- Design 1st Connector
- New Infrastructural Spine - Section 1

Construction - 2030

PHASE TWO

- Public boardwalk, bridge link
- Design 2nd Connector
- New Infrastructural Spine - Section 2

Figure 2.35 - Figure 2.37
Parti diagrams at intersection nodes
along the site, showing three key
stages of construction by the years
2050, author's own.

Construction - 2050

PHASE THREE

- Public boardwalk, bridge link
- - - Design 3rd Connector
- New Infrastructural Spine - Section 3

Axis of Infrastructural Significance

- Infrastructural Spine
- ⊕— Significant connections to be developed

Design Implications

Figure 2.34 illustrates the parti diagrams that were drawn from the data of traffic flows at predominant intersections along Bunny Street. From this analysis a formal diagram could be overlaid on the site in order to establish the design of the primary infrastructural trajectory, pivotal to the masterplan. This trajectory provides the transport axis for the connectors to bridge across. This axis was conceived as the primary infrastructural spine bisecting the site and running the length of Bunny Street. Refer to figure 2.38. This involved the design of public transport infrastructure coupled with pedestrian and cycle access routes. Refers to figure 2.35 - 2.37.

Figure 2.38
Diagram illustrating the axis for the design of an infrastructural trajectory within the site connected to the north and south of Bunny Street by forecast architectural intervention, author's own.

Processes: Digital Striation

From geotechnical data provided by GNS Science, a design experiment was undertaken to digitally analyse the site's underlying morphological condition and extrapolate data. The bedrock contours were extruded through a process of striation analysis. Refer to figure 2.39. This process enabled an undulating surface to be extruded on top of the site forming a protected infrastructural terrain that re-contoured the site affording a visual indication of the fluctuations occurring within low-lying areas during sea-level rise. This design experiment was undertaken in response to the geotechnical data examined in the research. Refer to figure 2.17. The new elevated site contours portrayed the instability of the city's geomorphology, through extruded spot heights that reflected the soft soil conditions present across the majority of the inner city. Significantly the shallowest depth to reach hard rock below Bunny Street was recorded at minus eighty meters. Refer to figure 2.16.

Design Implications

This design investigation identified the inherent fluctuating condition below the site that currently is invisible to users of the city. In response, the research sought to test the notion of 'flux' and how it could be represented through the design intervention within the study site - additionally investigating how the masterplan could become a tool for narration of these influential conditions. Refer to figure 2.40.

Figure 2.39
(Opposite page): Series of digital diagrams illustrating the process of striation analysis to derive a formal site strategy, author's own.

Figure 2.40
Photography of a physical model illustrating the design process formally manipulating the intervention of infrastructure across the site, author's own.

Figure 2.41
(opposite page): Photography of finished physical model illustrating the final terraced levels across the site, forming the strategy to protect vital infrastructure, author's own.

2.3 *The System*

Layered Site Strategy

The site strategy was conceived as a water management network that could grow outwards across the city. The network was separated into four key systems: lowline infrastructural canals, high-line aqueduct canal with a series of hydraulic locks, architectural connectors and the elevated park terrain. A multi-layered strategy provided a flexible framework to ensure that appropriate changes can be made in future as new methods of construction become available. Initially a low-line canal network was established along existing avenues to create a permeable defensive barrier running the length of Bunny Street and continuing beyond the site. Refer to Figure 2.42. The canals divert the sea-water away from vital infrastructure and channel overflow into alleviation zones. A series of hydraulic locks were designed to be located at the key transportation interchange points along the infrastructural spine (primary canal) to cater for ferries transporting commuters up and down the site, Refer to Figure 2.43. The north and south sides of the site were then connected by bridging architecture, ensuring access to key functions were maintained throughout incremental flooding. Refer to Figure 2.44. The overall network is then protected by an uplifted park terrain that promotes recreational and social functions within the site all year round. Refer to Figure 2.45.

INFRASTRUCTURAL LOWLINE CANAL

[PERMEABLE DEFENSIVE SYSTEM, FEEDS
WATER ALONG AVENUES]

Figure 2.42

Perspective of study site showing the primary construction of the water management network as a main infrastructural lowline canal, with secondary canals spreading laterally across the Central City, author's own.

SPLITTING WATER SUB-SYSTEM

[HYDRAULIC LOCKS PUSH WATER AROUND THE
LOW AND HIGHLINE CANALS]

Figure 2.43
Perspective of study site showing the
secondary stage of infrastructure: a
series of hydraulic locks that pump the
water from the lowline canals up to a
high line canal (aqueduct) and back out,
author's own.

CONNECTING THE SYSTEM

[THREE ARCHITECTURAL CONNECTORS BRIDGE
BETWEEN BUILDINGS OVER WATER]

Figure 2.44
Perspective of study site showing the
primary construction of the water
management network as a main
infrastructural lowline canal, with
secondary canals spreading laterally
across the central city, author's own.

PROTECTING THE SYSTEM

[UPLIFTED STREETSCAPE PROVIDES ARMATURE
FOR EXISTING ARCHITECTURE]

Figure 2.45
Perspective of study site showing the primary construction of the water management network as a main infrastructural lowline canal, with secondary canals spreading laterally across the Central City, author's own.

Flux Proximities: Accommodate

The research proposed to accommodate the water within the canal system through a series of hydraulic locks in order to manage the flow of water and storm surge around the canal avenues, essentially defending key assets, refer to figure 2.46. An open-loop system was identified as the most appropriate strategy to manage the broad spread of sea-water inundating the city site. This system involved the provision for channelled water to be diverted back through the wider water-management network exiting into the harbour (essentially the network holds, pumps and releases volumes of water in continual cycles).

Figure 2.46
Illustration of the hydraulic lock design operating at the entrance of the aqueduct canal system, Glasgow wharf, author's own.

Figure 2.47
Zoomed in view of figure 2.46,
showing detailed design,
author's own.

