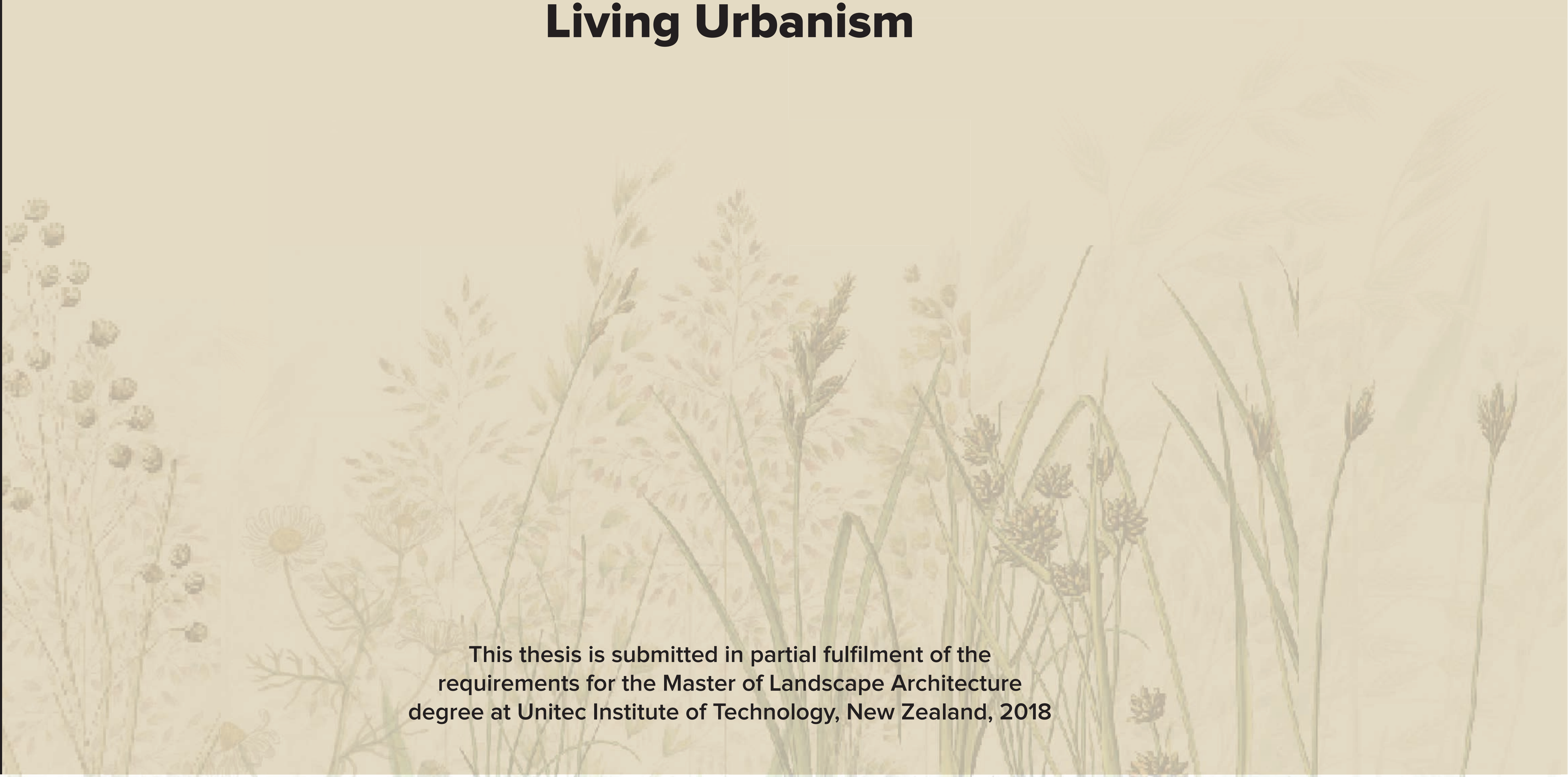
Living Roofs
+
Living Urbanism



This thesis is submitted in partial fulfilment of the
requirements for the Master of Landscape Architecture
degree at Unitec Institute of Technology, New Zealand, 2018

MASTER OF LANDSCAPE ARCHITECTURE | by Design - **Zoë** Avery 2018

Abstract

This research investigation poses the question, how could the development of a Living Roof Design Manual increase the effectiveness of living roof design?

Living roofs are becoming increasingly common in cities throughout the world for their ability to improve climate change adaptation, energy conservation, food production, and the potential to develop more sustainable and environmentally friendly living environments. Rapid population growth, advanced stages of urbanisation and the alteration of natural environments defined by increments of hard surfaces, along with pollution and a lack of contact with nature, underline the importance and relevance of green infrastructure solutions, such as living roofs. Despite this, in New Zealand, living roofs are rarely included in developments, and if they are, most are being designed in isolation. They are often disconnected, inaccessible, consist of vegetation monocultures, lack robustness, and are inappropriate for the location. This investigation, which is comprised of three phases, aims to identify strategies for addressing these deficiencies. Phase One comprises of a literature and precedent review, which seeks to define the current situation, in Europe and locally, in terms of existing knowledge and practice. Phase Two consolidates the findings from Phase One, and focuses on the Northland region of New Zealand, to form a 'Living Roof Design Manual' for the city of Whangarei. The investigation culminates in Phase Three, with a living roof design for the Hundertwasser Art Centre in Whangarei that utilises the manual to optimise living roof outcomes.

Figure 1: Xeronema flower (Photograph reprinted with the permission of Renee Davies)

Declaration

Name of candidate: Zoë Avery

This Thesis/Dissertation/Research Project **entitled: Living Roofs + Living Urbanism**

is submitted in partial fulfillment for the requirements for the Unitec degree of

Master of Landscape Architecture (by Design)

Principal Supervisor: Dr Hamish Foote

Associate Supervisor/s: Matthew Bradbury

Candidate's declaration

I confirm that:

- This Thesis/Dissertation/Research Project represents my own work. Note: the case study in this investigation, the Hundertwasser Art Centre living roof in Whangarei, is a real-world project and as such involved interdisciplinary collaboration. The author acknowledges the following contributions:
  a) Plant list and species. Living Roof Design Manual. Pages 58-64. Co-authored with Renee Davies - Zoë Avery worked collaboratively with Renee Davies to develop the plant list.
  b) Design. Hundertwasser Art Centre Living Roof and site landscaping. Pages 70-100. Designed by Zoë Avery. Reviewed by Renee Davies.
  c) Plans, elevations, sections and perspectives. Hundertwasser Art Centre living roof. Pages 75-84; 91-92; 94-97. Designed by Zoë Avery. Reviewed by Renee Davies. Drawn up (not designed) by CAD technician Sam Hendrikse.
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Candidate Signature: Date: 15 November 2018

Student number: 1407415

Acknowledgements

for Jon, Forest & Paz

Many thanks to Fred Tschopp Jr. and the New Zealand and California Tschopp family for granting me the Fred Tschopp Senior Scholarship; to my supervisor, Dr Hamish Foote for his guidance and belief that I would one day finish this Masters; to all of my family, friends and colleagues for their support, encouragement and professional wisdom; and most importantly, to Jon, Forest and Paz - for with their love and support I was able to complete my MLA whilst having two babies and retaining my love and passion for landscape architecture, urban design and planning.

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1.0 INTRODUCTION. KUPU ARATAKI

Living roofs are a form of green infrastructure that sit within the complex web of landscape, urban built form, nature, people, place and identity. These systems have significant relevance for pressing global issues related to rapid population growth, urbanisation and alteration of natural environments defined by increments of hard surfaces, pollution and people's increasing lack of contact with nature (Milliken, 2018). Research shows that people benefit from contact with other living things, the places where we engage all five senses - touch, taste, sight, smell and sound (Franco, Shanahan, & Fuller, 2017). We are also riding the largest wave of urban growth in history, with more than half of our world's population now living in towns and cities. This number is expected to swell, adding 2.5 billion to the world's urban population by 2050 (United Nations, 2018). Yet urban environments have inadvertently disconnected us from this important psychological need, and although we are beginning to understand this impact, we are still creating 'hard' spaces with limited opportunities for nature (Dover, 2018).

There is a need to develop a blend between built form and nature - the healthy spaces and places that are good for our hearts and minds - as well as ensuring functionality. Green infrastructure can improve the appreciated quality of urban areas noticeably, providing environmental, social and economic benefits while helping us build resilience into our urban fabric (European Commission, 2015). As the Austrian artist and architect, Friedensreich Hundertwasser (1928-2000) noted, "When one

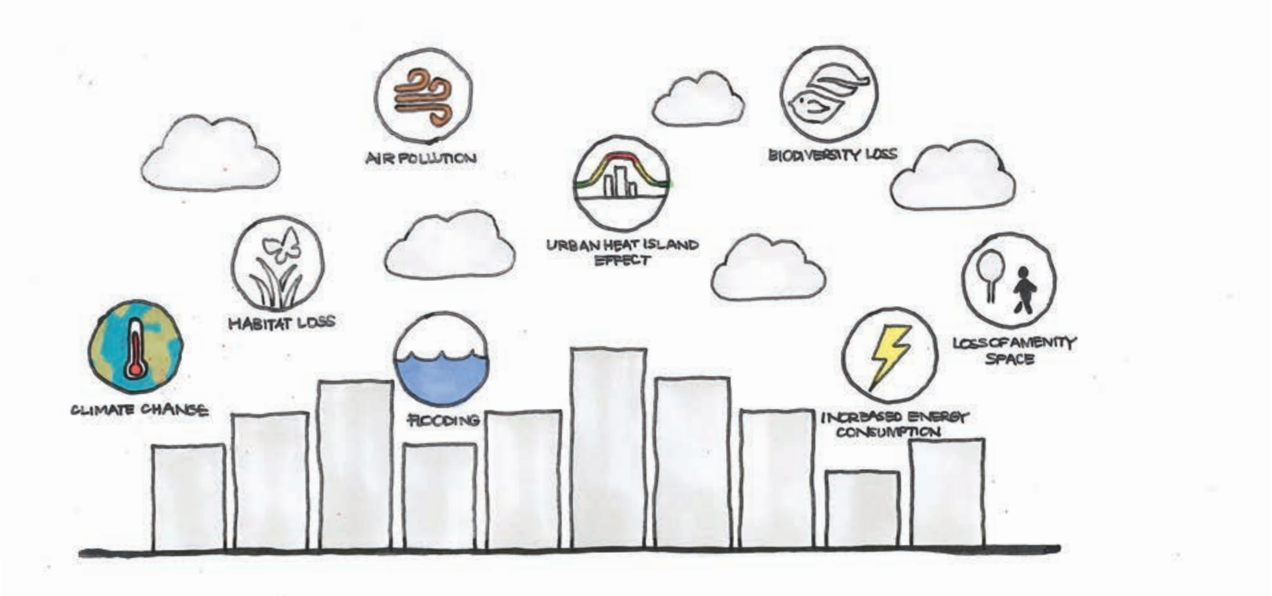


Figure 3: Negative impacts from urban built form

Figure 2: : Residential living roof, Auckland

creates green roofs, one doesn't need to fear the so-called paving of the landscape: the houses themselves become part of the landscape. People must use the roofs to return to nature what we unlawfully took from her by constructing our homes and buildings – the layer of earth for grasses and trees." However, there is still a lack of living roofs being incorporated into urban developments in New Zealand, and even where they are, most are being designed in isolation from the wider environment, resulting in living roofs that are disconnected, inaccessible and monocultures, poorly designed, ineffective, not robust, or inappropriate for the location. It is possible that the lack of living roof uptake in New Zealand does not relate solely to increased cost or perceived risk, but to a lack of knowledge about their benefits and of how the particular design of living roofs translates into such benefits (Curry & Larsson, 2017).

1.1 Question

How could the development of a Living Roof Design Manual increase the effectiveness of living roof design?

1.2 Aims and Objectives

The overarching aim of the present research is to reveal how living roof design can be developed to enhance the benefits for humans, the built environment and nature. The following objectives, across three phases, are integral to the design research process:

Phase One: Theory and Precedents

- To outline living roof typologies and benefits for humans, the built environment and nature informed by the literature.
- To identify living roofs in Europe and New Zealand and critically analyse those design characteristics that facilitate or prevent effectiveness. Note: effectiveness is defined in section 1.3. These characteristics will inform and lay the foundation for a Living Roof Design Manual, proposed in Phase Two.

Phase Two: Living Roof Design Manual - Whangarei

- To develop a Living Roof Design Manual, based on findings from Phase One, and populate this manual with Northland-specific information, to inform design considerations with the aim of enhancing benefits for humans, the built environment and nature.

Note: the Living Roof Design Manual is to be comprised of a set of criteria that can be utilised universally; in the present project, the content is Northland-specific.

Phase Three: Design - Hundertwasser Art Centre Living Roof

- To utilise the Living Roof Design Manual - Whangarei at the proposed Hundertwasser Art Centre site, to maximise benefits for the urban landscape, nature and our lives.

Figure 4: Photograph of Hundertwasser Haus, Vienna

1.3 About the Researcher

For over 19 years, I have been working on sustainable development in New Zealand and the United Kingdom, including the encouragement of green infrastructure through planning and policy development. I have a Bachelor of Planning with Honours from the University of Auckland and am currently studying for a Masters in Urban Design.

I am a Principal at 4Sight Consulting Limited, a planning, landscape and environmental services consultancy. I am also a Board Member of Green Roofs Australasia, the leading Australasian provider for education, advocacy, research, and professional development on living roofs and living walls, and Director of Living Roofs New Zealand, an independent organisation that encourages environmentally sustainable design. My personal and professional values are founded on the principles of an equitable society, in terms of economic, social, ecological and cultural capital. With a technical planning background and an environmentally-focused mind-set, I work with Councils, developers, architects and landowners to provide urban planning and landscape advice on developments, design and policy.

The present research project was drawn from a personal curiosity about why living roofs are rarely included in developments in New Zealand, and where they are, most are being designed in isolation from the wider landscape, resulting in living roofs which are disconnected, inaccessible monocultures, poorly designed, not robust, and therefore ineffective or inappropriate for the location. In a previous role as Major Projects Officer at the Environment Agency in London, I was surprised at the number of living roofs we secured by way of planning permissions - approximately 22 hectares south of the River Thames in two years. The impact that these living roofs had on the urban fabric of London was impressive, and I was especially astonished by the social impact these roofs had, connecting people to nature. I have always had a love of nature and a recognition that humans were impacting negatively on the natural environment. Now I believe that this love of nature is inherent in all humans. Exposure to vegetation is known to have positive effects on our feelings of wellbeing (Gesler, 2003, p. 2) and to reduce stress levels, health inequalities, anxiety, tension and postoperative recovery time (Luck, Davidson, Boxall, & Smallbone, 2011).

The field of design can be expressed in three main orders according to varying spatial scales. The first order is the scale of the site, the object that relates to the professions of landscape architecture and architecture. The third order is the scale of the neighbourhood, the city and/or the region, relating to the profession of planning. The second order is the discipline in-between, creating a bridge between the first and third orders of design. It involves identifying the first-order site-specific design outcomes that are necessary to achieve the third order expectations. This second order is the principle domain of urban design (George, 1997).

"It is clear after all that urban design is an interdisciplinary activity. If professionals from different disciplines of the built, natural, and social environments work together in teams, they create an urban design process. Similarly, if urban space is to be shaped and managed by any professional, there will be a need for multi-disciplinary concerns and awareness. The key is to go beyond the narrow boundaries of professions and disciplines and approach urban space from an interdisciplinary, socio-spatial perspective" (Mandipour, 1997, p. 376).

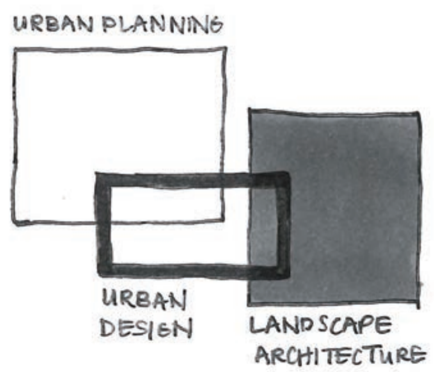


Figure 5: Urban Design as bridge between and intersecting landscape architecture and planning

As urban design could refer to any kind of design of the built environment, of varying scope and scale, and crucially deals with the in-between spaces, urban design and landscape architecture are important disciplines when considering living roofs. The connections between landscape and built form are commonly discussed where 'green infrastructure' is now common in the language of contemporary landscape architecture.

Living Urbanism

Through my current role at 4Sight Consulting Limited, I have been exploring how we can integrate living roofs and green walls better as urbanistic systems into our cities, considering urban population growth. When thinking about living roof morphological aspects, it is important to describe the notion of integrating human wellbeing and sustainability alongside design process and urban functionality. 'Living urbanism' is a concept I have developed to address this. It is comprised of a set of design principles that reflect the sensory connection of humans with the built environment and nature in order to help design green infrastructure that maximises benefits. It is concerned with creating spaces that connect the urban fabric to people and to nature – creating spaces that are healthy and enjoyable to live, work and play in. In this context, living urbanism is defined as the sensory connection of humans with the built environment and nature.

Living urbanism design-led principles, I propose, will help us better integrate living roofs into our urban landscapes to maximise benefits. The key principles, drawn from urban design, are permeability (Hillier & Hanson, 1984), legibility (Lynch, 1960), concentration (Bacon, 1976), diversity (Jacobs, 1961), sustainability

(Carmona, Sustainable Urban Design: Definitions and Delivery, 2009) (McHarg, 1996), identity (Relph, 2007), accessibility (Gehl, 2010), and robustness (Carmona, Tiesdell, Heath, & Oc, 2010). Case studies in this investigation are analysed through this lens and in conjunction with theory, lay the foundation for the proposed manual.