Flux Proximities: Retreat

The secondary low-line canals extend out from the central infrastructural spine along the existing pedestrian Avenues. Refer to Figure 2.42. The design sought to utilise the network of moats to visually increase the public's awareness, by observing the dramatic environmental changes occurring within the city due to a global rise in sea-level. Figure 2.48 shows a sectional drawing illustrating the proximity between users inhabiting the ground floor of the existing Asteron Centre and the surface water collected within the low-line canal. This secondary canal is envisaged to run within the cavity produced by the double façade designed to clad the interior expansion of the existing Asteron Centre created underneath the elevated terrain. Slanted steel fins on the exterior façade operate as grating to slow down the flow of sea-water as it is diverted into the canal. Refer to Figure 2.49.

*Figure 2.48
Illustration of the interface between the roadway and the space underneath the upper park (south of Bunny Street), showing the low-line canal running along the perimeter of the retreated ground floor, author's own.*

Figure 2.49
Zoomed in view of Figure 2.48,
showing detailed design of the
flood alleviation canal, author's
own.

Flux Proximities: Defend

The defensive low-line canal network travels around the front of the train station lobby and down the adjoining avenues to divert sea-water away from the historically important façade. Refer to Figure 2.42. A floating pathway was envisioned to provide access from the train station across Bunny Street into the commercial block (Asteron Centre) to the south. Refer to Figure 2.50. This strategy required stages of re-appropriation of the site during incremental sea-level rise, shifting functions from low lying areas such as the existing plaza in front of the train station, alternatively activating pathways and recreational space at an elevated level. Refer to Figure 2.51. The research directly engaged with implementing strategies for adaption to sea-level rise within the study site, and therefore it is assumed that the main transportation routes which extend beyond the site will in future operate until such time when the sea-water has inundated the area, necessitating relocation.

*Figure 2.50
Illustration of the lowline canal
design operating as a defensive
moat at the perimeter of the
historically significant railway
station lobby, author's own.*

Figure 2.51
Zoomed in view of Figure 2.50,
illustrating the proximity
relationship between the user
and the canal, author's own.

2.4 *Formal Investigation*

*Figure 2.52
Conceptual physical model illustrating
tectonics of water infrastructure and
bridging elements, author's own.*

Figure 2.53
Conceptual physical model
illustrating sectional arrangement of
infrastructural canal and pathways,
author's own.

Figure 2.54
Conceptual model illustrating plan
arrangement of infrastructural canal
and pathways, author's own.

Infrastructural Tectonics

Physical modelling was undertaken to formally test methods of design presented in existing canal construction. This identified an opportunity to manipulate the elements of traditional infrastructural engineering, adapting these towards a more sculptural expression to complement the architectural design integrity set-out by the research. Twentieth Century 'hard' engineering solutions for dams and canals were analysed along with more recent projects that involved the design of free-form concrete construction to test how curvature could function in section. Refer Figure 2.52 and 2.53. This design experiment proved there was a need to consider the existing aesthetic of the site to ensure that any new large-scale infrastructure envisaged would be desirable and complementary to the eclectic and artistic development of Wellington's existing waterfront. This was important as the rise in sea-level predicted will flood the vital waterfront boulevard within the research timeframe. To establish an approachable relationship between the users of the city and the design of new infrastructure, materiality will play an important role, affording the large-scale engineering the capacity to complement the existing urban waterfront condition, while showcasing a new approach to urban development.

*Figure 2.55
(opposite page): Conceptual
model illustrating tectonics bridging
infrastructure crossing an upper
and lower water canal, author's*

*Figure 2.56
Conceptual model illustrating
infrastructural trajectories in plan
and overlapping bridge pathways,
author's own.*

Bridging

The fundamental objectives of the architectural connectors were envisaged to bridge between and maintain the function of the existing buildings within the study site. This was undertaken in accordance to considerations set out within the research to maintain a high property value, and to protect previous capital expenditure. Physical modelling and sketching provided the means to test methods of design which bridge between programs at multiple levels on both sides of the site. Refer to Figure 2.55, 2.56 and 2.57.

*Figure 2.57
Conceptual diagram illustrating
bridging infrastructure via ramping
elements that allows access
between lower and upper parks,
author's own.*

Open facade for drainage,
partition to adjoining building

Lowline canal - interior

Figure 2.58
 Constructional diagram illustrating a cut through the site from north to south showing relationships between the lower park to the north, the high line aqueduct, the upper park to the south and interstitial spaces, scale 1: 250, author's own.

The Park

Established as a public recreational space and extension of the current waterfront parks, the elevated park terrain is an intrinsic part of the masterplan. The design carefully considered the extension of existing public spaces and park facilities currently provided on site at an elevated level to establish a hub for year round activity. The park operates as an armature infrastructure protecting the established water management network. The protective terrain meanders across the length of the site increasing pedestrian access to existing buildings, from the site boundaries and on and off the ferry transportation high-line canal. Refer to Figures 2.58 and 2.63. Among several precedents, Foreign Office Architects' Yokohama Terminal, and The New York *highline* project provided the influence for the proliferation of the terrain with plantings, timber and concreted areas with open spaces to play, exercise and socialise. Refer to Figures 2.59 and 2.61.

Figure 2.59
(top): Photograph illustrating an example of rooftop park materiality - FOA Yokohama Terminal, 2007

Figure 2.60
(second): Photograph illustrating an example of waterfront/park threshold-Seattle Olympic Sculpture Park - Weiss Manfredi Architecture, 2007

Figure 2.61
(third): Photograph illustrating an example of rooftop park materiality- Kenyo Kuma winning proposal V&A Dundee, 2010

Figure 2.62
(bottom): Photograph illustrating an example of formal transition between terraced levels, using curved decking, Henderswon Wave Bridge, 2008.

Figure 2.63
Drawing illustrating the
conceptual design of the park
form across the site, with a lower
(north) and upper (south) section,
author's own.