Throughout this research, an objective was to avoid idealising living roofs, as I had some preconceptions about how valuable they could be, as I understood a number of the benefits through my experience as practitioner. I wanted to investigate which constraints were myths and which were grounded and relevant. These processes provided a significant insight into the realities of how living roofs could be designed in a way that was feasible and the genuine scope of possibility for multi-functional benefits that these landscapes offer.

1.4 Methodology

Research design

The research was undertaken in three phases:

Phase One: Theory and Precedents - Literature and Precedent Review

This phase of the research explores living roof typologies and the benefits of living roofs as they relate to the built environment, humans and nature. Twenty living roof case studies were analysed through the lens of 'living urbanism' - an integrated set of principles drawn from urbanism for the purpose of improving the effectiveness of living roofs. Eleven case studies from Europe and nine from New Zealand were analysed in terms of the extent to which they clearly reflect an instance of living urbanism. This framework allows for a critique that encompasses the human dimension, as well as normative technical aspects.

Phase Two: Living Roof Design Manual - Whangarei

Phase Two aimed to develop a Living Roof Design Manual. This tool reflects the findings in Phase One and is populated with data specific to Whangarei, to inform design considerations to improve benefits realised on the built environment, humans and nature. As part of this phase, the research explored site analysis considerations, potentially appropriate exotic and native plants, which might be suitable for Whangarei and on-going considerations in terms of maintenance, all of which might inform the design response.

Phase Three: Design - Hundertwasser Art Centre Living Roof

The third phase utilised the Manual at the proposed Hundertwasser Art Centre site, to explore how such a manual may influence the design response, improve the effectiveness of design, and help to reveal the potential living roofs present to improve our urban landscapes and our lives.

Data collection and analysis methods

The research used a mixed approach including quantitative and qualitative data collection and empirically based on the case studies. Empirical data were collected from research papers, books, a policy document review, and site visits. Document review included government reports, planning legislation, policy documents, and government regulations. Site visits were undertaken in Europe in September 2012 and in New Zealand in 2017 and 2018. These site visits focused on living roof design, morphological aspects and benefits realised. Limitations to the methodology included a lack of secondary data from the European case studies including plant species, substrate mix and costs.

Figure 6: Photograph of sedum living roof, Emporia, Malmo

2. PHASE ONE: THEORY AND PRECEDENTS

Background

Living Roofs

Living Roofs + Living Urbanism

Case Studies

2.0 PHASE ONE: THEORY AND PRECEDENTS

Living roofs could be referred to as interstitial spaces in the urban fabric of cities (Jorgensen & Tylecote, 2007), where urban design crucially deals with these in-between spaces (Phelps & Silva, 2018). As such urban design and landscape architecture are important disciplines when considering living roofs. Hence the determination in this investigation to utilise principles of urban design, in the analysis and design of green infrastructure. It became apparent early on in this project, that a review of theory and the analysis of living roof morphology, would need to describe the notion of integrating human wellbeing and sustainability alongside design process and urban functionality. Living urbanism, which concentrates on the sensory connection between humans, the built environment and nature, is a means to this end.

This research is focused on living roofs as a green infrastructure solution that can provide the multitude of benefits; helping the urban environment to adapt to the effects of climate change (Li & Babcock, 2014); enhancing biodiversity (Kadas & Gedge, 2005); alleviating stormwater runoff and flash flooding (Ercolani, Chiaradia, Gandolfi, Castelli, & Masseroni, 2018); creating aesthetic green space (Jungels, Rakow, Allred, & Skelly, 2013); providing a habitat for wildlife (Braaker, Ghazoul, Obrist, & Moretti, 2014); reducing the urban 'heat island' effect (Peck & Richie, 2009); creating savings in energy consumption (Castleton, Stovin, Beck, & Davison, 2010); and, most importantly, an opportunity for beauty and nature to be brought into what is otherwise a hard and under-utilised space in our cities (Ambasz, 2014).

Phase One analyses the morphological aspects and benefits of twenty living roof case studies through the lens of living urbanism. These are an assemblage of roof spaces designed for a mixture of recreational, commercial, educational and residential use, highlighting diverse identities, cultural narratives, local ecological systems, and each specific area's planning framework. Diverse building typologies were assessed, including morphological aspects, vegetation and use, in terms of the principles of permeability; concentration; diversity; sustainability; identity; accessibility; robustness; and legibility. Findings highlighted the design problems with existing living roofs in New Zealand and revealed a lack of local design knowledge and information available. This analysis provides a catalyst for the development of a Living Roof Design Manual to help inform design considerations in relation to living roofs.

2.1 Background

Figure 7: University of Auckland research living roof

Green infrastructure is concerned with the complex set of relationships between landscape, urban built form, nature, people, place and identity. Living roofs have significant relevance with pressing global issues related to rapid population growth, urbanisation, and the alteration of natural environments defined by increments of hard surfaces, pollution and people's lack of contact with nature. It is increasingly argued, as previously stated, that people need contact with other living things, the places where people engage all five senses - touch, taste, sight, smell and sound (Franco, Shanahan, & Fuller, 2017). Spending time in nature can improve people's health, which makes sense given that, until very recently, most of the human evolutionary path took place in nature. Human brains are still adapted to being a part of nature, yet urban environments have inadvertently disconnected people from this important psychological need and although we are beginning to understand this we are still creating hard spaces with limited opportunities for nature (Vujcic, et al., 2017).

Human kind is riding the largest wave of urban growth in history with more than half of the world's population now living in towns and cities. This number is expected to swell to five billion, or 60% by just 2030. With more people living in cities globally, the state of the urban environment will directly influence quality of life. While cities occupy only five percent of the worlds land surface, they consume 75% of its natural resources and account for 80% of global greenhouse gas emissions (United Nations, 2016). There is increasing understanding of "human beings as the major consumer organism in all the world's ecosystems" (Rees, 1997, p. 65).

The problem is that cities have more hard surfaces, less green space and less permeable areas and this reinforces the disconnect from nature while also creating more surface runoff and flash flooding, along with interrupted or damaged ecological systems and processes. That is not to say cities are inherently bad, but it highlights that sustainability and wellbeing challenges must be resolved in cities. This is important because productivity is directly linked to wellbeing and 85% of global domestic product is generated in cities - places that arguably are not fit for human physical and psychological needs (United Nations, 2016).

There is a growing interest around the world in green infrastructure as a toolkit for integrating nature with built form and people. Where the common approach has been parks and open spaces, or street trees, more recently rain gardens, green and vertical walls and living roofs have added to the palette of opportunities. Living roofs can improve potential because, as described above, they have so many layers of benefit (Hopkins & Goodwin, 2011).

Worldwide living roofs are being prioritised and promoted by local, regional and national governments via a mix of guidelines, policy and incentives (Malina, 2011). This movement has promoted living roof installation and the uptake of green infrastructure. High-energy use cities are urban systems that create a range of negative outcomes for people and the environment, generating pollution and heat from commerce, industry and transportation (Milliken, 2018, p. 19). These impacts occur alongside the retention of the solar energy by buildings and hard surfaces that creates a warmer city environment (Dover, 2018, p. 6).

The apparent lack of living roofs being incorporated into urban developments in New Zealand may not relate solely to increased cost or perceived risk, but to a lack of knowledge surrounding the benefits and how the design of living roofs translates into the benefits achieved.

2.1 Living Roofs

Living roofs are simply intentionally vegetated roofs and include ornamental roof gardens, naturally vegetated roofs and biodiversity roofs (Grant, 2006). The types of roof range from the commonly seen extensively vegetated to intensively vegetated roofs. They are classified in different categories according to three main aspects: the intended use, physical properties (depth of substrate), and maintenance requirements (European Federation of Green Roof Associations, 2018). Closely linked in green infrastructure are living walls and facades, which are an intentionally vegetated vertical space that can either, be internal or external to a building. Living facades can have climbing plants growing on them or structures attached to the walls specifically designed to foster species able to thrive in such a condition (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V., 2008).

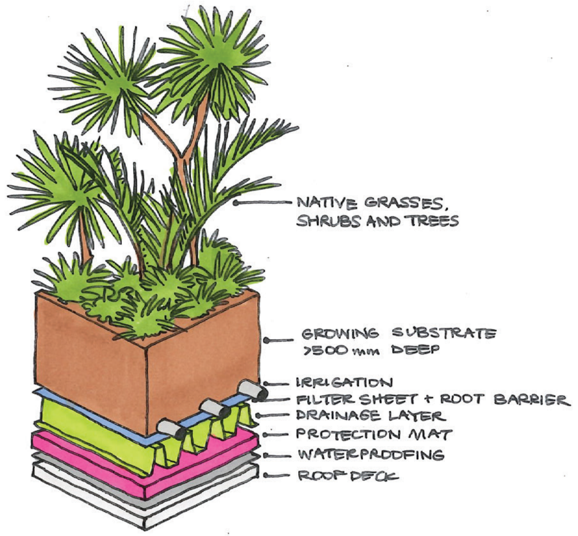


Figure 8: Intensive Living Roof Typology

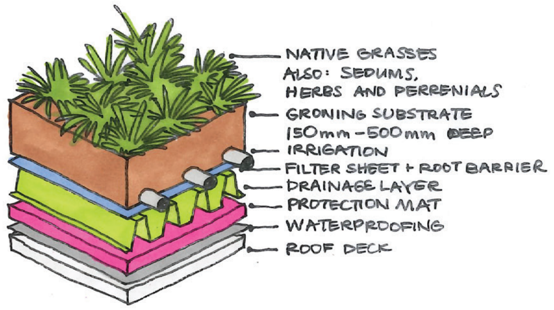


Figure 9: Semi-Intensive Living Roof Typology

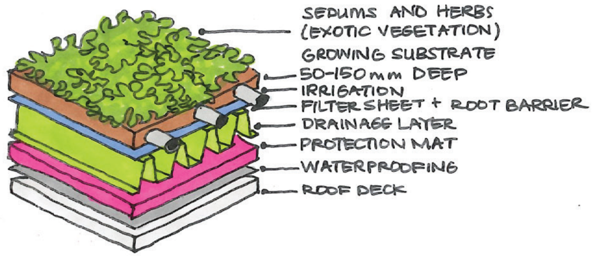


Figure 10: Extensive Living Roof Typology

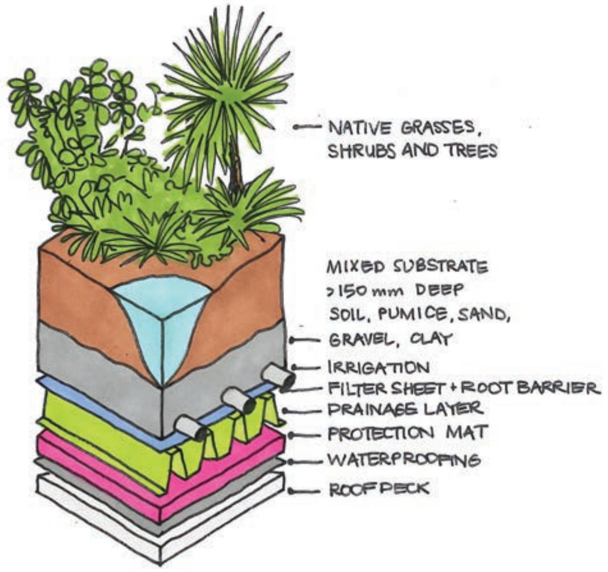


Figure 11: Biodiverse Living Roof Typology

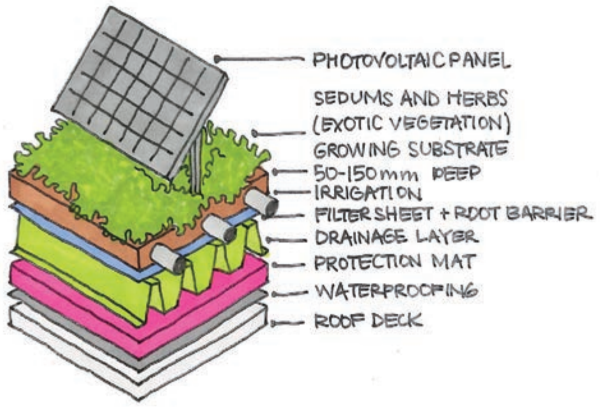


Figure 12: Bio-solar Living Roof Typology

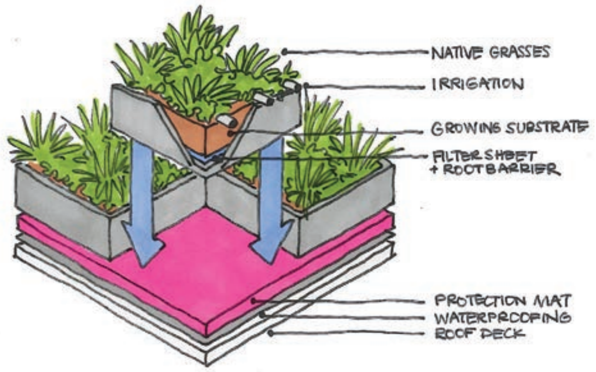


Figure 13: Modular Living Roof Typology

Living roofs can blend beauty and function. The multifaceted outcomes delivered by living roofs not only address non-human life within the city, but extend to engagement with human processes. This co-facilitation leads to a more resilient city providing for the inherent adaptability of city residents, both human and non-human in a changing world (Milliken, 2018, pp. 23-24).

Figure 14: Concept of living roofs and walls mitigating loss of green space

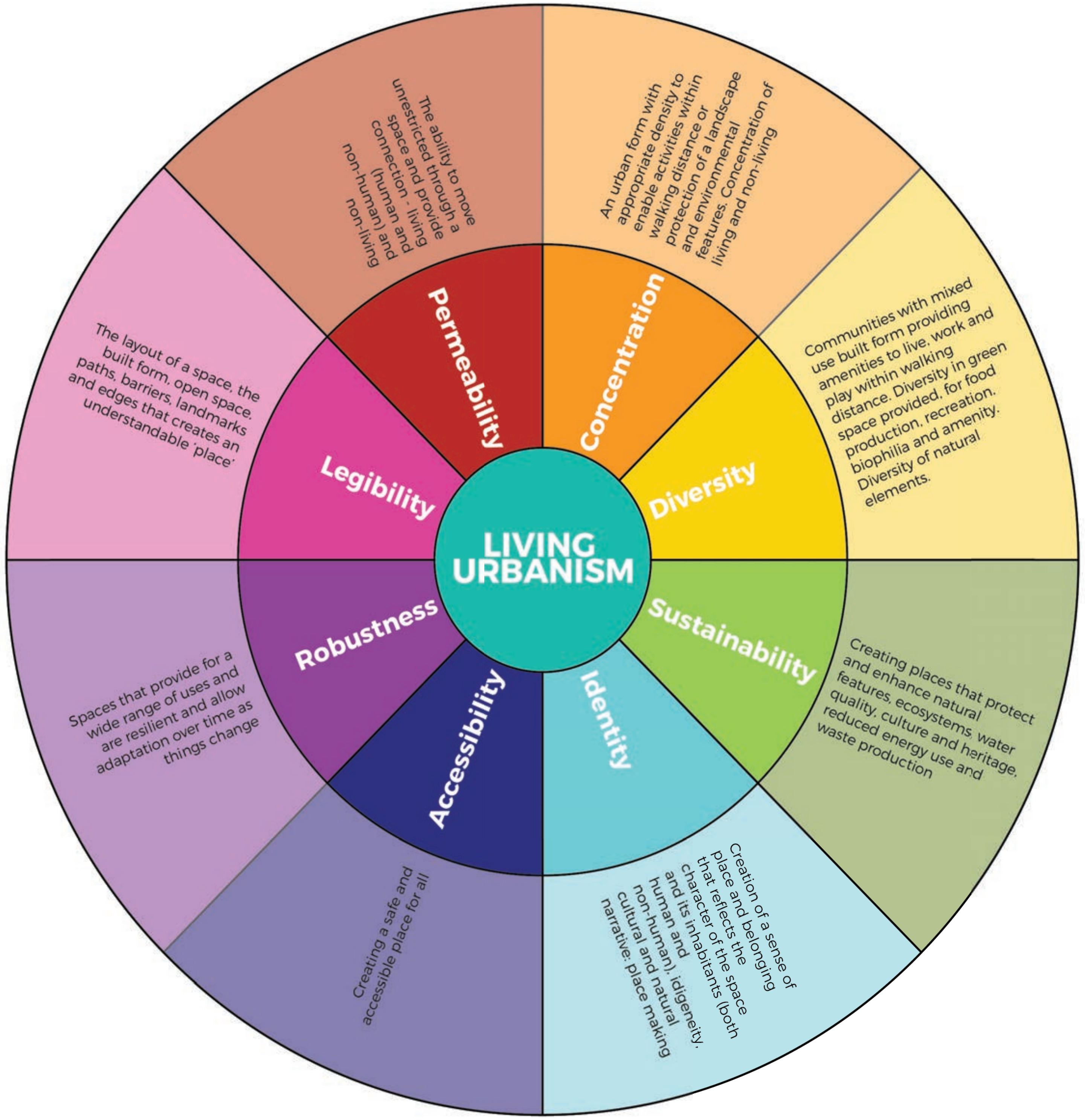
2.3 Living Roofs + Living Urbanism

The living urbanism principle (drawn from urbanism) of identity allows beauty and local stories to be embedded into design for the benefit of the urban dweller. Living urbanism's eight design-led principles, as illustrated in Figure 11, provide a means for integrating living roofs into our urban landscapes with the potential to maximise benefits.

Permeability is the ability to move unrestricted through a space and provide connection between the living (human and non-human) and non-living. "All functions relate to the form of the city through two generic functional factors: how we as individuals find the city intelligible, and how we move around it." (Hillier, 1996, p. 113).