KEY

- Ferry Transport canal highline
- Existing buildings on-site
- Public boulevard 2 meters wide

- [A] 1st Section of public boulevard +15 meter
- [B] 2nd Section of public boulevard +12 meters
- [C] Public bridge / look-out +15.5 meters
- [D] Public bridge / park access +12 meters

Figure 2.64
Diagram illustrating the upper
and lower sections of the public
boulevard running the length
of the aqueduct high line, scale
1:1000, author's own.

Boulevard

The extension of the existing waterfront boardwalk was essential for traversing the length of the new masterplan and to ensure that ready access to and from the water was maintained. It also provided a design opportunity to encourage a closer relationship between the users both within the park and those commuting along the high-line on ferry transport. Refer to Figure 2.64. Materiality from the current waterfront informed the design of a primary timber boulevard running parallel to the high-line aqueduct at elevations of fifteen and twelve meters across the site. Refer to Figures 1.13, 2.65 and 2.66.

Figure 2.65
photograph illustrating an
example of boardwalk materials
and detailing - OKRA Architects -
Storaa Stream Denmark - 2011

Figure 2.66
photograph illustrating an
example of boardwalk materials
and detailing - OKRA Architects -
Storaa Stream Denmark - 2011

Ferry entrance to lock at Glasgow Wharf

1st hydraulic lock, lifts to + 5 meters

2nd hydraulic lock, lifts to + 15 meters

Aqueduct conduit bridges over
Waterloo Quay

Figure 2.67
Constructional Diagram of Locks
at Glasgow Wharf Entrance to site,
scale 1: 200, author's own.

Figure 2.68
Axonometric detail diagram of spill
gates that form barriers between
the volumes of water in each
hydraulic lock, author's own.

The Locks

Current methods of retaining and releasing water in a periodic process were examined in order to provide a medium for ferry transport. The Clyde Dam, Clutha River, was an important precedent. Refer to Figure 2.69. After a site visit with the lead geotechnical engineer, it was established that the elements that defend and release the water within the design of the dam could be reinterpreted to operate at an appropriate scale for the series of hydraulic locks envisaged as part of the water management network. Refer to Figures 2.67 and 2.68. The designs of the spill gates at Clyde Dam were examined to translate their operation within the design of a hydraulic lock. To achieve the design integrity set out by the research, the engineering of the hydraulic locks was required to formally express the dynamic process taking place within them. Refer Figure 2.67. This was achieved by exposing the moving parts of the locks spill gates that frequently rotate, releasing large volumes of sea-water as ferries move throughout the transport system. Refer to Figure 2.68. The location for each lock was carefully considered to ensure the integration of public walkways; this is seen in the design of a pedestrian bridge, which provides public access into the site over the initial set of locks located at the harbour entrance. Refer to Figure 2.47.

*Figure 2.69
Sectional diagram of Clyde
River Dam, spillway system, to
alleviate an elevated water level
upstream, examined as a formal
precedent, photographed from
original.*

Figure 2.70
Constructional diagram of aqueduct
high line for ferry transportation up
and down the site, author's own.

The Aqueduct

Designed in accordance to current navigable canals in the Netherlands, the aqueduct high-line operates primarily as a transportation infrastructure, allowing ferries to commute up and down the site. Secondly the high-line was designed to retain and circulate large volumes of sea-water, emptying back into the envisaged wider water management network. Refer to Figure 2.70 and 2.42. The tectonic expression of the aqueduct was designed to reconcile the sculptural articulation of the fluid it retains with current modes of constructing large-scale infrastructure. Due to constructible considerations, reinforced cast-in-place concrete was conceived to be predominately used for the conduit of the aqueduct, while light weight steel would provide the surrounding structure, resting on precast concrete piers. The piers follow the curve of the aqueduct down its length and fall directly within the low-line canal which runs below the current ground level. Refer to Figure 2.72.

Figure 2.71
Sketch diagram of high line
canal concept with two sections
intersected by accessible
interchange, author's own.

Figure 2.72
(opposite page): Visualisation of the space below the rooftop park in front of the existing Asteron Center, illustrating the structural system for support of the roof and aqueduct, author's own.

Figure 2.73
(Top): Photograph of physical model illustrating the design of an undulating roof structure to create long spans between vertical supports.

Figure 2.74
(Bottom): Sketch diagram of the rooftop park structural system, illustrating the spanning of structural members to transfer loads between undulations, author's own.

8-Month Review - Critical Feedback

At the eight-month review, expert international reviewers praised the thoroughness of the strategies employed to produce the masterplan. It was suggested that further development was required to reconcile the design of the supporting structure for the park terrain and the aqueduct high-line with the design intent established in the research. Refer to Figure 2.72. The development of the structural system needed to adhere to the intent of the research by creating desirable spaces for civic use. Subsequently it was identified that the undulating nature of the park could be developed to self-support producing large structural spans, in turn creating the 'openness' envisaged for the internal spaces underneath. It was suggested that the research could analyse the work of Santiago Calatrava to derive finer detailing of structural elements, refer to figure 3.14. To complement the development of structural detailing, it was suggested to examine self-supporting roof structures that utilise undulations and folds to provide for rigidity and stiffness across large structural spans. Refer to Figures 2.73 and 2.74.

Design Implications

The critical feedback provided during the eight-month review facilitated on-going design experimentation. During this stage of development the formal articulation of the elevated park terrain was investigated. A follow-up discussion with structural engineers was undertaken to revisit the system supporting the park and aqueduct, initiating further design experimentation to achieve the intended design aesthetic. It was established that a combination of long spanning truss networks accompanied by slender split columns could provide the appropriate carrying capacity created by increasing the depths of undulations within the roof canopy. Refer to Figure

2.74. The feedback provided at the eight-month review became a driver for design development and therefore played an instrumental role in shaping the formal expression of the final design outcome.

AXO

SECTION

Figure 2.76
(Opposite page- top): Photograph of
steel folded plate roof structure of the
Yokohama Ferry Terminal, Japan.

Figure 2.77
(Opposite page- bottom): Section
diagram illustrating the refined
slender structural elements, scale
1:200, author's own

Figure 2.78
Photograph illustrating the design
application of steel folded plate in the
support of a bridge.

Developing - The Aqueduct

A closer examination of the structural elements that formed the support system for the aqueduct conduit identified an opportunity for further design experimentation. The formal elements were retested to explore the use of a more slender structure that could provide adequate support, while accomplishing a more refined aesthetic. Refer to Figure 2.77. Case studies from previous formal experiments were revisited to provide insight into methods of achieving self-support. Refer to Figures 2.76 and 2.78. Foreign Office Architect's Yokohama Terminal in Japan identified such methods. The use of steel folded plates in this project provides structural stiffness through the rigidity of a fold, which was conceived to enhance the architectural expression required for the articulation of the underbelly of the aqueduct high line. Refer to Figure 2.79.

Figure 2.79
 Section illustrating the developed
 design of the park terrain- supporting
 roof structure and the refined vertical
 supports, scale 1:250, author's own.

Developing - The Park Terrain

To maintain the sculptural expression of the conceived infrastructural elements the supporting piers were redeveloped as slender steel forked columns. These were developed to complement the redesign of the park infrastructure, creating a self-supported undulating roof. Refer to Figure 2.79.

Conclusion - Formal Experimentation

The approach of design-led research ensured formal experimentation through physical and digital modes was rigorously undertaken. The outcome of these experimentations revealed a set of formal approaches for design to deploy when conceiving the redevelopment of Wellington's city centre in preparation for sea-level rise. The design limitations, constraints and opportunities established through this process continue to be developed and implemented within the framework of the final design. Each conceptual design investigation was evaluated against the three key aims that were established early in the research. Refer to Figure 1.8. The research aims conceived were: firstly to ensure the design responded to the impending sea-water and protected the city's vital infrastructure, secondly to investigate how current strategies of adaption to sea-level rise can play a pivotal role in preparing coastal cities for climate change and thirdly to critically reflect upon the design of dynamic infrastructure and architecture against current discourse on architecture's role in preparing coastal cities for sea-level rise. Each design outcome was reviewed to establish a set of conceptual approaches, undergoing refinement in accordance with a range of critiques provided by reputable international and national academics and practitioners throughout the experimental design stage of this research.

“It’s not the
strongest of the
species that
survive nor the
most intelligent,
but the one most
responsive to
change”

- Charles Darwin

Figure 3.1
Photograph of Clyde Dam during the
release of the spillway.

CHP.

03

*CITY OF
FLUX*

3.1 *Designing: Masterplan*

City- *A center of population, commerce, and culture; a town of significant size and importance*

Flux- *The flow of a physical property in space, with time variation*

Designing Dynamic Infrastructure

The history of Wellington City and its waterfront shows a strong correlation between the development of a trading port and the ongoing reclamation of land extending the reach of the central business district out into the harbour. However, while history deals with land reclamation the future points to a need to engage the opposite; the loss of important waterfront land due to predicted inundation promotes the implementation of new strategies for urban development. The 'City of Flux' proposal seeks to create a new connection between past and future, land and water by introducing controlled flooding. Many of the major buildings and infrastructural elements vital to Wellington and the surrounding regions are located within the central city. The most critical are rail, road and ferry transportation, water reticulation, telecommunications, electricity cabling, emergency management and central

government (Semmens, Perrin 1).

The overall site scheme pursues a responsive (dynamic) engagement with the rising datum of the ocean. It incorporates a layered masterplan developed from the four key adaption strategies: defend, retreat, attack and accommodate. The conceived masterplan illustrates an opportunity to develop a new urban precinct catering for living, working, exercising and socialising. The conceived site intervention exchanges the current dispersive city grid for an integrated network of flows and nodes. The newly designed territory (elevated terrain), operates as a visual indicator to monitor the transforming condition of the site during sea-level rise. The design intent to directly address the fear associated with the implications of climate change was achieved by proposing a new experiential landscape of opportunity and intrigue where users of the city can actively engage with the transforming site. The objective of the masterplan was to provoke a discussion and even possible national action by offering a site considered design response to sea-level rise. Using a familiar central city site permits the engagement of design within a broader discussion encouraging the investigation of the systems conceived to extend elsewhere in the

central city. The masterplan is envisioned to be constructed in 'three key stages' over the ninety year timeline, by establishing shifting thresholds (physical boundaries) that continually allow for new areas of the site to be activated once others become redundant in a process attuned to the flexible morphology of the primary building material (sea-water).

It is important to note here that the design as a whole is not seeking to alleviate climate change or sea-level rise. It was also not the intention of the research to disperse the large mass of water coming in, to avoid flooding altogether, as this is unrealistic. Rather the design intent was to use a combination of the adaption strategies discussed in the research to allow water to penetrate controlled areas and therefore sacrifice some less important zones to create opportunities within others. It could be described as 'controlled flooding'. Controlled flooding refers to mechanisms of control that are in place within the project to determine the volume of water that is diverted into the canal system to alleviate a buildup at the defence barriers to avoid damage such as was achieved in the Room for the River Project examined earlier in the research. Refer to pages 40 and 41.

*Figure 3.2
(top): Photograph of physical model illustrating the design process to establish datums between the elevated park and the infrastructural transport spine (high line aqueduct), author's own.*

*Figure 3.3
(bottom): Photograph of completed physical model, lit up to highlight the sculptural form of the canal running through the site, author's own.*

Design: Site Scheme - Collapsing scale and experience

The design proposal treats water as an architectural material, and in doing so opens up the design to the dynamic dialogue between existing static and fluid systems. The system controlling the flooding of volumes within the city over the coming century will be periodically controlled and governed by programmatic and tidal regimes. The overflowing sea water will be periodically diverted into the city via a system of channels. The water management network will become a flexible joint in an existing environment of rigid infrastructure - creating a new type of boundary, one of shifting thresholds. Refer to Figure 3.5.