Legibility is the layout of a space, the built form, open space, paths, barriers, landmarks and edges that creates an understandable 'place' (Lynch, 1960).

Concentration and dispersal of the living and non-living link to many realised benefits with living roofs. These include improved health and wellbeing, by enabling activities within walking distance, and protection of a landscape and environmental features, to connect people with nature. Exposure to vegetation is known to have positive effects on people's feelings of wellbeing, stress levels, health inequalities, anxiety, tension, and postoperative recovery time (Luck, Davidson, Boxall, & Smallbone, 2011).



The ability to move unrestricted through a space and provide connection - living (human and non-human) and non-living

An urban form with appropriate density to enable activities within walking distance or protection of a landscape and environmental features. Concentration of living and non-living

Communities with mixed use built form providing amenities to live, work and play within walking distance. Diversity in green space provided, for food production, recreation, biophilia and amenity. Diversity of natural elements.

Creating places that protect and enhance natural features, ecosystems, water quality, culture and heritage, reduced energy use and waste production

Creation of a sense of place and belonging that reflects the character of the space and its inhabitants (both human and non-human), idigeneity, cultural and natural narrative: place making

Creating a safe and accessible place for all

Spaces that provide for a wide range of uses and are resilient and allow adaptation over time as things change

The layout of a space, the built form, open space, paths, barriers, landmarks and edges that creates an understandable 'place'

Figure 15: Living Urbanism Principles

Sustainability benefits are far-reaching, with one benefit being the reduction in heating and cooling bills (Mowad, 2008). These systems can act as a natural insulator, helping keep heat out and reducing the need for air conditioning in summer (Berardi, Ghaffarianhoseini, & Ghaffarianhoseini, State-of-the-art analysis of the environmental benefits of green roofs, 2014). Planting can further reduce energy costs by providing shade and relief from summer heat. Naturally, vegetation and substrate lose water through evaporation and transpiration, which has a further cooling effect in summer (Lundholm, MacIvor, MacDougall, & Ranalli, 2010). In winter, living roofs act as another insulation layer, helping keep the warmth in the building, and as such reduce heating demand and costs. Research undertaken in Toronto estimated that there could be a $21 million energy saving from the implementation of a citywide living roofing scheme, based on annual energy savings of 4.15 kWh/m2 (Banting, Currie, & Verrati, 2005).

Diversity on living roofs relates to a mix of plant species, creating spaces and landscapes that enhance the local areas biodiversity, providing food for insects, birds and humans (Oberndorfer, et al., 2007). This creates benefits for the community with mixed use built forms, providing amenities to live, work and play within walking distance. Diversity in the green space provided on living roofs achieves this benefit, creating interstitial spaces for food production, recreation, biophilia, and amenity (Papageorgiou & Gemenetzi, 2018). This principle also relates to the provision of diverse natural elements, incorporation of a mixed species list to avoid monocultures, and use of logs and clay banks for different species and habitat creation (Walker & Lundholm, 2018).

Legibility of a living roof relates to the layout of the space, how the living roof relates to the built form, surrounding open space, paths, barriers, landmarks, and edges, which all work together to create an understandable 'place'. The design of path locations and connections to the edges of the building can inform how users relate to the wider landscape, and how they connect, at height, to the broader built environment and landscape (Falcidieno, Ruggiero, & Castellano, 2014).

Robustness considerations for a living roof relates to maintenance across changes in building ownership and activity use. As such, designing living roof spaces that provide for a wide range of uses, are resilient, and allow adaptation over time, as things change, is beneficial to the efficiency of the living roof.

Accessibility of a living roof is concerned with creating a safe and accessible place for all. This is important when considering universal accessibility, or access to the living roof in the event of a fire. When designing a living roof, the access to and from the roof is important and this translates into plant selection and irrigation when considering the types of plants alongside fire escape paths. Several forms of access to the roof are available, including ramps and stairs (see Appendix 2). **Identity** benefits are extremely important for areas, where living roofs can create of a sense of place and belonging that reflects the character of the space and its inhabitants (both human and non-human), reflecting indigeneity, cultural and natural narratives, which all assist in place-making (Pitt, 2014).

2.3.1 Benefits. Painga

Living roofs protect the roof membrane from UV and weather damage and can extend the roof life by as much as two or three times (Chain Store Age, 2006). They can add to property values by providing additional and more marketable living space, increasing rents by up to 16% (Ichihara & Cohen, 2011), and can save a significant amount of energy by reducing heating and cooling bills through insulation of the building, which reduces energy expenditure and carbon emissions (Berardi, The outdoor microclimate benefits and energy saving resulting from green roofs retrofits, 2016).

With global temperatures changing, these systems also offer a cheap way of reducing the urban 'heat island' effect (Horwitz-Bennett, 2013). They can reduce noise levels entering and leaving the building by up to 18 decibels (dB) and reflective noise by 3 dB or more (Van Renterghem, 2017).

Living roofs are a form of sustainable drainage, replicating natural drainage patterns, reducing stormwater runoff and flash flooding through stormwater attenuation (in many cases up to 70%, depending on substrate depth), where stormwater is soaked up by the soil and vegetation and gradually released back into the atmosphere and drainage system (Fassman, Voyde, Simcock, & Wells, 2008).

Living roofs can provide a valuable public amenity for residents and workers, and improved views from surrounding buildings (Ichihara & Cohen, 2011). Importantly for developers, they raise a company's green credentials and are an effective way to demonstrate corporate social responsibility.

The potential benefits are far-reaching, as shown in the Living Urbanism benefits diagram below. Throughout the proposed Manual, the different interconnected benefits, highlighted with icons, will be shown alongside the relevant projects.

Living Urbanism Benefit	Economic	Environmental	Social
Increased employment from local food production	✓		✓
Reduction in transportation of food with associated air pollution, greenhouse gases, traffic, etc	✓	✓	✓
Reduction in the frequency of combined sewer overflow events	✓	✓	✓
Reduction in the frequency of flooding	✓	✓	✓
Reduce stormwater runoff	✓	✓	
Improved markets for recycling plastics - reuse of waste materials	✓	✓	
Improved markets for compost and recycled aggregates - reuse of waste materials	✓	✓	
Lower energy in overall system	✓	✓	
Improved thermal performance - insulatating and cooling	✓		✓
Reduced patient care costs in health facilities	✓		
Replacement cost savings on public buildings	✓		
Increase in life expectancy of pipes and other grey infrastructure	✓		
Reduction in costs of erosion control	✓		
Increase in property values with a corresponding return in property taxes to the city	✓		
Increase in employment from design, manufacture, installation, maintenance and new uses	✓		✓
May assist planning process	✓	✓	✓
Extended roof life	✓		
Improved whole life cost of building	✓	✓	
Compliment photovoltaic panels	✓	✓	
Reduction in associated health care costs from improving air quality and reducing heat	✓		
Contribution to savings on power plants and transmission infrastructure	✓		
Energy savings in building and resulting greenhouse gas emission reduction	✓	✓	
Reduce water storage requirements and drainage infrastructure on site	✓		
Increased amenity	✓	✓	✓
Increased recreational space and opportunities, such as bird watching	✓	✓	✓
Improved human health (physical and mental)	✓	✓	✓
Improvements to work environments/workplace productivity	✓		✓
Improved vistas	✓		✓
More liveable environment for citizens and less heat related stress			✓
Sound insulation - less noise entering and leaving buildings	✓		✓
Biophilically satisfying noises (like wind rushing through grass)			✓
Cooler more enjoyable streets and public space			✓
Healthier and more productive population	✓		✓

Figure 16: Living Urbanism Benefits

Less crime and associated policing, judicial and incarceration related expenses	✓		✓
Increasing community cohesion	✓		✓
Increase in walking, cycling, gardening and running			✓
Beautifying unattractive building features			✓
Opportunities for artistic expression			✓
Educational/Urban nature experiences	✓	✓	✓
Improved biophilia and therapeutic value of additional natural space		✓	✓
Greater food security	✓		✓
Improved biodiversity		✓	
Improved water quality		✓	
Receiving waters become more fishable, swimmable, drinkable		✓	✓
Greenhouse gas emission reductions		✓	✓
Less smog formation		✓	✓
Reduction in particulate matter in the air		✓	✓
Plants and growing media can sequester carbon		✓	
Provide a habitat for wildlife		✓	
Contribute to reducing climate change effects	✓	✓	✓
Contribute to reducing Urban Heat Island effect	✓	✓	✓
Reduction in landfill waste	✓	✓	
Pollination by insects, particularly bees		✓	
Increased environmental building rating score	✓	✓	

Figure 16: Living Urbanism Benefits (cont.)

2.3.1.1 Increase in Property Values

The provision of a living roof can result in increased property values because of the following:

- Enhanced aesthetic appeal;
- Increased marketable floor space, in the case of accessible living roofs; and
- Lower building operating costs.

It is being shown that living roofs are beneficial in terms of workplace productivity, recruitment and staff retention (Loder, 2014). It is also being shown that the more attractive and environmentally friendly a building is, the more sought after it will be, and therefore higher leases and property values can be demanded (Ichihara & Cohen, 2011).

Canadian research estimates that buildings with a recreational living roof can achieve an 11% increase in property value, and buildings with views onto living roofs may have a 4.5% increase in property value (Tomalty & Bartek Komorowski, 2010).

At a broader scale, overseas studies show that aesthetics and biodiversity in an urban context appeal to city dweller (Qiu, Lindberg, & Nielsen, 2013), and that green infrastructure will be essential to the long-term sustainability of city environments (Pinho, et al., 2016).

Key Findings

- The design of the living roof in terms of aesthetics and accessibility can contribute to increased property values, and as such should be a key design consideration in the Manual.

2.3.1.2 Financial Savings/Improved Building Performance

Energy Savings

As stated, living roofs can reduce insulation requirements, energy demands and associated costs. Research undertaken in Toronto estimated that there could be a $21 million energy saving from the implementation of a citywide living roofing scheme, based on annual energy savings of 4.15 kWh/m² (Banting, et al., 2005). Studies in Germany and the United States also suggest that cities can have significant energy savings from the introduction of living roofs (Castleton, Stovin, Beck, & Davison, 2010).

Environment Canada has undertaken research showing that the upper floor of a building with a living roof is likely to save 20% of its energy demand through reduction in cooling needs. A five-storey or higher building in summer could save in the region of 6% and a two-storey building in summer, would be between 10-12% (Environment Canada, 2008: Dr Brad Bass, personal communication, March 2016).

Thermal performance

Due to the insulating properties discussed above, studies have shown that the membrane temperature beneath a living roof can be significantly lower than where the membrane is exposed.

Temperature fluctuations during spring and summer on a conventional roof were of the order of 45°C, whereas under a living roof the fluctuations were in the order of 6°C (Karen Liu, 2013).

The reduction in membrane temperature fluctuations, in conjunction with protection from sunlight, frost and other weather damage, means that a living roof can extend the life of the membrane by two to three times, thus providing further cost savings over the life of the building.

Extended roof life

Living roofs protect the roof membrane from ultraviolet and weather damage, which in turn can extend the roof life by two or three times. The installation of a living roof can therefore save the client money by doubling the life of the waterproof layer. In Germany, the first living roofs were created by covering wet bitumen with 60mm of sand. These roofs subsequently became naturally vegetated, where vegetation spontaneously self-seeded.

Sound insulation

Living roofs can act as a significant barrier for sound. The components of a living roof system, from the soil, vegetation and drainage layers, all act to either absorb, reflect or deflect sound waves. Studies suggest that a living roof can reduce sound compared to a standard roof (Galbrun & Scerri, 2017). Urban areas that suffer from high levels of noise pollution, such as buildings within flight paths, could benefit from the installation of living roofs.

Whole life costs

Living roofs can benefit the 'whole life' cost of the building. Whole life costing is an investment appraisal and management tool which assesses the total cost of an asset over its whole life (The Chartered Institute of Public Finance & Accountancy, 2011). Limited research is available on this matter, but recent research in London has shown a benefit to the whole life cost of a building with the incorporation of a living roof (Feng & Hewage, 2018).

Increase Environmental Rating Score

NZ has an independent green building rating system called 'Green Star NZ and Homestar NZ',that promotes better buildings, because better buildings mean healthier, happier people (The New Zealand Green Building Council, n.d.). Living roofs are the only system that, when introduced, provide points in Green Star and Homestar NZ rating tools. Living roofs can provide more benefits than living walls and the benefits could be extended, providing more points from energy and ecology to emissions. For example, under 'Homestar V4', living roofs and living walls can contribute up to a higher score in the native ecology (if they are planted with native species) and on-site food production (vegetable gardens and fruit producing plants) credits. Depending on the type proposed, living roofs can also receive an innovation score. As such they can easily increase the score achieved in the tool.

Key Findings

- Improved building performance and the resulting financial savings are apparent for any living roof designed.
- The thermal performance is dependent on the site location, substrate depth and type of plants used.
- In terms of achieving the highest increase in environmental rating score, innovation in design is another key consideration for the Manual and could reveal a number of additional components to include on the roof (such as beehives, solar panels, native plants and vegetables), using the living urbanism principles as a guide.

2.3.1.3 Improvements to Stormwater Management

Living roofs are one system used in water sensitive urban design (Razzaghmanesh, Beecham, & Kazemi, 2012). Stormwater management is a common issue we face in our cities. Most of our existing urban drainage systems are currently at capacity (Quinn, 2016), many having been designed so long ago and as a system of combined surface water and waste water (Sharman, Captin, Miselis, & Davis, 2012).

If a sustainable drainage or low-impact design approach is taken as part of a development, it ensures the site is not increasing surface water flood risk or polluting the environment.

The three key factors in the sustainable drainage approach are:

- Quantity of surface water run off;
- Quality of surface water run off;
- Amenity benefits.

The nature of climate change at a regional level will vary in New Zealand. Projections of future climate change indicate that there will be more frequent, short-duration, high intensity rain (Ministry for the Environment, 2018).

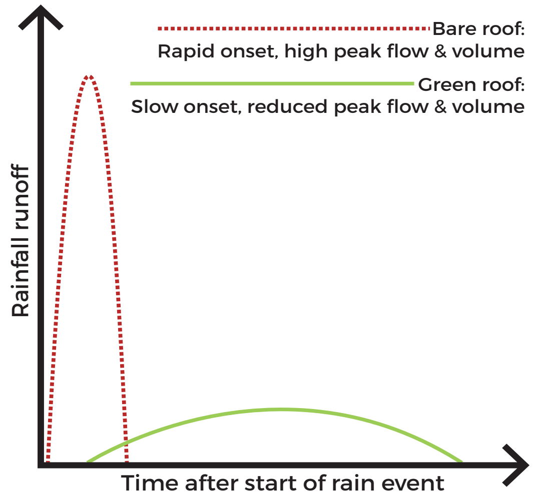


Figure 17: Rainfall event on a living roof vs standard living roof

Extreme rainfall is likely to increase in most areas, with the largest increases being seen in areas where mean rainfall is also increasing, such as the West Coast.

Living roofs may reduce the water storage requirements and drainage infrastructure on a site.

Key Findings

- Living roofs have multiple stormwater management benefits, reducing runoff and improving the quality of runoff, and can result in financial savings by reducing water storage and drainage infrastructure requirements on site. This reduction in storage requirements and drainage infrastructure are highlighted as design objectives for consideration in the Manual.
- Anticipated climate change effects for rainfall events, as they relate to Whangarei, may inform the drainage layer choices.

2.3.1.4 Human Health & Wellbeing

Biophilia is proposed as an innate and genetically-determined affinity that human beings have with the natural world, with evidence that contact with greenery or vegetation provides benefits to humans (Heerwagen & Hase, 2001). Reduced stress levels and cleaner water and air have been attributed to the provision of green space (Richardson, Pearce, Mitchell, & Kingham, 2013).

As described by Dusty Gedge, director of LivingRoofs.org and president of the European Green Roof Association:

> "A Texan study of post-surgery recovery in hospitals demonstrated that recovery was quicker and had less chance of relapse if patients could look out onto green space. Many American hospitals have subsequently been redesigned to bring these benefits to patients, and have been rewarded with greater patient 'through-put'.
>
> A roof on the Kanton Hospital in Basel was redesigned 20 years ago by vegetating it, as it was felt that patients in intensive care would benefit from looking out onto this rather than the existing grey space. A few community hospitals in the United Kingdom (UK) are now being designed with greater consideration of green space provision. The good practice work on hospital design being developed by the Commission for Architecture and the Built Environment (CABE) is likely to support this.
>
> The thermal benefits that green roofs provide may also have indirect benefits for people living or working within the building. This has not been researched, but anecdotal evidence from Germany in the late 1990s is of interest. In a

survey of staff absence through sickness at the Bundepost offices in Stuttgart, staff in one building demonstrated significantly lower absences than those in others. The only change in the 4-year period that could be identified was that one of the buildings was given a green roof. This building supported lower staff sickness levels. It is possible that the green roof reduced the fluctuation of daily mean temperatures within the upper levels of the building, and/or the vegetation helped cool and moisturise in-coming air near ventilation ducts.

In the past 2-3 years, possibly picking up on the increasing interest in green roofs and the UK government's interest in green space, developers are increasingly showing green roof space as a component of their new commercial development proposals. The provision especially of accessible green roof space for future workers appears to be gaining currency, and could help off-set the likely constraints of green space provision on the ground" (Gedge, 2018).

Key Findings

- Connection with nature can improve health and wellbeing, highlighting the key design consideration of having an accessible or visible living roof to obtain this benefit. This is highlighted as one of the design objectives for consideration in the Manual.
- To ensure a strong connection to nature, additional components such as clay banks to provide a habitat for solitary bees, logs or dead wood for insect habitat, bird and bee attractors, access over vegetation and views to the roof, enhance nature on the roof. Living urbanism principles can act as a guide in the selection and design process.