The infrastructure and architecture conceived forms a series of seawalls that are perpendicular to the waterfront instead of parallel. These are scaled appropriate to their location across the site, and in response to their specific adaption operations. Refer to Figure 3.6. The first connector is designed in accordance with current methods of amphibious architecture. The pontoon decking that surrounds the public tidal pool complex at the harbour entrance to the site moves flexibly with the tidal cycles. Refer to Figure 3.10. The second connector transverses the middle section of Bunny Street at an elevated level of seven to fifteen meters, with spaces above and below the rooftop park facilitating public transport, recreation and commerce. The third connector is located at the termination of the study site, where it forms a new urban condition at the threshold of the original shoreline (Lambton Quay) and the

university campuses. The third connector is envisaged to operate as an institutional hub with a north and south wing bridging the aqueduct high line to provide future expansion space for the commerce and laws schools on site. The three connectors were designed through an architectural approach in accordance to the masterplan framework in order to transcend multiple scales, from urban to intimate spaces. Refer to Figure 3.4.

Key

[A] Waterloo Quay

[B] Thorndon Quay

Figure 3.4
Map showing the locations of the three architectural connectors on site, author's own.

Figure 3.5
(Opposite page): Masterplan of final site proposal, scale 1: 750, author's own.

Phases of Response

2025/ +0.3 meter rise

Water overflows Glasgow harf, tidal pool fills

2050/ + 0.7 - 1 meter rise

Water overflows Waterloo Quay, low-line canal begins to fill, ground floor functions adapt

2100/ 1.5 - 2 meter rise

Water overflows Lambton Quay, low-line and high-line canals are in full operation pumping water around the system

Figure 3.6
Section A, illustrating the final design
proposition from Lambton Quay to
Glasgow's Wharf, highlighting the
relationship of the rising water datum
within the new site intervention, scale
1: 500, author's own.

3.2 Designing: Architecture Connectors

Introduction

A series of canals make up the water management network and form the masterplan of a new infrastructural intervention within the study site. Refer to Figure 3.5. Connections across the site provide bridge access over the envisaged canals, maintaining the operation of key functions to the north and south of Bunny Street. Ensuring the ongoing operation of vital public links, the design of each architectural connector provides pathways from the conceived new infrastructure to existing buildings. Furthermore it increases the public recreational amenities offered within Wellington's central business district. The secondary function of each connector is to provide opportunities for future commercial and institutional development in accordance with current and predicted programmes within the study site.

Figure 3.7
(top): Image of a proposal for the design of the Riverboat Dock Memphis, illustrating an example of materiality and public amenity at the waterfront.

Figure 3.8
(bottom): Image of a proposal for the design of an amphibious house on the Thames River, illustrating the shift in level of the building as it engages with the fluctuating site condition.

Figure 3.9
(Opposite page): Partial site plan, illustrating the final design of the public pool and dock facility (1st connector), scale 1:500, author's own, see figure 3.10 for section B.

Design: 1st Connector

The first connector functions as a destination and entry point into the re-appropriated site. Refer to Figure 3.9. It was the intent of the research to create a sense of arrival at the terminus of the current waterfront boulevard upon entering the site; this was achieved by elevating the park on the southern side, providing views out to the harbour and down towards the ferry entrance and the adjoining public tidal pool complex. The tidal pool facility maintains surveillance at the harbour entrance, ensuring personal safety and security. The open-air complex provides moments of shelter (retreat) and exposure to the sea. Refer to Figure 3.11. The facility includes a rooftop deck with café; this can be accessed from the waterfront boulevard by crossing over the hydraulic locks from the elevated waterfront park to the south, providing many opportunities for observation.

Figure 3.10
Section B, illustrating the relationship
of the recreational pool complex with
the ferry canal entrance at Glasgow
wharf, scale 1: 150

Figure 3.11
Visualisation of semi-private spaces
within the tidal pool complex, author's
own

Operations:

Defend- At this first line of defence the new elevated park on the southern side of the site operates as a barrier to prevent overflowing water entering the existing historic building (Shed 21). The new elevated ground level maintains pedestrian access from the existing waterfront boulevard into the site. Refer to Figure 3.10.

Accommodate- The hydraulic locks at the harbour entrance accommodate the movement of water and commuting ferries up to new elevated levels, to travel into the site along the aqueduct high-line. The tidal pool was designed to utilise the fluctuating tidal cycles to provide a bathing facility similar to the historically significant Thorndon Baths that once were located next to the site, prior to the final stage of reclamation. Refer Figure 2.4 (3).

Attack- The wharf boardwalk that extends out into the harbour provides the visual marker for ferries entering the site and allows users to access the boarding platform. By advancing out into the water the design intent was to create more usable space: firstly for recreation, and secondly to operate as a formal marker of the rising water level. By the year 2050 the extended boardwalk would be flooded during high tide and the ferry entrance would become disguised by the rising sea-level.

Figure 3.12
Partial Section A, illustrating the
relationship of the tidal pool complex
with the harbour (Glasgow wharf),
scale 1: 500, author's own

Design: 2nd Connector

The second connector operates as the public transport interchange between the elevated boardwalk and the aqueduct high-line at a height of fifteen meters above the site, descending to twelve meters to begin the second leg of the canal. Refer to Figure 3.20. The primary function of the interchange is to allow ferries commuting along the high-line to continue from the first stage into the second. Therefore a set of hydraulic locks on either side facilitates the lifting movement. Each lock serves to provide ferry access to the disembarking and loading decks consecutively. Refer to Figure 2.23. Pedestrian access to both decks is facilitated by entry points from the park and the existing buildings to the north and south of the site. When entering the second connector from the train station (north) users pass directly under the interchange conduit. Refer to Figure 3.21. It was the design intent to ensure a close proximity, and therefore direct engagement between the users and the fluctuating conditions periodically occurring, as ferries move in and out of the interchange at fifteen minute intervals. Refer to Figure 3.16. Figures 3.13 - 1.15 illustrate precedents that influenced the landscape and architectural detailing of the second connector.

Figure 3.13

(top): Photograph illustrating an example of a terraced elevated park terrain bridging across transport infrastructure, Weiss Manfredi - Seattle Olympic Sculpture Park.

Figure 3.14

(middle): Photograph illustrating an example of slender steel structural detailing, Calatrava - New York World Trade Centre Underpass.

Figure 3.15

(bottom): Photograph illustrating an example bridge/ observation deck detailing, OKRA Architecture - Storaa Stream development, Denmark.

Figure 3.16
Partial site plan illustrating the ferry
transport interchange from aerial
view (2nd Connector), scale 1: 500,
author's own. See Figure 3.21 for
Section C.

NEW FIRST LEVEL

SCALE 1:500

Figure 3.17
Partial site plan illustrating the
ferry transport interchange
and commercial extension (2nd
Connector), scale 1: 500, author's
own.

Figure 3.18
Partial plan illustrating the ferry
transport interchange (2nd
Connector), scale 1: 200, author's
own.

Figure 3.19
Visualisation of basement space-
extension to the Asteron commerce
centre by 2100 (2nd Connector),
author's own.

Operations:

Retreat- It is proposed to retreat the ground floor of the existing building to the south of the site (Asteron Centre) by shifting function upwards to the first floor. This action maintains the operation of the commercial hub to avoid the overflow of water within the ground floor space damaging the critical commercial block. In return the ground floor space extending into the adjoining second connector is re-appropriated, becoming a recreational breakout space with floating and fixed boardwalks. Refer to Figure 3.19.

Defend- The lowline canal running along the current pedestrian footpath area on the northern side of Waterloo Quay is located between the double façade to channel water away from the ground floor space, facilitating flood alleviation. Refer to Figure 2.49.

Accommodate- The set of hydraulic locks accommodates the movement of the commuter ferries up and down the site within the highline canal. Refer to Figure 2.47. The water is pumped around the system to provide for hydraulic lifting.

Attack- The second connector extends forward from the commercial block, bridging over Bunny Street to the low-lying park to the north. This forms the recreational space in front of the existing train station lobby, ensuring that public social space is maximised. Refer to Figure 3.21.

Figure 3.20
Partial Section A, illustrating the
relationship of the new elevated
terrain and existing ground floor
re-appropriation in front of the
commercial block (Asteron Centre),
scale 1: 500, author's own

Figure 3.21
Section C, illustrating the relationship of
the many accessible paths between the
exterior elevated park, boulevard, ferry
boarding deck and the entrance to the
transport interchange from the train
station lobby to the north, connecting
into the commerce block to the south,
scale 1: 250, author's own.

2100 Datum

2050 Datum

Figure 3.22
Sectional perspective of the ferry
transport interchange (2nd Connector),
scale 1:500, author's own.

Figure 3.23
 Enlarged sectional perspective of transport
 interchange (2nd Connector), illustrating
 the connections between the various
 accessible levels, author's own.

Design: 3rd Connector

The third connector operates as future expansion space for both university campuses within the study site, (Pipitea - Business School and the Faculty of Law). The north and south wing allow for direct access from the existing campuses into the institutional hub. Refer to Figure 3.28 and 3.29. The spaces for learning include open-plan studios with communal work stations, a lecture theatre, semi-private window cubbies for meeting opportunities and access to and from the rooftop park and eateries. Refer to figures Figure 3.28, 3.32 and 3.34. The north and south wing meet at bridge connections that span over the aqueduct high line below. Refer to Figure 3.33. The aqueduct brings commuters in and out of the site. The design intent is to provide institutional facilities for the university to expand in the future with predicted demand and also to provide social amenities at the terminus of the site, creating legibility at the boundary of the study site adjoining Lambton Quay. Refer to Figure 3.32.

Figure 3.24
(top): Photograph illustrating an example of LVL (laminated veneer lumber) structural frame, Massey University College of Creative Arts, Athfield Architects, 2011.

Figure 3.25
(bottom): Photograph illustrating an example of internal meeting cubbies (window box), Parliament Building Scotland, Eric Miralles.

Figure 3.26
(opposite page): Partial site plan, aerial view of institutional hub (3rd connector), scale 1:500, author's own, see Figure 3.33 for Section C.

NEW GROUND LEVEL

SCALE 1:500

2

3

Figure 3.27
Floor plan illustrating the layout of
the north and south wings of the
Institutional Hub at the new elevated
ground level, scale 1:500, author's
own.

Figure 3.28
Floor plan illustrating the layout of
the north and south wings of the
Institutional Hub at the second floor
level, scale 1:500, author's own.

LEVEL FOUR

KEY

- 12. Roof Park Access
- 13. Rooftop Bar
- 14. Ferry Loading Platform
- 15. Aqueduct High line +12m
- 16. Aqueduct Conduit
- 17. Institutional Hub North Wing
- 18. Institutional Hub South Wing
- 19. Bridge Access
- 20. Open Plan Studio
- 21. Collaborative Workspace
- 22. Breakout Workspace
- 23. Seminar room

Figure 3.29
Floor plan illustrating the layout of
the north and south wings of the
Institutional Hub at the fourth (top)
floor level, scale 1:500, author's own.

Figure 3.30
Axonometric illustrating the variations
of cubby arrangements offered on the
southern facade of the Institutional hub's
southern wing, scale 1:200, author's own.

Meeting cubbies

The meeting cubbies were designed to encourage collaboration throughout the four levels of the institutional hub; these range from intimate single user couches to seating and desk arrangements for a pair or a small group to use. Figures 3.30 and 3.31 show the arrangement of these various spaces based on the dimensions of the timber diamond-grid façade extrusion, which forms the threshold of each cubby. Flanking the perimeter of the studio and open-planned floor space on each level, these cubbies form additional opportunities to socialise and collaborate.

Figure 3.31
Axonometric illustrating the variations of cubby arrangements offered on the eastern facade of the Institutional hub's eastern wing, scale 1:200, author's own.

Operations:

Retreat- The third stage of the masterplan has been designed to terrace between the existing ground datum to the newly elevated park level on the north and south side of Bunny Street. This action ensures pedestrian access between the existing university campuses and the conceived institutional hub is maintained, increasing connection to the park level as the water datum rises. Refer to Figure 3.33.