2.3.1.5 Green Space, Amenity & Vistas

Our appreciation of an area can be significantly increased by the installation of living roofs (Veisten, et al., 2012). This is apparent when looking over the roofscape of Whangarei – i.e. there is almost unlimited potential for the greening of roof environments.

It is important to provide aesthetic green space for people living, working or visiting Whangarei. Living roofs can provide visually appealing green space, visually soften the built environment, and help people's mental and physical health. They have an important ecological role, supporting biodiversity, and providing a 'sense of place'.

Within urban centres there is a need for increased residential densities as cities continue to grow in population and expand in area. As residential infill occurs, there is a loss of aesthetic green space and amenity. Living roofs are a solution to help mitigate these adverse effects.

Whangarei's rooftops can be seen as an under-utilised asset. Living roofs can provide valuable recreational resource. The Michael Hill Golf Course living roof is an example of where a living roof installation provides significant visual aesthetic mitigation. Recreational green space has been provided on living roofs all over the world, Jubilee Gardens at Canary Wharf Station in London is a prime example.

London's Kensington Roof Gardens, built in 1938, provide gorgeous aesthetic recreational space in the middle of a heavily populated city. Cannon Street station is another example of an intensive roof garden in the heart of London.

Living roofs can significantly improve local vistas. This can be of value when adding extensions to dwellings or commercial buildings and visual mitigation is required at the planning stage.

Key Findings

- Visual mitigation or aesthetic improvements is a benefit. These should be highlighted in the design objectives of the Manual.
- The ability to use local species, relevant to the local landscape, can create a 'sense of place', enhancing the identity of the roof space with the city of Whangarei. This should be reflected in the Design Manual plant list, which includes species from the Whangarei Ecological District.
- Accessibility of green space is important and should be reflected in the Manual as a potential design objective.
- Another key consideration for the Manual is including components, on the roof to enhance green space and provide diversity. These can include playgrounds, recreational space, walkways, access, and seating areas, with living urbanism principles serving as a guide.

2.3.1.6 Biodiversity & Habitat Creation

Living Roofs can provide significant biodiversity benefits enhancing sustainability. Many countries use living roofs as mitigation for the loss of habitat. Switzerland has moved towards introducing living roof systems that mimic natural habitats found locally (Kazmierczak & Carter, 2010).

Living Roofs can improve biodiversity by providing much needed green space especially in industrial or commercial areas. They create new green links/corridors for species to network and move along. They may also provide a mosaic of habitats for endangered plants, invertebrates and birds (Mayrand & Clergeau, 2018). Living roofs can provide connections across cities that short-range species would not be able to cross otherwise. This is important in ensuring populations do not become isolated.

It has been demonstrated that to create an invertebrate rich living roof, you need to consider varying substrates, varying depths, different local plants and incorporation

Figure 18: Bere House, Islington, London, UK (Photograph reprinted with permission from Dusty Gedge)

of dry wood or rocks for habitat (Brenneisen, 2006).

“Although gardenesque in character such roofs can provide a significant resource for local biodiversity with good planting schemes. These should include some native and certainly include flowering plants that are of known foraging value for bees. Inclusion of water features, dead logs and nest boxes can increase the potential for such roofs to act as a resource for local wildlife.” (reference Dusty Gedge, personal communication, July 2017).

Key Findings

- In relation to Whangarei, living roofs could connect the forest areas of Parihaka and Pukenui for species. As a result, bird, insect and lizard food plants should be included in the plant list of the Manual as they can create living roof habitats and enhance biodiversity providing diversity.
- Incorporation of sun, shade, minimum substrate depths provide a minimum design guide to ensure species success across the roof.
- To achieve addition Green Star points, the use of beehives, solar panels, native plants and vegetables can provide additional “Innovation” points and should be included in the Manual as a consideration.

2.3.1.7 Urban Air & Water Quality

Vegetation and soil have been proven to help filter pollutants and dust from the air and water (Wang, Qin, & Hu, 2017). Wetlands are being trialled on living roofs in the United Kingdom, which can provide sustainability helping filter and treat water (Thuring, 2007).

Key Findings

- Plant selection can contribute to an increase in urban air and water quality and as such should be a key design consideration in the Manual.

2.3.1.8 Food Production

Living roofs are being considered more for food production, with the increasing cost of food transportation and reducing “food miles” (Walters & Midden, 2018). Inner city market gardens are being installed in Europe, the US and China and more often and more widespread are living roofs used for hydroponic or container food production. On occasion, this approach has been expanded to include living walls and facades, with fruiting climbing plants as a means for food production.

Living roofs are particularly important for densely populated cities where space is at a premium. Singapore, China and the United States have many thriving food producing living roofs (Ehrenberg, 2008). The incorporation of beehives on rooftops is also becoming more common throughout the world to support and enhance the urban bee population (Hofmann & Renner, 2018).

Key Findings

- Potential for food production should be a design consideration in the Manual.
- The Manual and could reveal beehives and food production as potential additional components to include on the roof, linking back to the living urbanism principles.

2.3.1.9 Climate Change Adaptation

Urban Heat Island Effect

Our urban areas have a higher average temperature than our rural areas (Zhao, Lee, Smith, & Oleson, 2014). The urban heat island effect is the term used to describe the difference in these temperatures. With the effects of climate change taking hold, the number of hot days we experience in our cities will increase along with our reliance on air conditioning. Living roofs are a proven technique to help mitigate the urban heat island effect (Susca, Gaffin, & Dell'osso, 2011).

The two most recognised methods for reducing the urban heat island effect is to:

- Introduce more vegetation into the urban environment which will provide shading and cooling through evapotranspiration.
- Increase the albedo or reflectiveness of roofs to reflect a higher amount of solar radiation back into the sky, thereby producing less heat.

Living roofs are now commonly being used overseas to mitigate the effects of the urban heat island effect.

Key Findings

- Although living roofs are commonly used overseas to mitigation effects of climate change – this is not a design consideration for the Manual for Whangarei.

Figure 19: Biosolar living roof in Friberg, Germany (Photograph reprinted with permission from Dusty Gedge)

2.3.2 Case Studies. Ako Take

2.3.2.1 New Zealand Living Roof Case Studies

New Zealand Aotearoa is an ideal context in which to analyse living roofs through the lens of living urbanism, as there is currently no policy, guidelines or incentives provided by local, regional or national governments. New Zealand has been very slow compared with European countries to increase the number of living roofs, and in recent years the industry has slowed, if not halted. During this time, government bodies have not promoted the uptake of living roofs, beyond some briefly mentioning the benefits that can occur in terms of stormwater management and aesthetics, with one technical document focussing on this benefit for shallow substrate, lightweight, inaccessible roofs (Auckland Council, 2013), and one demonstration project in Waitakere, Auckland (Waitakere City Council, 2007).

The Auckland City Centre Masterplan (2012) detailed objectives that reference the inclusion of living roofs, with the possibility that certain areas in the central business district (CBD), including bridges, will be designed with living roofs. One outcome sought in the Plan is that the city will be an “exceptional natural environment and leading environmental performer” (Auckland Council, 2012, p. 39), with the indicator of increasing the number of living roofs and walls. Since this document was published, only living walls and façades have been installed within the city centre (R. Davies, personal communication, June 11, 2018).

Christchurch City Council adopted the Central City Plan for the redevelopment of Christchurch following the 2011 earthquakes with the expectation that new buildings might incorporate living roofs. This framework document included the aim to encourage living roofs in the central city through projects, incentives and best practice guides, including at least five demonstration projects from 2017 at a cost of $10 million (Christchurch City Council, 2011). These local government documents have been New Zealand’s first planning documents to mention the incorporation or potential requirement for living roofs.

Urquharts Bay Toilets

This living roof was designed as a biodiversity living roof on a public toilet block at the entrance to Bream Head walk, on Department of Conservation land. The living roof is partially visually permeable and is legible in terms of the native plant species chosen for the location.

This roof was not designed to be accessible, and in terms of maintenance can only be accessed via a ladder and a harness clip station that was included following completion, for maintenance of the roof. In terms of diversity, sustainability and identity, the common thread was the use of native plants, found locally and appropriate for the location and landscape, resulting in a living roof that was appropriate for the landscape. In terms of living urbanism, this roof does not score well, being mainly designed for aesthetic

Figure 20: Native semi-intensive living roof, Urquharts Bay, Whangarei Heads, NZ as viewed from the bank behind in context of surrounding landscape

benefits and lacking a strong sense of legibility, accessibility and visual permeability for the location.

Key Findings

Legibility – One of the Urquharts Bay project drivers was to create an aesthetic living roof, but this is not reflected in the design. The design consideration was not translated into a roof, which showed a lack of permeability and legibility, with the height of the building and roof pitch falling away from the visible façade. The importance of ensuring design considerations reflecting the site locale is further highlighted by the location within the steep landform surrounding the building and the roof not being physically accessible.

Buckleton Beach Shed

The Buckleton Beach shed has a semi-intensive living roof located on a new boat shed building, with the planting taking inspiration from both its coastal location, and from known successful New Zealand natives that have been used as living roof plants to create a native living roof, which has botanical and visual links with the adjacent coastal garden design. Buckleton Beach Shed is visually and partly physically permeable, especially from the dwelling to which it serves as an extension to the living area, providing a partly accessible outdoor private open space over the new boat shed. The native planting is protected from access, with only the grassed lawn being accessible for recreational use. This roof provides some diversity of natural elements in terms of planting suitable for the location and grass for play space, creating a sense of residential open space amenity for users. Alongside sustainability benefits of stormwater attenuation, added biodiversity with native plants and noise attenuation, this living roof creates a sense of place for the owners and an identity in what would otherwise be an unusable space with no access.

Figure 21: Native living roof diverse species mix, Urquharts Bay, Whangarei Heads, NZ (Photograph reprinted with permission from Renee Davies)

Key Findings

Accessibility and **legibility** - The aesthetic design consideration for this roof translated into the provision of access onto the roof. This further enhanced the benefits achieved by creating a space from which to gain views out over the water, and creating a recreation space extending the living areas of the adjoining residential house, thereby providing identity, legibility, accessibility and diversity of use.

Figure 22: Photograph of native portion of living roof, Buckleton Beach, Tawharanui, NZ (Photograph reprinted with permission from Renee Davies)

NZI Building

This living roof creates an elevated space for staff and client respite from city life with the space for seating, connection to the wide landscape and an area to entertain visitors and guests that displays a good sense of legibility and identity. Seating and planter boxes provide some accessibility, connection and a sense of identity being easily read as a commercial recreational space available for staff and clients. There is limited diversity of planting with exotic sedums being used due to the very thin substrate on the roof as a result of structural loading constraints. Nonetheless, this roof provides some diversity of social elements in terms of seating and places to sit and enjoy vistas out towards the city and harbour. In terms of sustainability, the benefits are limited to reduced stormwater runoff, where any surplus rainwater is used for flushing toilets.

Key Findings

Robustness – The thin layer of substrate, 50-75mm thick and designed to this medium weight loading, has resulted in structural loading constraints whereby a very limited amount of species can grow on the roof and be successful, namely sedums. This case study revealed the importance of understanding what plants can survive in what level of substrate as this informs aesthetics and robustness of the roof to change over time.

Legibility, Accessibility and **Identity** – has been achieved to a degree with the incorporation of access for staff, a seating area and planters.

Figure 23: Photograph showing exotic planting on extensive living roof, NZI Centre, Fanshawe Street, Auckland

Mt Difficulty Winery

Mt Difficulty Winery's living roof was designed on a new building to create a temperature-controlled and aesthetic space that would fit into the surrounding Central Otago landscape. The roof provides visual permeability with the use of locally appropriate native grasses over the 900m2 roof, which is viewed from the restaurant and wine-tasting cellar door above. However, the roof was constructed using a modular living roof system and as such provides no accessibility or physical connection, albeit not being physically constrained with handrails or barriers. The living roof provides a sense of identity with the winery logo detailed in the landscape planting on the roof, but is not legible in terms of restricting access to avoid damaging the roof.

The main driver of the project was sustainability, where temperature control, being a vital component of the wine-making process, was a key factor in the design of the building. The building was set into the earth hillside and a 150mm deep roof of native plants was installed on the insulated roof slab, in an effort to keep the temperature constant and correct. The resulting energy requirement has been reduced primarily to increase or reduce the temperature artificially for the wine-making process. All of the process water from the wine-making is used to irrigate the roof, reducing loading on the onsite wastewater plant. Rocky outcrops were strategically placed onto the living roof to encourage habitat successfully for the local Cromwell geckos.

Figure 24: Native modular living roof, Mt Difficulty Winery, Cromwell, Otago, NZ

Key Findings

Robustness – The use of modular trays for the living roof system resulted in a living roof that does not have any formal access through it. This case study revealed the importance of understanding what living roof systems are available and how these translate into the future robustness of the roof, especially when the roof area is physically accessible.

Permeability, identity and **sustainability** are principles that have been achieved, reducing heating and cooling costs with the living roof insulating the wine barrel store, keeping it at an ambient temperature. Use of plants in the form of the company logo created a sense of identity.

Waitakere Civic Building

The Waitakere civic building living roof was designed to demonstrate the range of sustainable benefits of living roof technology. In terms of sustainability, the native plants used are reflective of species found in the local Waitakere environment. The sustainability benefits achieved are stormwater management, habitat creation and amenity, when viewed from certain parts within the office building. The high-embedded energy of the imported clay balls from Germany was not necessary, with an established understanding that local pumice stone is a suitable substrate component for living roofs.

Figure 25: Native living roof, clay ball substrate and viewing room, Waitakere Civic Centre, Henderson, Auckland, NZ

The living roof is visually permeable from a limited number of rooms within the building and provides a viewing room that is not readily or easily accessible to staff, visitors or the public. No access is provided to the roof, apart from for maintenance. The roof is legible in terms the native plant selection, but not legible in terms of paths, connections and its orientation to the building itself, severely restricting its connection or ability to be seen.

Key Findings

Permeability, legibility, accessibility and **sustainability** – Visual and physical access to the roof is importance to create identity and create a 'sense of place'. This living roof is not visually permeable from ground level or easily within the building. It has a separate small room that is not linked to the main building thoroughfare or offices, and as such has limited connection for the public and staff, resulting in a lost opportunity to connect people with nature and potentially improve workplace productivity. Understanding substrates available within New Zealand is also important to incorporate into the Manual.

Potters Children's Garden Entrance

An extensive living roof is located at the entranceway to the Children's Garden at the Auckland Botanic Gardens. The planting on this living roof has been designed for maximum visual impact, utilising plants that showcase outstanding form and colour, creating a sense of identity as the gateway to the garden. The roof slopes towards the road, and although the roof is not physically accessible, its proximity to large flat boulders allows the roof to be visible from some vantage points. All the plants are exotic but are known to thrive on living roofs with a shallow substrate. This living roof does not provide any sustainability benefits beyond education, due to its design being based around aesthetics only. However, this treatment and use of flowering plants ensures that the living roof is legible in terms of its setting within the Botanic Gardens.

Figure 26: Exotic flowering plants on entrance to Children's Garden, Auckland Botanic Gardens

Key Findings

Identity, permeability and **legibility** – Although this case study related only to an entranceway, it revealed the impact that living roofs can have in creating an identity to a space with the use of a colourful plant palette and visual permeability. Colour and texture of plants are an important element in the design of living roofs and should be detailed in the Manual.

Potters Children's Garden Toilet Block

An extensive living roof is located on the roof of the Children's Garden toilet block at the Auckland Botanic Gardens. The planting on this green roof has been designed to showcase native plants and complement adjacent native landscaping, so it provides legibility in terms of plants and is visually permeable due to the slope of the roof. This living roof forms part of a stormwater treatment train where rainfall is discharged to a swale planted with sedges and rushes, and then drains into a pond. The tussocks and *Libertia* were immediately visible, while the *Muehlenbeckia* and *Coprosma* blended into the substrate. The use of high visibility plants was essential for this public site to act as an educational tool on sustainability and ensure some identity and legibility were achieved. This was achieved through clustering and the use of contrasting plant colour and texture. The roof, albeit successful in terms of sustainability, does not achieve permeability beyond visual accessibility or robustness.

Key Findings

Identity – Although this case study related only to an entranceway, it revealed the impact that living roofs can have in creating an identity to a space with the use of a colourful plant palette and visual permeability. Colour and texture of plants is an important element in the design of living roofs and should be detailed in the Manual.

Wiles Ave Studio

This living roof was designed to incorporate the site's herb garden, being one of the only sunny places on the section. It is an area that is overlooked by a bedroom and the neighbour's deck, so was designed to be aesthetic. This roof provides some permeability, identity and legibility, with stairs for access, paths and raised beds, and a mix of edible species providing colour and texture. In terms of sustainability, the roof provides stormwater attenuation, helps suppress noise from the wood workshop's noisy equipment below, and provides food. Due to the thin substrate depth, fertilisers are used, resulting in elevated nutrients in water runoff and soil replacement required for longer-term maintenance.

Key Findings

Legibility – The incorporation of vegetables and herbs in raised garden beds in a residential setting is legible and provides a level of sustainability, creating food production in interstitial spaces. The location of the paths in between planted beds alongside the use of a different substrate to visually demarcate areas to walk enhanced the roof's legibility.

Figure 28: View of gardens beds and formed paths in-between

Figure 27: Mix of native planting on toilet block providing texture and contrast of form and colour, Auckland Botanic Gardens

Wiles Ave Carport

This living roof was designed to test native and non-native plants and demonstrate techniques to manage drought stress and stratify a roof by microclimate. With a substrate depth of 20-200 mm, it successfully shows a mix of exotic and native species that can survive on a thin substrate extensive roof. The sustainability benefits include stormwater attenuation, biodiversity and research. The roof provides visual permeability and a sense of identity, as the roof acts as a striking entrance to the dwelling. Access is limited to maintenance.