Defend- The newly elevated ground level protects the existing buildings onsite from flooding by creating an infrastructural armature, integrated into the low-line canals running along the perimeter to divert water away. Refer Figure 3.32

Accommodate- The high-line boulevard enters the second section of the site at an elevated level of twelve meters, allowing direct pedestrian access into the northern wing of the institutional hub. Access to and from the aqueduct for ferry commuters is also achieved at this level. Refer to Figure 3.34.

Attack- The primary low-line canal that travels directly below the high-line aqueduct extends from the site and travels across Lambton Quay, allowing provision for future development of the water management network beyond the study site.

*Figure 3.32
Partial Section A, illustrating the
new elevated park terrain forming
entrance into the new institutional
hub southern wing, showing sectional
relationship between the open plan
studio spaces with informal breakout
and lecture spaces, scale 1: 500,
author's own*

Figure 3.33
 Section D, illustrating the spatial
 relationship of the new elevated
 park terrain to the Institutional hub -
 northern and southern wings, bridging
 over the aqueduct high-line, showing
 the informal meeting cubbies at the
 perimeter of internal floors, scale
 1:150, author's own.

Figure 3.34
Visualisation of the Institutional Hub
offering social facilities at night,
showing ferry commuters arriving at
the site to enjoy the rooftop bar and
park facility. author's own.

2100

Design Conclusions

The final design addresses the incremental rise in sea level by directly engaging a range of scales from urban masterplanning to architectural detailing: first by implementing the design of infrastructure for the extension of the city's transport systems, and secondly by engaging with the specifics of the existing buildings within the study site. Proposing a strategy for the future, the masterplan provides accessible connections that will maintain the operation of the city's critical infrastructure as the existing ground level floods. Strategically, it was not the intent of the research to ensure the form of large-scale elements within the new site intervention read as 'discrete' objects within the existing fabric of the city, but rather to assert leadership by proposing a design that articulates the fundamental operations required to successfully integrate the management of flooding within the city. The formal expression of the final design negotiates the dynamic changes that are taking place in the city and offers a visual proposition to promote new urban development opportunities. The masterplan conceived affords a design proposal that encourages the public to discuss the impending issue of flooding in coastal cities and towns around New Zealand.

The final design frees up the existing ground plane and offers an activation of a range of social spaces at elevated levels to extend the public amenities offered within the central city. The many recreational spaces are tied together by the main infrastructural canals that bisect the site. Materiality from Wellington's existing waterfront spaces was integrated into the site, through the design of a timber boulevard running parallel to the high line aqueduct at elevations of twelve and

fifteen meters, flanked by generous park space. The extension of the existing waterfront boardwalk was essential to allow the public to traverse the length of the site uninterrupted. The primary canals operate as an ordering device to provide legibility and to allow easy navigation on and off the boulevard as the public meander between the park and the water. It forms the primary formal trajectory. This trajectory punctures the current city grid as a bold formal gesture to afford a certain confrontational presence in the context of the central city site. The axis for the predominant trajectory was established early in the research in accordance with historic Maori strategies for resilience. This conflicted with the motivations of Twentieth Century European urban development that sought to occupy close proximity to the coastline in order to increase the buildable area of the city. In this manner the final design reconciles contemporary urban development with indigenous understandings of conservation ensuring the sustainable management of the city's natural and physical resources.

The current city grid is disrupted by the new network of connections created by re-linking land parcels through cross access-ways between vital functions, with contingency for the network to extend into adjoining sites. It was essential that the final design increased public links across the length of the site for pedestrian, cyclists and ferry commuters to readily access buildings to the north and south of Bunny Street. The final design of the site scheme achieves this while offering recreational, educational and commercial development opportunities within the re-appropriated streetscape.

*Figure 3.35
(opposite page): Visualisation of
design proposition in the year 2100,
with a predicted 1.5-2 meter rise in
sea level, author's own.*

Ultimately the design research sought to reconcile the commonly perceived 'threat' of sea-level rise with opportunities for 'productive' and 'creative' growth within Wellington City - initiating a dialogue towards public acceptance and ultimately triggering action, rather than dismissal or avoidance behaviours. To that end it was significant that the research depart from a unilateral remedy, but rather set up a framework to showcase how a masterplan can integrate the four main adaption strategies within a study site that contains vital infrastructure by offering options for local preparation.

*Figure 3.36
(opposite page): Photograph of a physical model showing the final design intervention in relation to the city context by the year 2100, with a predicted 1.5-2 meter rise in sea level,*

*Figure 3.37
(opposite page): Photograph of a
physical model showing the spatial
arrangement of the final masterplan
within the study site by the year 2100,
author's own.*

3.3 Conclusion

Recent history has reminded us that our natural weather systems are constantly in a state of flux, making it clear how dramatic the reality of living next to water is in coastal communities. Global sea-level rise will dramatically change the ground condition of Wellington City as the encroaching water floods low-lying regions. Wellington's waterfront and central business district are vital to the City's operation, and as such should be afforded every opportunity to proactively prepare for incremental flooding over the following century. In the decades to follow the primary focus of urban development in Wellington City will shift to address the fluctuating condition of the ground plane. Existing functions at the waterfront will be reconsidered for relocation or elevated to maintain operation, and new design opportunities will emerge.

New design initiatives will need to be implemented in stages to effectively prepare for the long-term implications of a sea-level rise in Wellington's harbour. The four main contemporary strategies: defend, attack, retreat and accommodate will play a central role in the policy planning of Wellington's urban development over the coming century and beyond. The integration of these strategies will require creative collaboration between urban designers, engineers and

architects to implement a city-wide masterplan that considers the unique condition present in the many affected sites around the city. Government leadership will be required in order for the public and private sector to reconsider the boundaries of ownership within affected sites, allowing an integrated approach when preparing for city-wide flooding.