Key Findings

Permeability, Legibility and **Diversity** – The diversity of plants trialled on the thin substrate roof enhanced the visual permeability and effectiveness. Due to the site's topography, the roof was visually permeable and legible at the entrance to the site, creating a visual screen from the vehicles and service area below.

Figure 29: Mix of native and exotic plants on extensive living roof carport, Auckland

2.3.2.2 European Living Roof Case Studies

A number of cities in the UK, Demark, Switzerland, Austria, United States (US), Canada, Germany, China, Australia and Japan promote green roofs through a combination of demonstration projects, legal frameworks, financial grants, policy incentives, and design guidelines (Carter & Fowler, 2008). "Germany has installed about 130km2 of living roofs and is installing them at a rate of approximately 13km2 every year" (Grant, 2006, p. 4). Case study sites in Europe were visited in 2012 and have been analysed in terms of living urbanism.

Hundertwasser Haus, Plochingen

This mixed-use development housing, comprising 16 commercial units and 64 residential units, included a number of living roofs, variously extensive and intensive, some publicly accessible and others private for sole residential use. The main living roof was both visually permeable and connected by a series of paths, linked to street level on two different roads, with numerous access points via stairs and directly to surrounding mixed uses. The common living roof was extremely legible with clear access points and barriers (permeable gates) delineating private versus public space. Extremely good concentration was achieved with planted areas having a mix of forms and heights designed for different uses, creating different zones outside in the common areas, which create robustness. This concentration of robust areas for play and connection to nature, connection to residential dwellings and space for community engagement, is extremely good. It also creates an active space where the uses provide passive surveillance of a common living roof.

Key Findings

Permeability, legibility, concentration and diversity – This living roof, was permeable on a number of levels, is in a central location with many adjoining uses, overlooking and connecting to the entire development. Although some parts were for residents use only, those spaces are delineated from public use with the use of visually permeable gates. Concentration was achieved with a mix of planted areas, forms and heights, paved areas, recreation uses – places to play and areas of respite with more diverse planting and enclosure.

Nine Houses, Earth House Estate

Earth House Estate is a nine-dwelling residential development in Dietikon, Switzerland, with intensive living roofs covering all nine dwellings. These roofs are visually permeable from within the development, the surrounding streets and adjoining park. The roofs are very legible in terms of the shape and number of dwellings alongside the type and organic form of the landscaping surrounding the roofs. There is a good concentration of native and exotic plant species on the roof and diversity of natural and hardscaping elements suitable for the residential development. The living roofs are effective in terms of sustainability by

Figure 30: Photograph showing common living roof in centre of development with mix of planting, paths, passive surveillance from adjoining mixed of uses, Hundertwasser Haus Plochingen, Germany

creating enhanced natural features, noise attenuation for dwellings, stormwater attenuation benefits, biodiversity, and residential amenity benefits. The development has a strong sense of identity created through the use of building and private open space form and a mix of plants.

Key Findings

Permeability, accessibility and **robustness** – Nine Houses shows a link between permeability, accessibility and robustness when considering living roofs that have slopes, where most roofs are limited in terms of access and permeability, while the slope dictates plant selection.

Figure 31: Streetscape view of Nine Houses, Switzerland

Therme Vals

Therme Vals is a pool and spa facility located in a small rural village, Vals, in Switzerland. The building is constructed from the local stone, half built into the hillside and further integrated into the landscape with the incorporation of a grass meadow roof. The roof is visually permeable from the surrounding uses, especially the hotel complex that is part of the facility and overlooks the Therme Vals building. The roof is also permeable in terms of the local farmed landscape. It is partially accessible and connects visitors to it with the incorporation of a visually transparent and minimalistic handrail that encourages visitors to walk up on the roof and as far as is safe. The use of the visually permeable handrail allows connection to the small village of Vals and hillside beyond.

Along with the building being embedded into the hillside, the living roof has no edges and skylights act as fissures in between the concrete slabs, connecting light to the pools below. The limited access to half of the roof allows for extremely concentrated elements, where planted areas can be on shallow substrate with a thin and uncomplicated design. Extremely good concentration and dispersal of access, and a lack of urban features, together create connection to nature and the local environment. Alongside amenity benefits, good sustainability benefits are achieved in terms of enhanced biodiversity, stormwater attenuation and noise attenuation.

Key Findings

Legibility and **concentration** – Therme Vals revealed the importance of a strong design brief that balances concentration and dispersal. The uncomplicated living roof blends beautifully with the architectural elements of the light wells, creating fissures that provide light into the building below. This connection, reflected in the materiality of the balustrade, allows access to view the roof design, wildflower meadow roof and Swiss hillside landscape beyond.

Figure 32: Handrail provides clear legibility on what part of the roof is accessible, Therme Vals, Switzerland

Figure 33: Photograph showing the non-accessible portion of the roof, with shallow substrate and uncomplicated edges and ability to access the roof from alongside the structure

Katstrup Power Plant

The Katstrup Power Plant in Copenhagen International Airport was designed with a lightweight extensive sedum living roof and covers 1200m² with a slope up to 22 degrees. This living roof complements the form of the building on the flat land at Copenhagen Airport, creating a legible and iconic building. This roof has little diversity in plant species due to the shallow substrate depth, but has provided sustainability benefits, with native frogs found living in the bottom sections of the roof. The roof has visual permeability and no accessibility.

Key Findings

Identity - Like the entranceway at Potters Children's Garden this roof, although just sedums in a thin substrate, provides a big impact in terms of identity, especially given the building's sloping form.

Permeability and **accessibility** – Although not accessible, the roof provides visual permeability, enhancing connection with the roof.

Figure 34: Extensive sedum living roof on sloping power plant roof creating a visual icon on the flat land of Copenhagen International Airport

8 House

The 8 House in Copenhagen is a mixed use residential development that includes two sloping extensive roofs covering 1700 m² of building reflecting the adjoining protected open space and Copenhagen Canal. It also includes 100 semi-intensive living roofs for each residential unit adjacent to internal ramped pedestrian streets. The living roofs are highly permeable with access to private roof top gardens, penthouse access to roof decks with balustrades, with platforms to view inaccessible arms of the living roofs. The adjoining fields are perceptually drawn into the building on 30-degree slopes, softening the building form and honouring the adjoining protected nature reserve and farmland character. The living roofs have a strong legibility with paths, stairs, ramps and access/viewing points throughout the development. There are legible and clear barriers and paths these create a clear delineation of space as aesthetic, private or accessible.

Key Findings

Permeability, legibility, concentration, diversity and **accessibility** – Due to the architectural morphology of the building, which incorporates visually permeable living roofs and semi-private living roofs that link internally to the space and to the countryside beyond, the living roofs connect people to many different elements within nature and the built form.

Figure 35: 8 House living roofs accenting the built forms morphology and reflecting the landscape of the surrounding farmland, including a viewing deck above the café and at the base of the two slopes

Birkegade Penthouses

This retrofitted living roof in the densely populated Elmegade district of Copenhagen was designed to give three penthouses access to a private garden. The living roof is very permeable, providing access to the penthouses via stairs on a sloped grass roof that provides a viewing platform and seat for informal use. It is robust in nature and diverse in hard elements, with a suspension bridge, play surface for recreation, outdoor kitchen and barbeque, and a timber deck for formal seating. Overall the living roof creates an extremely strong sense of recreational and playful identity in a built-up city form.

Key Findings

Permeability, identity and **accessibility** – This accessible roof creates sense of playful identity in a hard urban landscape with the use of grass on the stair slope.

Figure 36: Grass sloped living roof with access stairs leading to roof access with viewing platform above, Birkegade Penthouses, Copenhagen

The City Dune Urban Space

The City Dune is a privately owned public space covering 7,300 m² as part of a bank headquarters development. This living roof is extremely permeable and accessible, providing part of a through-site link allowing access to a train station with ramps and stairs. The park is a series of ramps that form stairs that are legible as a path. When viewed from the adjoining street level, the living roof is read as a landmark park form, where the paths create space to sit and rest, gather and have lunch. The living roof creates a sense of identity with different areas being created using ramps, where near the street the ramps are narrow and lead into wider ramps and larger planted areas, creating a sense of enclosure.

Key Findings

Permeability, accessibility and legibility – The use of ramps has created a sense of place, identity and permeability across the living roof. The ramps have also created areas of concentration for planting, recreation space and areas of respite. This overall design creates an urban park in the city. This development prompted an auxiliary, minor design investigation into ways and means for achieving access (see Appendix 2). This design foretells the design moves at Whangarei.

Figure 37: Wider ramps further from street level change the user experience and provide wider garden beds for more planting and enclosed space, The City Dune, Copenhagen

National Archives

Adjoining the City Dune is a 7000 m2 Danish State Archives living roof that is part of the through-site link connecting to the Central Railway station in Copenhagen. The design of the living roof is legible and connects to the adjoining brickwork façade articulation on the State Archives building. The living roof is extremely permeable, with legible paths intersecting large areas of living roof planting with a diversity of plant species. Being open in nature, and bounded by two buildings on opposite sides, creates a large green park-like space with pergolas and seating that create spaces for respite in the city. The design has created a good sense of diversity and sustainability, where large planted areas will attenuate significant flows of stormwater and provide biodiversity enclaves within the centre of the city.

Key Findings

Permeability, accessibility and **legibility** – Like the City Dune roof, this living roof provides a through-site link and sense of urban park. The design of the living roof and its paths connecting the building creates a sense of identity and distinguishes it from the adjoining park.

Figure 38: National State Archives functional living roof with legible paths that connect to the brickwork in the adjoining government buildings

Tivoli Congress Centre

Part of the elevated through-site link to the Central Train Station, this roof creates a highly vegetated urban park with different recreational uses adjoining an existing conference centre and hotel. Visually permeable, incorporating paths, pocket parks, play structures and seating areas, it also connects well to the existing hotel and restaurant use, where tables and chairs fill the space adjoining the hotel, creating an active edge. The living roof is diverse in terms of planting with a mix of species, form and heights, resulting in a green park within the heart of the city centre. All the rainwater from the roof is collected and reused for watering the gardens as part of the sustainability strategy for the park.

Key Findings

Permeability, legibility, concentration, diversity, sustainability and **accessibility** – This case study revealed the diversity of design elements creating a space that is permeable and links all of the living urbanism principles to provide an effective living roof design that connects people to nature and the built environment while functionally acting as a through-site link to the railway station.

Figure 39: Creative play spaces on Tivoli Congress Centre living roof

Emporia Shopping Centre

The Emporia living roof provides a mix of recreational and amenity spaces over 27000 m2 on top of a retail mall in Malmo, Sweden. The roof has little diversity in plant species, with mainly sedum used to blanket built forms in the shape of hills. Visually permeable, incorporating paths, enclosed pocket parks, a lookout, event spaces, and seating areas. There are four main access points to the roof, one of which connects the rooftop park the public street below via a large staircase. The rooftop park creases a sense of identity with similar geometric built forms around the roof, covered in sedum blankets.

Key Findings

Identity and **sustainability** – This living roof links several principles of living urbanism. However, due to the plant palette chosen across the majority of the roof, it does not successfully create diversity in spaces, with mainly paving and sedums. The roof does provide diverse hard-scape elements and is open and accessible within the mall shopping centre hours.

Figure 40: Open recreational spaces and event spaces provided on the Emporia Shopping Centre living roof

Augustenborg Botanical Roof Garden and Scandinavian Green Roof Institute

This series of retrofitted living roofs is a demonstration project in terms of living urbanism. The roofs provide an education, research and promotion facility for living roofs throughout Scandinavia. Diverse mixes of extensive, semi-intensive and intensive roofs are incorporated into the existing buildings to showcase the mix of planting options possible. Highly permeable, clip-on boardwalks were attached to the building to create permeable spaces that link numerous buildings with staircases to connect changes in levels. The sites are legible, with paths dissecting the planted roofs, showing a mix of planted recreation space on roofs, including permaculture options. The living roofs have created an elevated aesthetic education space for disseminating living roof research information and trialing new plant and substrate options. This construction is further linked to include sustainability benefits across the site, where the stormwater discharge connects into open waterways planted with species to reduce runoff and treat water prior to it entering the greater infrastructure network.

Key Findings

Permeability, legibility, concentration, diversity, sustainability, identity, accessibility and **robustness** – All of the living urbanism principles are demonstrated clearly in this case study, which provides a number of elements that enhance the effectiveness of living roof design. Access paths are used across the space and, where that is not structurally possible, a clip-on boardwalk has been utilised. This space shows the concentration of living roof types - different types of roofs and planting integrated with recreational space.

Figure 41: Cantilevered boardwalk retrofitted onto existing local government buildings for the creation of the Augustenborg Botanic Roof Garden and Scandinavian Green Roof Association

2.3.3 Conclusion to Theory and Precedents. Whakarāpopoto

Phase One of the present study was about gaining an understanding of the current situation, where living roofs provide a multitude of benefits to urban developments in New Zealand and overseas, blending beauty and function. In contrast to many cities worldwide, in New Zealand living roofs are not a commonplace landscape architecture or urban design intervention, even though our cities are experiencing rapid population growth, advanced stages of urbanisation and the resulting adverse effects. In this vein, New Zealand needs to be designing urban spaces that use a living urbanism approach that connects people to the built environment and nature.

The Phase One analysis revealed design elements that need to be included in a Living Roofs Design Manual as a consideration informing design choices, including aesthetics, plant selection, types of access, connections with nature, provision of natural elements for other species, and use of species or materials to create a sense of **identity** consistent with the surrounding landscape. The importance of establishing these elements was highlighted through a site analysis for determining the Manual's design brief. Consideration of **diversity** of use on the roof was also highlighted as a consideration for effective design, such as for food production, recreation and creating areas of respite where people can connect with nature. Consideration of **diversity** can link to **robustness** and detail the importance of having a substrate depth that can sustain a wide variety of plants.

In New Zealand, several studies highlight that a key issue in the design of living roofs is the lack of visual connectivity of the roof to the broader public and an associated lack of access onto the roof – both of which are important issues of **permeability** and **legibility**. This design gap prompted an auxiliary, minor design investigation into ways and means for achieving access (at Wynyard Quarter, see Appendix 2). Another issue in New Zealand that was emphasised is the lack of living roof spaces providing **diversity** of use, where communities can engage with the space and understand the multitude of benefits this infrastructure can provide. **Identity** has also been highlighted as an issue where cultural and natural narratives have not been recognised resulting in a space that is disconnected and does not reflect the character of the space. The European studies showed a clear social narrative, creating a sense of place, encouraging people to connect with the living roof. As such, living roof spaces in New Zealand do not appear to address **permeability**, **diversity** or **identity** issues in relation to the living urbanism principles, which results in roofs that feel disconnected and as such not viewed as worthwhile contributions to urban form.

Through the Phase One analysis, a gap was identified in the design process that lead to Phase Two of the research - the development of a Living Roof Design Manual. To address the lack of knowledge about and unrealised benefits of living roofs, it was proposed that a living urbanism approach could be adopted in the design of living roofs that would ensure those principles are integrated within such infrastructure developments and, as such, create spaces that connect people, the built environment and nature, and result in an increased uptake of living roofs. Utilising a living urbanism approach to analyse existing living roofs could also allow an understanding of the strengths and weaknesses of existing projects, facilitating further interventions to improve the many potential benefits from designing new living roofs. Accordingly, this approach and the key findings described above were incorporated into the development of the Living Roof Design Manual to enhance benefits realised on the built environment, humans and nature.

3. PHASE TWO:
LIVING ROOF DESIGN MANUAL - WHANGAREI.
KA HURITAO KI NGA HOAHOA

Introduction

The Manual

3.0 PHASE TWO: LIVING ROOF DESIGN MANUAL - WHANGAREI. KA HURITAO KI NGA HOAHOA

3.1 Introduction

The Living Roof Design Manual has as its foundations the principles of living urbanism, as defined above, and the findings from the investigation into theory and precedent in Phase One of this research. The Manual aims to inform design considerations to create an improved urban landscape with maximised multi-functional living roof benefits. An essential component is the input into this framework of data pertaining to Whangarei and Northland. It is this site-specific dimension that ensures effectiveness of living roof design. For example, this site-specific data included specific plants that would be appropriate for the location, climatic conditions, and material available for system composition.

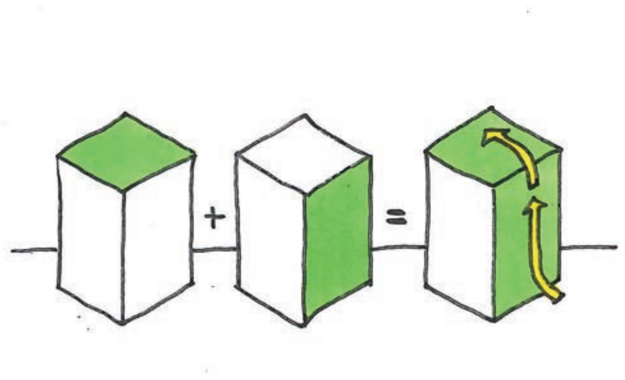


Figure 42: Connection of ground plane to living wall and living roof

Living roofs are becoming increasingly common in cities throughout the world. The purpose of this design manual is to highlight the multitude of economic, social and environmental benefits that these living systems can provide to improve the quality of Whangarei infrastructure for its people, land, water, nature, and visitors. The aim is to provide locally relevant information for anyone embarking on a living roof project. The role of green infrastructure in the built environment is to start to redefine the human role in integrating life processes into future city landscapes and how our indigenous flora and fauna can play a part

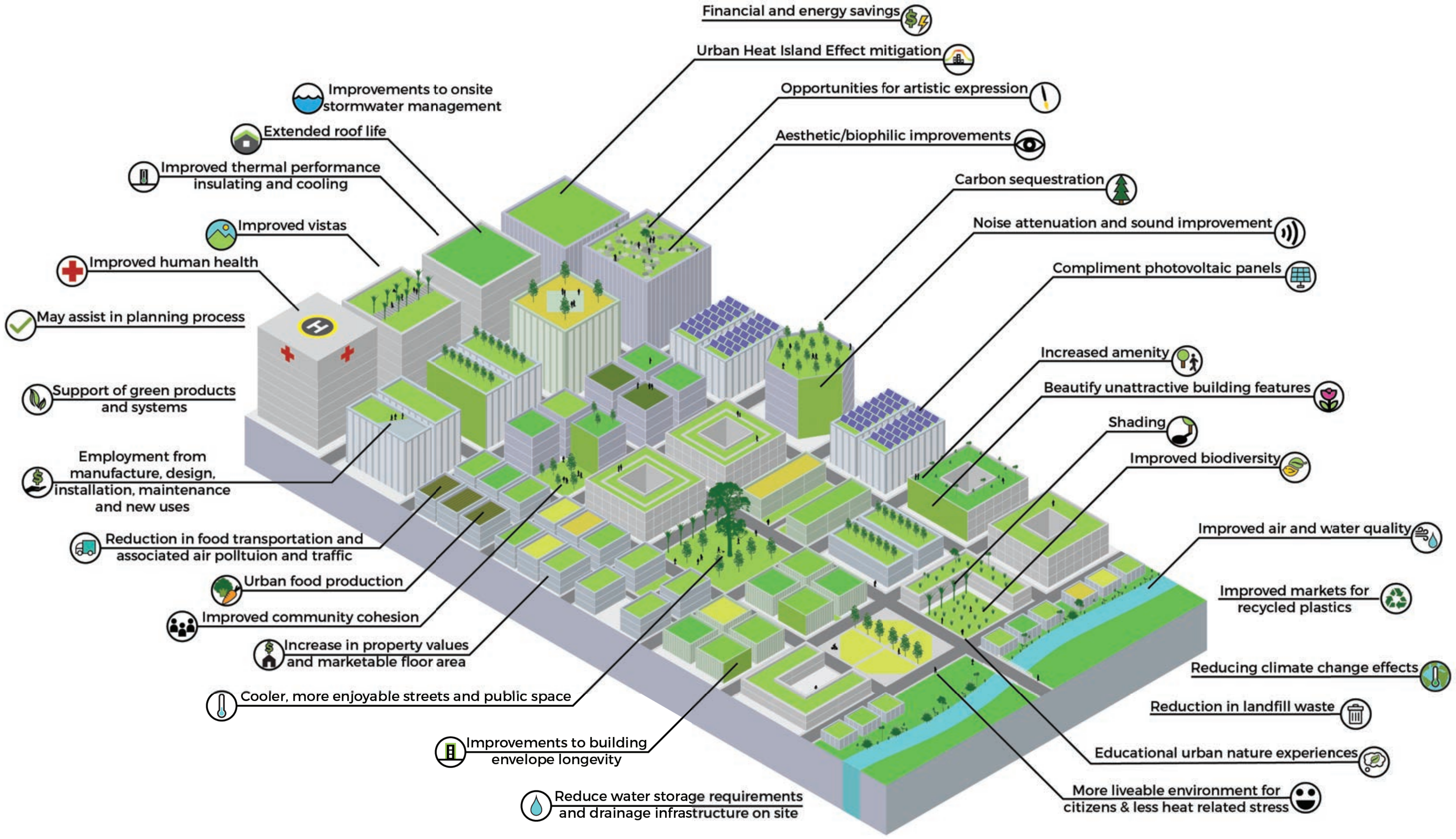


Figure 43: Benefits of the Living Urbanism City

in these life processes, thus protecting and enhancing indigenous biodiversity resilience and sustainability in our cities.

Living roofs blend beauty and function. The multifaceted outcomes delivered by living roofs not only address non-human life within the city, but extend to engagement with human processes. This co-facilitation leads to a more resilient city, providing for the inherent adaptability of city residents, both human and non-human, in a changing world. Currently, most living roof designs do not consider the roof space as an extension to the landscape, which results in elevated landscapes that are disconnected, ineffective or inappropriate for the location.

With a retrofit living roof project, the ability of the roof to support the weight of the system components is the first consideration, to ensure the structure does not collapse (the level of detail for this is reduced, depending on the scale and type of structure on which the living roof is being located). With a stronger roof base, a deeper substrate can be achieved to grow a wider variety of plants.

The ideal scenario for a living roof design is to work from an initial design brief, project drivers and aspirations, then undertake a site analysis to determine the most appropriate environmental and social considerations (the living urbanism choices), and subsequently work from this to determine the structural loading and infrastructure components required to support the chosen approach.

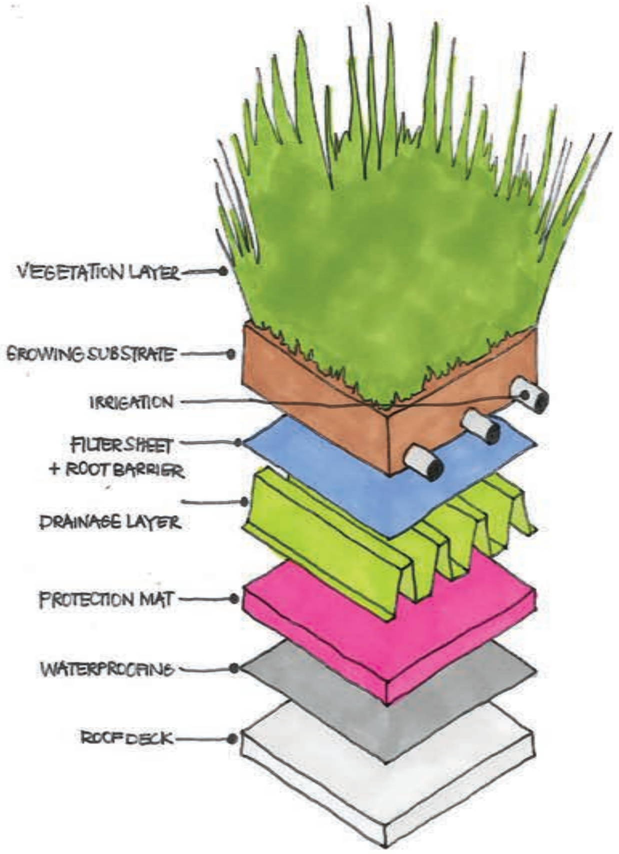


Figure 44: The components of a living roof

Figure 45: Lavender thriving on the living roof on the Offices of Allen & Overy LLP, London

3.2 The Manual

3.2.1 Design Brief

Composition of the manual commences with creation of a site-specific design brief.

The principal design objectives, project aspirations or reasons for incorporating a living roof, wall or facade needs to be identified at the beginning, as this brief informs the planning, design, construction, and on-going maintenance.

3.2.2 Design Objectives

The design aesthetic and anticipated benefits need to be understood to deliver a living roof that meets the client's anticipated aspirations. If a brief is for native vegetation and recreational access, this then informs the plant palette, depth of substrate and access options. This design may not be suitable for a person who wants a low-maintenance, low-cost, light-weight living roof retrofit.

- Increase in Property Values
- Overarching Concept (in this case, it is to reflect the philosophy of Hundertwasser)
- Financial Savings/Energy Savings
- Aesthetic/Biophilic Improvements
- Improvements to Building Envelope Longevity
- Shading/Integration with photovoltaic panels (solar panels)
- Improvements to onsite stormwater management
- Noise Attenuation and Sound Improvement
- Improved Biodiversity
- Food Production
- Urban Heat Island Mitigation
- Carbon Sequestration
- Improved Air and Water Quality
- Reducing Climate Change effects
- Improved human health
- Support of Green Products and Systems
- Support emerging Manufacture, Design, Installation, Maintenance and New Uses

Hundertwasser Art Centre Concept

When embarking on the afforestation of the Hundertwasser Art Centre, it is important to read and understand Hundertwasser's writings and manifestos on architecture, design and nature, along with his '5 Skins' philosophy. The Hundertwasser Art Centre will be the last authentic living roofed Hundertwasser building in the world and is intended to be a significant asset to Whangarei, the Northland Region and New Zealand. Hundertwasser was not only an artist and an architect, he was an environmentalist and philosopher who incorporated elements from nature into his works, notably living roofs and 'tree tenants' (indoor trees growing out of windows). His living roofs and tree tenants were more than just aesthetic features; these spaces were given back to nature where people could enjoy them as a guest of nature, just like walking through the forest. The Art Centre will be multi-functional, including a main gallery showcasing Hundertwasser's work, a contemporary Māori art gallery, café, cinema, and student resource centre. The Wairau Māori Art Gallery will be the world's first gallery dedicated solely to contemporary Māori art.

When taking a living urbanism approach, it is important to note that the living roof will form part of the wider landscape, environment and community, and will essentially create a 'sense of place' in the built form. As such it is good to assess surrounding uses, views, aspect, street trees, parks and planting.

Worldwide research continues to confirm that living roofs provide both urban habitat and social benefits, alongside a range of ecosystem services within the predominantly hard surfaces of our urban environments. In New Zealand, living rooftops are an underutilised asset that can assist with climate change adaptation and improved amenity in our urban and rural areas if the appropriate features are incorporated into the roof design process.

Figure 46: Bere House, Islington, London (Photograph reprinted with permission from Dusty Gedge)

Clay banks - habitat for native solitary bees

Logs and dead wood - insect habitat

Water and/or boggy areas

Mounds

Rubble mounds

Scree/rock areas

Shell/gravel beds

Bird and bee attracters

Diversity of plant form and shape

Photovoltaic panels

Solar hot water panels

Beehives

Interpretive signage/education

Playgrounds/recreational space

Permeable walkways

Seating areas

Access over vegetation

Views to roof

Figure 47: Living Urbanism Palette

There is a palette of tested design interventions and approaches that provide options to increase the benefits of a living roof. Any combination and mix of the components from this palette can be used, depending on the drivers for the project and desired functional and aesthetic outcomes.

3.2.3 Habitat

Living roofs are an artificial environment that allows for manipulation of both the range and type of microtopography, materials and vegetation diversity to transform into an elevated habitat that provides ecosystem services. Natural analogues of living roofs, such as cliffs, scree slopes, riverbeds, coastal rock outcrops and dunes, provide inspiration and guidance to the types of vegetation communities and natural features that will improve habitat outcomes for a roof.

The different growing conditions is particularly relevant to the New Zealand situation, where environmental and ecological conditions vary considerably from other countries where most living roof research has been carried out before now. The range of plants found in these ecosystem types are adapted to shallow substrates and extreme temperature and moisture conditions, which are common characteristics of extensive and intensive living roofs (Snodgrass & McIntyre, 2010).

Insect habitat

Invertebrate diversity on a New Zealand natives living roof can provide the required array of prey species for skinks. Invertebrate biodiversity potential on New Zealand living roofs differs from Europe and America due to our non-flying native invertebrates (Davies, et al., 2010). Native vegetated living roofs provide temperature variables similar to terrestrial environments. Humidity (and lack of) is the main difference compared with terrestrial situations and therefore the main constraint to biodiversity on a New Zealand living roof (Davies, 2012).

Self-seeded orchids

A phenomenon that has been encountered on many NZ living roofs is the natural arrival of a small New Zealand native perennial grass orchid, Microtis parviflora. These orchids appear to love the conditions of living roofs and pop up amongst the existing vegetation (both exotic and native).

Orchid seeds are microscopic and find their way to the roofs on the wind. Although a common orchid, it is normally hidden from sight, whereas on living roofs its stands out and is quite impressive.

3.2.4 Site Analysis

Site analysis is the preliminary phase of the living roof design process. It includes the study of climatic conditions, structural loading, geographical setting, access, drainage, irrigation, and infrastructural context of the specific site. Understanding the site characteristics is important for both retrofit and new build living roof, wall or facade developments, as these elements affect the desired design, cost and outcomes.

3.2.5 Climatic Conditions

Climatic conditions vary from site to site depending on the geographic location as well as surrounding

Figure 48: New Zealand native orchid *Winika cunninghamii* on green a wall (Photograph reprinted with permission from Renee Davies)

Figure 49: Example of living roof in full shade - that allows for a unique mix of native plants

topography, aspect, height of building, and surrounding buildings. Understanding the high and low temperatures, wind, sun, shade, and rainfall will inform the plant selection and design of the living roof or wall (Dunnett & Kingsbury, 2004).

Sun

In assessing a site for sun, it is important to consider multiple factors: the time during the day that the living roof or wall receives sunlight; the sun's path at different times of the day and year; how the living roof or living wall's shape, slope and orientation affect solar access; any obstructions such as parapets, adjacent buildings, trees and landforms that will impact on the living roof or wall; and the users of the space, in particular whether they want to have sun or shade at certain times of the day for maximum enjoyment of the space.

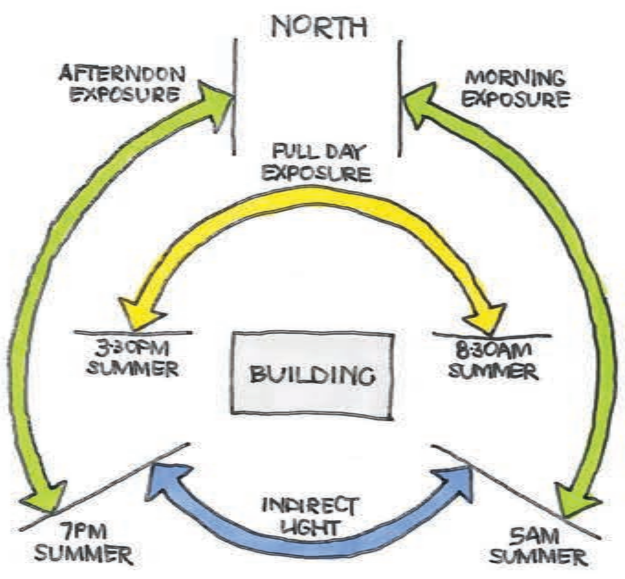


Figure 50: Solar orientation of a living roof

The effect of sun on the living roof or wall plays a key factor in determining which plants will be appropriate for the different sites.

Rainfall

Whangarei averages 1500 mm of rainfall annually (World Weather Online, 2018). However, Whangarei's rainfall is generally not sufficient to support a living roof, wall or facade throughout the year and irrigation needs to be considered for hot and drought-stricken summer periods (NIWA, 2013). Irrigation is determined by the type of plants chosen. Consideration is needed of use of water from other areas on site, storage and reuse, or whether potable water would be required for irrigation.

Wind

The effect of wind load needs to be considered as it relates to the living roof, wall or facade (Aly, et al., 2013). Wind speeds are generally higher at roof level than at ground level. Wind can also be stronger around building corners. Tall buildings can cause a downdraft and updraft effect where air hits a building and is pushed up, down and around the sides. Air forced downwards increases wind speed at street level. The more buildings, the more complex the wind patterns are. The stronger the wind, the greater the evaporation (dehydrating) effects will be, resulting in higher irrigation requirements.

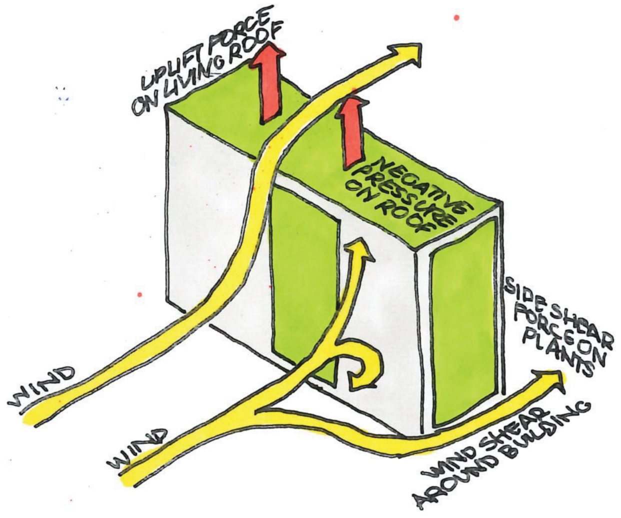


Figure 51: Diagram of wind forces on living buildings

Temperature

Whangarei's climate is warm and temperate with an average annual temperature of 15.7°C. In the urban environment, it is important to note that temperatures commonly increase with elevation from an increase in the thermal mass from the city's built form. It is important to assess the site's potential temperature range, including considering recent extremes. This affect will not only plant selection but also planting design and locations.

Microclimate

Different spaces on a roof or around a building (i.e. urban canyons) can have their own microclimate where temperatures, humidity and wind can increase. These areas need to be designed with plants and material able to support these local conditions.