Evidently the public perception in Wellington is forward thinking in its consideration for long-term design initiatives to be undertaken. The resulting statistic of Wellington's residents revealed a desire to begin action for preparation immediately and encourages the implementation of three of the four main strategies for adaption by the year 2050. To date these strategies have been operational in low-lying countries in Europe for a short period of time and therefore have yet to be thoroughly critiqued. However as the most recent predictions reveal sea level rise is a fast arriving reality in New Zealand's coastal cities. The challenge will be to implement the adaption strategies to achieve timely reactions to the impacts of sea level rise incrementally. Local councils will be required to closely analyse the implications of each adaption approach and develop suitable combinations, informing new designs around the city where appropriate.

A Critical Review of Process and Outcome

The design process and approach the research undertook began by understanding the implications of sea-level rise, as made evident by the most recent scientific projections. It was imperative to establish accuracy of the research by examining the potential environmental implications that the extensive flooding of Wellington's waterfront and central business district will cause. The complex scope of the research problem presented a challenge when distilling ideas to academics and practitioners reviewing during the conceptual design phase. This was overcome by implementing a top-down approach, whereby a collapsing of scales from urban to architecture was achieved. The masterplanning directly engaged design at a strategic level; the project constraints and opportunities presented by the resulting final masterplan informed the design of architecture for the three envisaged connection nodes.

A study site was established early in the research in order to test experimental design in relation to site-specific programme and constraints. The study site provided a framework within which to test experimental design and therefore the specific conditions within the chosen study site played a central role in shaping the final design

*Figure 3.38
(opposite page): Photograph of a
physical model showing the design
intervention, showing the final
masterplan, author's own.*

outcome. It was therefore critical to select a site that encompassed vital infrastructure and public amenity, that if neglected would subsequently be rendered unusable due to flooding. The central city site of Bunny Street provided this framework as a contentious space within the city affording a range of design constraints and programmatic imperatives. While a boundary was overlaid upon the study site for practicality, the masterplan negotiated this threshold by providing contingency for the water management network envisioned to extend along the adjoining avenues, spreading across the central city, eventually creating a connective network.

The final design outcome examined how the development of new urban infrastructure could modify a site within Wellington's central business district to engage directly with sea-level rise over the following century. Significantly the predominant challenge presented within the research was designing within a framework to achieve not only a physical transition of the city's built fabric from existing land-based functions towards operations that remained responsive to a fluctuating ground condition, but further to negotiate a shifting social awareness. The design approach sought legitimacy in the early stages of the research from contemporary international case studies, and extrapolated the four main adaption strategies discussed in recent literature. From this foundation the research tested the role of infrastructure and architecture to design for climate change. Essentially conceptual design examined approaches for preparation of coastal cities predicted to be inundated by a global rise in sea-level during the following

century. The subsequent final developed design outcome triggers further discussion and asserts leadership by provoking a conversation that appears to be neglected at present. The future of New Zealand's coastal cities will be shaped by dynamic infrastructure and architecture that offers an alternative approach to the static arrangement of city blocks at present. This will require extensive financial investment. To afford such a huge financial undertaking local councils and national government will need to carefully consider the integration of new infrastructure with opportunities to increase public amenity and offer commercial development within the affected sites.

A limitation of the final design outcome is that it presents only one particular scenario in which Wellington City adapts and prepares for flooding. Various combinations of the four adaption strategies could be employed in accordance to site-specific constraints; this would significantly impact the outcome. Therefore the design operates as a catalyst for further exploration. Sea-level rise presents an unprecedented opportunity for Wellington city to address its changing natural environment and reconsiders methods of urban development, creating a space for explorative design to emerge. As such the research is situated in the current gap between theoretical urban planning and progressive international projects.

As a future stage of this design investigation, but beyond the scope of this thesis, it would be useful to develop a framework offering a variety of design options for each of the four adaption approaches. This would provide the foundation

for future design initiatives to emerge encouraging ongoing development. Following more research it is hoped that local councils will assert leadership and take immediate steps to prepare the city's waterfront region for flooding, in order to maintain the recreational connection that Wellington's residents enjoy at the threshold of the harbour.

Sea level rise will extensively change the face of the world's coastlines, the outcome of which will be largely dictated by the extent to which coastal cities prepare themselves for the encroaching water. In order to envision a vital urban future for New Zealand's capital city we must challenge our current mode of urban development and address our temporal relationship to the sea.

Figure 3.39
(opposite page): Photograph of a physical model, showing the new proposition in relation to the city geotechnical context, author's own.

GRAPHISOFT AWARDS 2013

Thank you to all those who supported me through this final year of adventure, a special thank you to my family, especially dad, who built a kick ass display case and Arthur Mahon for helping with the stressful preparation for this event.

04

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List of Figures

Appendix

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Appendix A1.

Figure 4.1
Map illustrating the depths recorded to reach hard-bedrock below Wellington City.

A2.

Table 3: Wellington Region population and population projections 2006 to 2031

	2006		2031		Percentage Change	
	15-24 Years	Total Population	15-24 Years	Total Population	15-24 Years	Total Population
New Zealand	571,176	4,027,947	639,810	5,089,470	12.0%	26.4%
Wellington Region	65,790	448,956	66,840	529,000	1.6%	17.8%
Kapiti Coast District	4,386	46,200	5,150	60,700	17.4%	31.4%
Porirua City	7,017	48,546	6,600	53,400	-5.9%	10.0%
Upper Hutt City	5,070	38,415	4,910	40,400	-3.2%	5.2%
Lower Hutt City	13,413	97,704	12,840	104,000	-4.3%	6.4%
Wellington City	31,680	179,466	33,880	231,700	6.9%	29.1%
Masterton District	2,754	22,623	2,110	22,400	-23.4%	-1.0%
Carterton District	735	7,098	650	7,420	-11.6%	4.5%
South Wairarapa District	732	8,889	700	8,960	-4.4%	0.8%

Source: Population Projections 2007 (2006 base), Statistics New Zealand

Note: For more information about the population projections data, see the Data Dictionary.

Figure 4.2
Table of data illustrating the
projected population from the
year 2006 to 2031. Wellington
City Council, 2013.