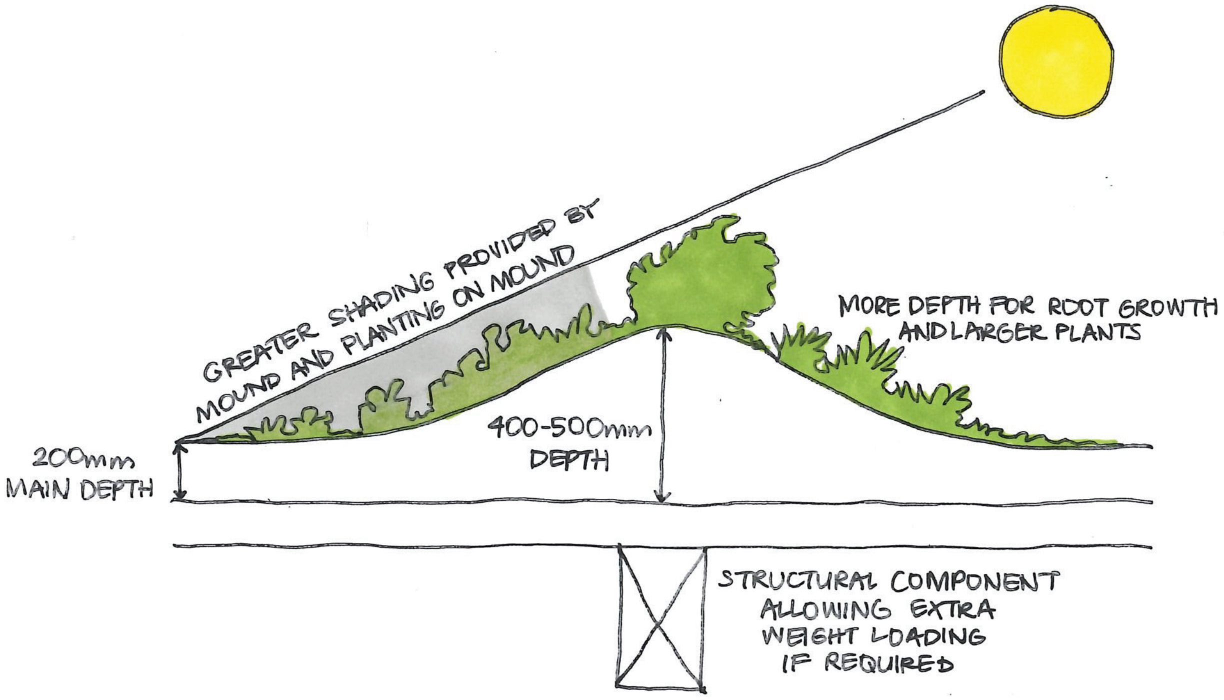


Figure 52: Mound Diagram

Where the roof structure allows (such as over support pillars), the addition of small mounds of deeper substrate creates a varied microclimate on the roof that supports a broader range of plant species and provides vital diversity of habitat, such as shaded areas and shelter.

3.2.6 Structural Loading

The structural loading of a living roof needs to be considered at the design stage (Peck, Living architecture for urban infrastructure, 2012) delete title. It is worth noting that many flat roof structures with ballast or paving slabs may be able to be replaced with an extensive living roof system with no structural loading implications. Early engagement with a structural engineer for advice on the existing or proposed building's structural loading capacity is required. When retrofitting a living roof, wall or façade, it is essential for costings and design process to understand whether the building will need to be modified. The structural engineer will need to consider the weight of plants at maturity, saturated plants and substrate. They will consider the 'dead load' as the constructed roof, wall or facade with maximum saturation; the 'live load' is the weight of people using the space; and the 'transient load' comprises short-term loads of wind and seismic activity. The table below details the saturated weights of different green roofs and landscape elements.

Roof type	Loading
Gravel surface	90-150 kg/m²
Paving slabs	160-220 kg/m²
Vehicle surface	From 550 kg/m²
Extensive green roof (sedum mat)	60-150 kg/m²
Extensive green roof (substrate based)	80-150 kg/m²
Intensive green roof	200-500 kg/m²

Figure 53: Indicative Structural Loading for Various Types of Roof

Note: Loads are fully saturated.

Source: Living Roofs and Walls, Technical Report: Supporting London Plan Policy, Greater London Authority, 2008

The table below details the saturated weights of different green roofs and landscape elements.

Green roof vegetation type	Weight loading (kg/m²)
Low herbaceous (succulents and grasses)	10.2
Perennials and low shrubs up to 1.5 m	10.2-20.4
Turf	5.1
Shrubs up to 3m	30.6
Small trees up to 6m	40.8
Medium trees up to 10m	61.2
Large trees up to 15m	150

Figure 54: Living Roof Vegetation Weight Loadings

Source: FLL The German green roof design standards - Guidelines for the Planning, Execution and Upkeep of Green Roof Sites (2008)

3.2.7 Fire

In Germany, buildings with a living roof get a reduction in fire insurance, as the system can protect the building from fire. German FLL guidelines state that the design of a living roof should have, at a minimum, a 500 mm shingle perimeter to act as a fire break. There are also guidelines for the percentage of combustible material that is to be incorporated within the living roof substrate. A perimeter that is vegetation-free can also serve as the edging for the retention of substrate. The extent of any vegetation-free perimeter will also be guided by the type of vegetation on the living roof, where larger woody shrubs and trees have a higher risk than low growing plant species. These vegetation-free areas are also useful adjacent to walls, parapets and any other structures on the roof that are constructed of non fire-resistant materials.

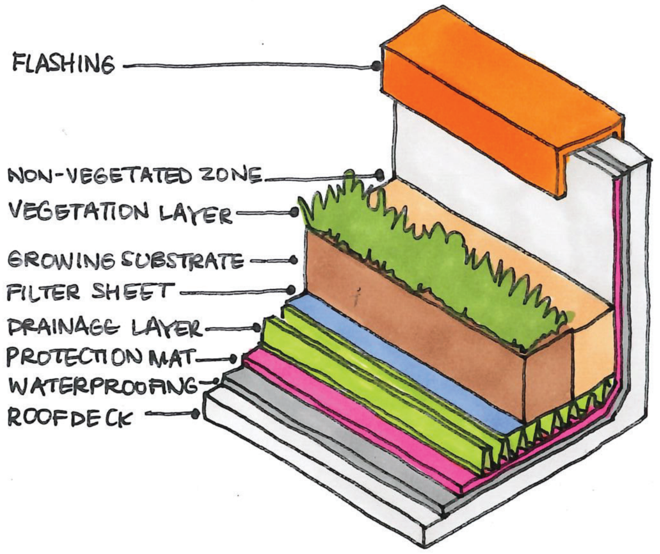


Figure 55: Non-vegetated zone of living roofs

3.2.8 Building Structure, Slope, Drainage and Size

A number of building components need consideration as part of the site analysis process. These include the building design and size, roof slope, drainage features, and water collection.

An assessment needs to be undertaken of the size of useable roof or wall area, taking into consideration roof equipment/infrastructure and windows, together with an assessment of the condition and quality of the roof and wall materials, and existing or proposed waterproofing. What are the slopes or angles to the roof and wall being covered? Living roofs are easiest to design and build on slopes less than 15 degrees. They can be built on steeper slopes, but doing so requires additional design consideration and materials to hold the soil and plants in place.

Does the roof have positive drainage, as ponding on the roof can cause problems for the plants and add to the structural loading? What type of drainage is proposed? Where are the stormwater discharge points? Are overflow drains required in the case of severe weather?

Water storage, collection and use needs to be assessed for living roofs and walls as well. Water reuse tanks can service both irrigation and toilet flushing. As such, consideration of water use and collection is important early in the design stage.

3.2.9 Access

Physical access onto the roof or to the green wall needs to be carefully assessed during site analysis . Permanent access by users for recreational or private open space living roofs will need to consider safety requirements, access points, viewing points, seating, paths, and balustrades. Temporary installation access for machinery, and delivery and storage of materials during the construction period, also need to be considered in the design phase. This can include scissor lifts, cranes, trucks, and a substrate blower.

Assessment of how users will access the living roof during the building period, and maintenance and use by stairs, lifts and viewing platforms is necessary. Safety, working at heights or fall protection once on the roof need to be allowed for within the design of the roof with either balustrades, clip points, cables, or ladders. Living walls or façades can usually provide for this type of requirement at ground level, allowing space and access for scissor lifts or similar.

3.3 Living Roof Design

The design stage is the most critical part of creating a successful living roof, as it informs whether the project drivers are met, how easy it will be to build and maintain, the cost, and use and enjoyment.

The scale of the living roof, wall or façade will inform the level of planning, detailed design and expert input required. Following the site analysis the design stage considers the project drivers, brief or aspirations, budget, maintenance, and all of the core elements of a living roof system.

There are some core system elements that all projects require for success. Additionally, there are components that are optional, depending on the type of outcomes desired for the living roof.

Essential components:

- Vegetation
- Substrate
- Root barrier
- Filter layer
- Drainage layer
- Waterproof layer
- Structural roof deck

Optional components:

- Access features such as walkways
- Railings
- Lighting
- Ecological features
- Irrigation
- Erosion protection layer
- Water retention layer
- Membrane protection layer
- Leak detection device
- Insulation

3.3.1 Access features such as walkways

All living roofs require some form of access to be accommodated within the design, whether for maintenance or for other human uses. If a living roof is to be used, either in part or fully, by residents or visitors to the building, then accessibility on the roof must meet all the building code requirements. Generally, design in these instances will require balustrades or guardrails, lighting, fire safety, disability access, seating, and signage.

Paths can be paved, aggregate, or structural elements elevated over plantings, such as raised aluminium grates over plantings. Aluminium grated paths are considered to provide dappled shade and shelter, reducing substrate temperature and evapotranspiration. This approach is considered to provide longer-term moisture supply for plants, and shading should be considered when selecting plants for these areas.

Figure 56: Musée du Quai Branly, Paris, France

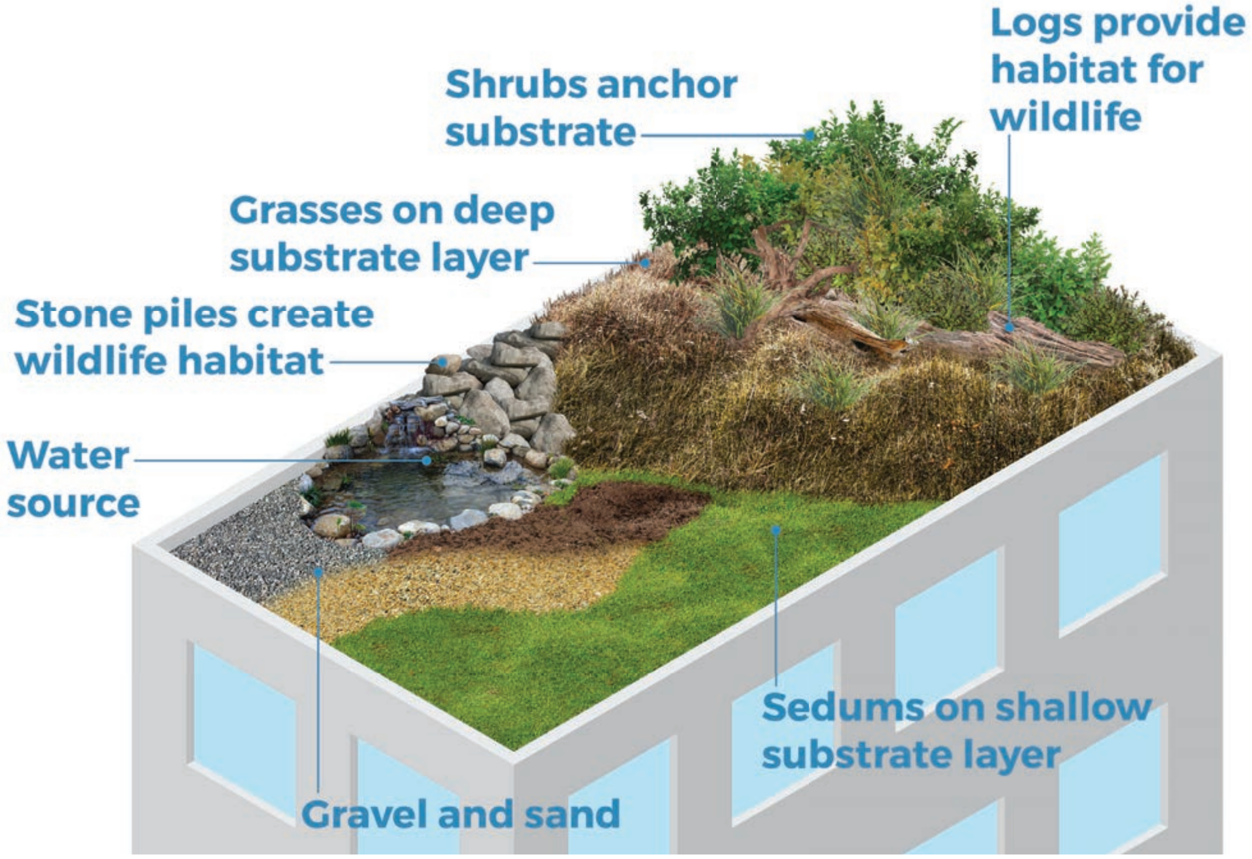


Figure 57: The components of a biodiverse living roof

3.3.2 Vegetation

The vegetation choices for a living roof in New Zealand include both exotic and native plant species. The choice of plants is influenced by the type of living roof, the conditions the plants will be required to adapt to, the aesthetic, and the ecological outcomes desired.

The plant options outlined in this guide are provided from known examples of New Zealand living roofs and overseas roofs. It is not practicable to list every plant that might be suitable, but included here is a selection of species that are most likely to be appropriate to the Whangarei area or considered worthy of trying.

Plants have been grouped under main plant categories:

- Succulents
- Groundcovers
- Grasses, sedges, rushes
- Small ferns
- Herbaceous
- Shrubs
- Trees
- Climbers and vines.

3.3.3 Why use Native Plants?

Many of New Zealand's native plants and animals are endemic – that is, found nowhere else in the world (Dawson & Lucas, 2012). The level of endemism among New Zealand plants and animals is one of the highest in the world. There are 2,500 native species of conifers, flowering plants and ferns and 80% are endemic. New Zealand's evergreen forests are among the most ancient and unique in the world and have evolved over millions of years, with lineage dating back 100 million years. Many birds, animals, fish, insects, and fungi are also endemic (Te Ara, 2018).

Up to 15% of the total land area of New Zealand is covered with native flora, from tall kauri and kohekohe forests to rainforest dominated by rimu, beech, tawa, matai and rata, ferns and flax, dunelands with their spinifex and pingao, alpine and subalpine herb fields, and scrub and tussock.

However, plant selection is not just about the scientific facts. New Zealand's flora and fauna provide the predominant genius locii of a place where Māori believe that people and plants have a common origin. Māori saw plants as having senior status, Tane created them before humankind, and they were therefore respected as older relatives. They are the link between people and sacred ancestors, Papatūānuku and Ranginui (Tipa, 2018). There is, therefore, a strong cultural and spiritual imperative to ensure the use of native plants in New Zealand's built environments.

In New Zealand, the expansion of the urban palette of biodiversity to living roofs and walls by referencing the nation's unique and adaptable natural ecosystems, and using native plants and local substrate mixes, will build biodiversity and the inherent efficiency and contributions these systems have to the ecosystem of the city.

Selection of plant options for a living roof is derived by looking at plants that are adapted to the types of conditions that are found on a living roof.

3.3.4 Success with Native Plants

New Zealand native plants can be used and will survive on extensive or semi-intensive living roofs. Documented New Zealand living roofs include 71 different native plant species used. Some key success factors for New Zealand native plants on living roofs include the following:

- Summer drought irrigation increases the survival and growth of New Zealand native plants on living roofs (Fassman-Beck, 2013).
- Soil depth (over 150 mm, and ideally 150-200 mm) increases the growth and success of New Zealand native plants on living roofs (Auckland Regional Council, 2010).

3.3.5 Offshore Island Plant Options

Whangarei and its nearby offshore island neighbours have a range of threatened plant species that have unexplored yet exciting potential for local living roof environments. They are not only beautiful and uniquely adapted to harsh conditions, but also contribute to preservation of these special treasures.

Plants for consideration include:

- *Alectryon grandis* (Three Kings tītoki)
- *Carmichaelia williamsii* (Giant flowering broom)
- *Chinochloa bromoides*
- *Colensoa physalioides* (Koru)
- *Coprosma neglecta* (Maunganui Bluff)
- *Coprosma repens* ‘Poor Knights’
- *Dianella latisama* (Waimea dianella)
- *Elingamita johnsonii*
- *Hebe adamsii*
- *Hebe brevifolia* (prostrate form)
- *Hebe diosmifolia* ‘Wairua beauty’
- *Hebe parviflora*
- *Hibiscus diversifolius*
- *Hibiscus richardsonii*
- *Lipidium oleraceum*
- *Macropiper mechior*
- *Macropiper psittacorum*
- *Myoporum decumbens*
- *Myrsine aquillina ‘Poor knights’*
- *Nestegis apelata*
- *Pennantia baylisiana*
- *Phebalium nudum*
- *Pimelea tomentosa*
- *Pittosporum cornifolium*
- *Pittosporum fairchildii*
- *Pittosporum obcordatum* (kohukohu)
- *Pomaderris prunifolia var edgerleyi*
- *Scleranthus biflorus* ‘Tutukaka’
- *Streblus banksii* (Coastal milk tree)
- *Streblus smithii*
- *Tecomanthe speciose*
- *Xeronema callistemon*

3.3.6 Whangarei Ecological District

The topography of the Whangarei District is complex, with a varied landscape of predominantly low hills, indented coastlines and numerous islands close to the shore (Manning, 2001).

The climate is warm and humid with mild winters and an average annual rainfall of 1500-2400 mm. Summer droughts occur, as do occasional tropical storms from the north-east and north. Soils are predominantly clay, strongly leaches and generally acid. There are some areas of volcanic loam soils.

The original vegetation of the district is mainly kauri-dominated, species-rich forest. There are large areas of tōwai shrubland and leptospermum scrub, dense kauri and podocarp regeneration (tōtara, kahikatea, rimu) and coastal forest remnants dominated by pūriri and pōhutukawa.

Within and around the Whangarei District boundary

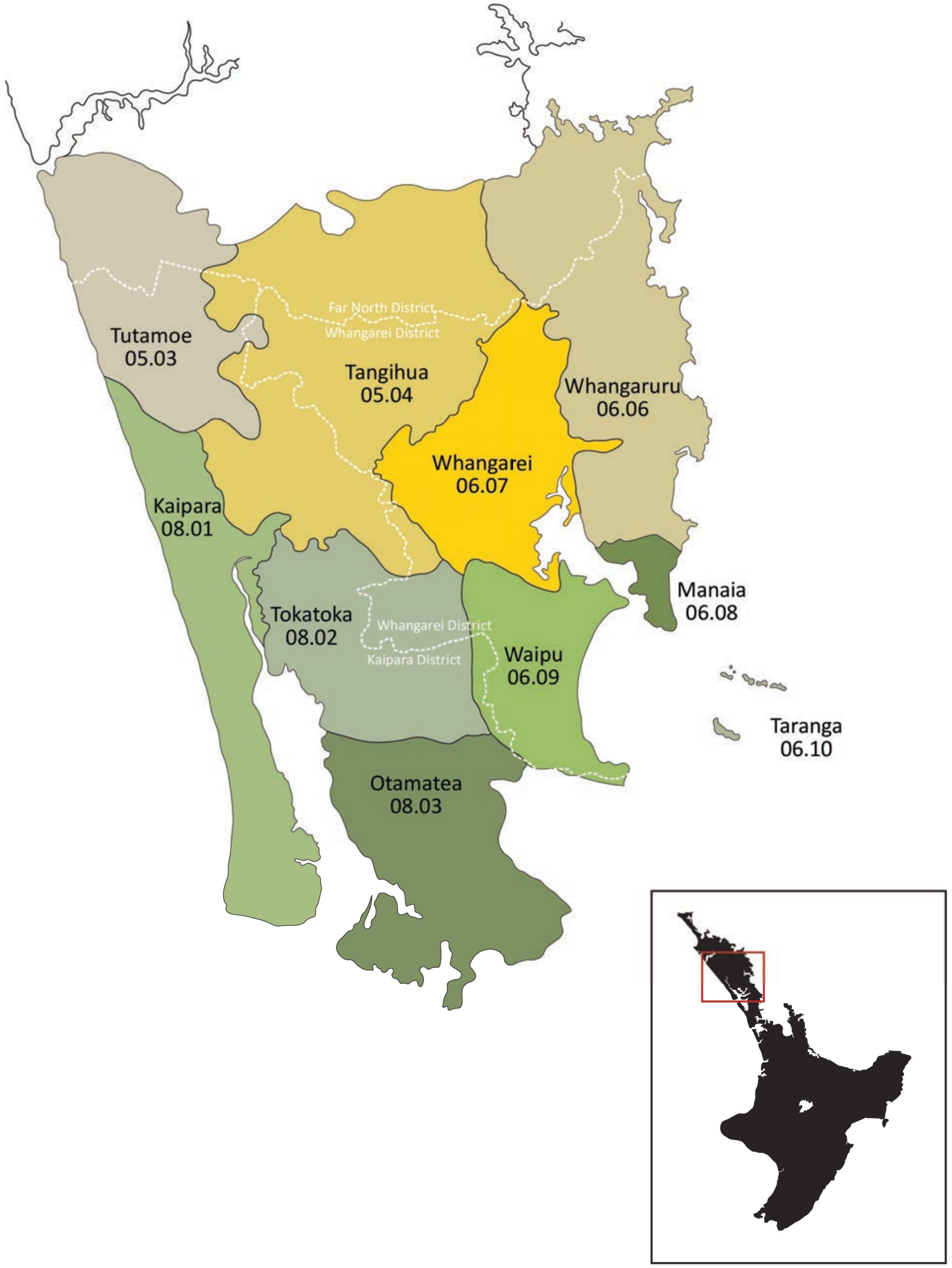


Figure 58: Ecological Districts of Whangarei Map Adapted from Whangarei Ecological District Report by Department of Conservation (2001)

there are a number of ecological regions and districts represented. These include:

- Western Northland
- Maungataniwha
- Hokianga
- Tutamoe
- Tangihua
- Eastern Northland
- Eastern Northland and islands
- Otamatea
- Whangarei
- Waipu
- Manaia
- Whangaruru
- Poor Knights
- Kaipara

3.3.7 Plant Lists

How to Use Plant Lists

The following plant lists are suggestions for a range of either native or exotic species that have been grown on living roofs in New Zealand. The table can be used to help filter plant choices depending on the outcomes needed from the living roof.

As living roofs are in their infancy in New Zealand, the table is based on known species that have been used on living roofs in this country. There are new species being trialled all the time and new information coming from projects across New Zealand, so the table should be viewed as a working document.

- Plants specific to the Whangarei ecological district: restrict search to plants with that column ticked in the table.
- Providing bird or insect food: concentrate on those plants identified to provide ecosystem services.
- Threatened plants, or a particular form/plant e.g. low-growing, or a mix of textures and forms.
- A particular colour palette: looking at the characteristics of leaf and flower colour will assist.

The success ranking indicates what is known, based on existing living roofs in New Zealand, of the relative success of the plant species listed (these range from unknown, excellent to poor).

Native Plant Selection

KEY:
● Fully tolerant
◐ Tolerates some
× Not tolerant
▲ Mounded or spreading
⬮ Oval
✳ Spiky
▂ Prostrate
◠ Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Succulents		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Crassula sieberiana		●	◐	50-150	✓	🟢	🟣	▂	Not threatened	Varied	✓			2
Disphyma australe	Horokaka, NZ Ice Plant	●	×	150-500	✓	🟢	🟣	▂	Not threatened	Coastal	✓		✓	4
Groundcovers														
Acaena microphylla	Piripiri	◐	●	150-500	✓	🟢	🔴	▂	Not threatened	Bush edge	✓		✓	3
Anaphalioides bellidioides	Everlasting Flower	●	◐	150-500	✓	🟢	⚪	▂	Not threatened	Montane			✓	0
Calystegia soldanella	Rauparaha	●	◐	150-500	✓	🟢	🟣	▲	Not threatened	Coastal	✓*		✓	3
Centella uniflora		●	●	150-500	✓	🟢	🔴	▂	Not threatened	Varied				3
Coprosma acerosa	Tātaraheke	●	◐	150-500	✓	🟠	⚪	▲	At risk	Coastal	✓*		✓	1
Coprosma brunnea		●	◐	150-500	✓	🟠	🔵	▲	Not threatened	Inland rocky areas			✓	0
Coprosma acerosa f. mangatangi	Coprsoma mangatangi	●	◐	150-500	✓	🟠	🔴	▲	Not threatened	Bush edge			✓	0
Dichondra brevifolia	Mercury Bay Weed	◐	●	150-500	✓	🟢	⚪	▂	Not threatened	Coastal	✓*			2
Dichondra repens	Mercury Bay Weed	◐	●	150-500	✓	🟢	⚪	▂	Not threatened	Coastal	✓*			2
Fuchsia procumbens	Creeping fuchsia	◐	●	150-500	✓	🟢	🔴	▂	At risk – naturally uncommon	Coastal	✓		✓	3
Leptinella dioica	Bachelors Buttons	●	●	150-500	✓	🟢	🟡	▂	Not threatened	Coastal			✓	2
Lobelia anceps	Shore lobelia	●	●	150-500	✓	🟢	⚪	▲	Not threatened	Coastal	✓*		✓	3
Muehlenbeckia axillaris	Creeping Pōhuehue	●	◐	150-500	✓	🟢	⚪	▂	Not threatened	Rocky			✓	3

* distribution North Island

Figure 59: Native and Exotic Plant Selection

Native Plant Selection

KEY:

●	◐	✗					
Fully tolerant	Tolerates some	Not tolerant	Mounded or spreading	Oval	Spiky	Prostrate	Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Groundcovers continued		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Muehlenbeckia complexa	Pōhuehue	●	●	150-500	✓	🟢	⚪	Mounded or spreading	Not threatened	Coastal			✓	2
Pimelea prostrata	Pinātoro	●	◐	150-150	✓	●	⚪	Prostrate	Not threatened	Coastal to montane			✓	1
Raoulia australis	Common Mat Daisy	●	◐	150-500	✓	●	🟡	Rounded	Not threatened	Montane	✗		✓	3
Leptospermum (prostrate)		●	◐	150-500	✓	🟢	🔴	Prostrate	Not threatened	Cultivar			✓	1
Pratia angulata	Panakenake	◐	●	150-500	✓	🟢	⚪	Prostrate	Not threatened	Coastal/Bush	✓		✓	3
Raoulia hookerii	Scabweed	●	◐	150-500	✓	●	🟡	Rounded	Not threatened	Montane	✗		✓	3
Raoulia parkii	Celadon Mat Daisy	●	◐	150-500	✓	●	🟡	Rounded	Not threatened	Montane	✗		✓	3
Samolus repens	Mākoako	●	◐	150-500	✓	🟢	⚪	Prostrate	Not threatened	Coastal	✓		✓	2
Selliera radicans	Remuremu	●	●	50-150	✓	🟢	⚪	Prostrate	Not threatened	Coastal to alpine	✓*			3
Grasses, sedges & rushes														
Anementhele lessoniana	Hunangamoho	●	◐	150-500	✓	🟢	🟡	Spiky	At risk – relict	Cliff & Forest				3
Apodasmia similis	Oioi	●	◐	150-500	✓	🟤	🟤	Spiky	Not threatened	Coastal	✓*		✓	0
Arthropodium cirratum	Rengarenga	●	◐	150-500	✓	🟢	⚪	Spiky	Not threatened	Coastal rocky	✓		✓	3
Astelia banksii	Wharawhara	●	●	150-500	✓	🟢	🟡	Spiky	Not threatened	Coastal epiphyte	✓		✓	3
Austrostipa stipoides	Buggar Grass	●	◐	150-500	✓	●	●	Spiky	Not threatened	Coastal	✓*			
Carex pumila	Sand Sedge	●	◐	150-500	✓	🟢	🟢	Spiky	Not threatened	Coastal	✓*			2

distribution North Island *

Native Plant Selection

KEY:

⚫	◖	✖	⛰	⬮	✳	▁	◠
Fully tolerant	Tolerates some	Not tolerant	Mounded or spreading	Oval	Spiky	Prostrate	Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Grasses, sedges & rushes continued		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Chionochloa rubra	Red Tussock	⚫	◖	150-500	✓	🔴		✳	Not threatened	Montane			✓	3
Festuca actae	Banks Peninsula Fescue	⚫	◖	150-500	✓	🟠	⚪	✳	At risk	Coastal to montane	✖			1
Festuca coxii	Cox's Fescue	⚫	◖	150-500	✓	🟢	🟣	✳	At risk	Coastal	✖			1
Festuca mathewsii		⚫	◖	150-500	✓	🟢	🟢	✳	Not threatened	Montane	✖			2
Libertia ixioides	Mikoikoi	⚫	◖	150-500	✓	🟠	⚪	✳	Not threatened	Coastal/River/ Montane	✓		✓	3
Phormium cookianum	Wharaiki	⚫	⚫	500-1500	✓	🟢	🟡	✳	Not threatened	Coastal	✓	✓	✓	4
Poa cita	Pātītī	⚫	◖	150-500	✓	🟠	🔴	✳	Not threatened	Montane coastal	✓			2
Xeronema callistemon	Raupo taranga	⚫	◖	150-500	✓	🟢	🔴	✳	At risk	Montane -rocky coastal	✓*		✓	1
Herbaceous														
Anaphaloides bellidiodes	Everlasting Flower	⚫	◖	150-500	✓	🟢	⚪	⛰	Not threatened	Montane	✖		✓	3
Apium prostratum	Tūtae Kōau	⚫	⚫	150-500	✓	🟢	🟤	⛰	Not threatened	Coastal	✓			3
Euphorbia glauca	Waiūtua	⚫	◖	150-500	✓	●	🔴	⛰	At risk	Coastal cliffs			✓	3
Fuchsia procumbens	Creeping fuchsia	◖	⚫	150-500	✓	🟢	🔴	▁	Not threatened	Coastal	✓		✓	3
Haloragis erecta	Toatoa	⚫	⚫	150-500	✓	🟢	🟣	⛰	Not threatened	Costal to montane	✓*		✓	3
Veronica obtusata	Hebe	◖	⚫	150-500	✓	🟢	⚪	✳	At risk	Coastal rocky			✓	2
Hibiscus diversifolius	Prickly Hibiscus	⚫	◖	150-500	✓	🟢	🟡	⛰	Critically threatened	Coastal wetlands/ streamsides			✓	3

* distribution North Island

Native Plant Selection

KEY:								
	●	◐	✗					
	Fully tolerant	Tolerates some	Not tolerant	Mounded or spreading	Oval	Spiky	Prostrate	Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Herbaceous continued		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Hibiscus richardsonii	Puarangi	●	●	50-150	✓	🟢	🟡		Critically threatened	Coastal	✓		✓	0
Leptostigma setulosum		●	●	150-500	✓	🟢	🟡		Not threatened	Varied	✓			3
Microlaena stipoides	Pātītī	●	◐	150-500	✓	🟢			Not threatened	Varied	✓			3
Microtis unifolia	Onion Leaf Orchid	●	◐	50-150	✓	🟢	🟢		Not threatened	Varied	✓			1
Tetragonia implexicona	Native Spinach	●	◐	150-500	✓	🟢	🟡		Not threatened	Coastal to montane	✓		✓	1
Ferns														
Austroblechnum penna-marina	Alpine Hard Fern	●	◐	150-500	✓	🟢	🔴		Not threatened	Coastal to alpine	✓		✓	3
Doodia australis	Pukupuku	●	●	150-500	✓	🟢	🔴		Not threatened	Coastal to lowland	✓		✓	0
Pteris tremula	Shaking Brake	●	◐	150-500	✓	🟢			Not threatened	Coastal to montane	✓*			3
Pyrrosia eleagnifolia	Ngarara Wehi	●	●	50-150	✗	🟢			Not threatened	Coastal to montane	✓			2
Shrubs & Trees														
Veronica hectorii	Hebe					🟢			Not threatened	Montane	✗		✓	4
Hebe obtusata	Titirangi	●	●	150-500	✓	🟢	🟣		At risk	Coastal	✗		✓	2
Plagianthus divaricatus	Mākaka	●	◐	150-500	✓	🟢	🟡		Not threatened	Coastal	✓		✓	3

distribution North Island *

Exotic Plant Selection

KEY:								
	●	◐	✗					
	Fully tolerant	Tolerates some	Not tolerant	Mounded or spreading	Oval	Spiky	Prostrate	Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Succulents		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Aloe humilis	Spider Aloe	●	◐	50-150	✗	🔴	🟡		N/A	Dry	N/A			2
Bromeliad 'Night Sky'	Bromeliad	●	●	50-150	✗	🟢	○		N/A	Dry	N/A			2
Bromeliad 'Sugar and Spice'	Bromeliad	●	◐	50-150	✗	🟢	🔴		N/A	Epiphyte	N/A			2
Echeveria splendens		●	◐	50-150	✗	🟢	🔴		N/A	Coastal	N/A		✓	3
Kalanchoe sp.	Kalanchoe	●	◐	50-150	✓	🟢	🔴		N/A	Dry	N/A		✓	3
Lampranthus sp.		●	◐	50-150	✗	●	🟣		N/A	Coastal	N/A		✓	2
Mesembryanthemum 'Yellow'		●	◐	150-500	✗	🟢	🟡		N/A	Coastal	N/A		✓	3
Sedum acre		●	◐	50-150	✗	🟢	🟡		N/A	Dry	N/A		✓	1
Sedum azore		●	◐	50-150	✗	🟢	○		N/A	Dry	N/A		✓	1
Sedum dasphyllum		●	◐	50-150	✗	●	○		N/A	Dry	N/A		✓	1
Sedum decumbens		●	◐	50-150	✗	🟢	🟡		N/A	Dry	N/A		✓	1
Sedum hintonii		●	◐	50-150	✗	🟣	🔴		N/A	Dry	N/A		✓	1
Sedum kamtschaticum		●	◐	50-150	✗	🟢	🟡		N/A	Dry	N/A		✓	1
Sedum mexicanum		●	◐	50-150	✗	🟡	🟡		N/A	Dry	N/A		✓	1
Sedum murabilis		●	◐	50-150	✗	🔴	🟣		N/A	Dry	N/A		✓	1
Sedum moranense		●	◐	50-150	✗	🟢	○		N/A	Dry	N/A		✓	1

Exotic Plant Selection

KEY:

● Fully tolerant
◐ Tolerates some
✗ Not tolerant
☁ Mounded or spreading
⬮ Oval
✳ Spiky
▁ Prostrate
◠ Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Succulents continued		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Sedum oaxacanum		●	◐	50-150	✗	🟢	🟡	▁	N/A	Dry	N/A		✓	1
Sedum pachyphyllum		●	◐	50-150	✗	🟢	🟡	▁	N/A	Dry	N/A		✓	1
Sedum reflexum		●	◐	50-150	✗	⚫	🟡	▁	N/A	Dry	N/A		✓	1
Sedum rubroctinctum		●	◐	50-150	✗	🟣	🟡	▁	N/A	Dry	N/A		✓	1
Sedum rupestre		●	◐	50-150	✗	⚫	🔴	◠	N/A	Dry	N/A		✓	1
Sedum spathufolium		●	◐	50-150	✗	⚫	🟡	▁	N/A	Dry	N/A		✓	1
Sedum spurium 'Dragons Blood'		●	◐	50-150	✗	🔴	🩷	▁	N/A	Dry	N/A		✓	1
Sedum spurium 'Voodoo'		●	◐	50-150	✗	🔴	🩷	▁	N/A	Dry	N/A		✓	1
Sedum ternatum		●	◐	50-150	✗	🟢	⚪	▁	N/A	Dry	N/A		✓	1
Sempervivum species		●	◐	50-150	✗	🟢	🔴	▁	N/A	Dry	N/A		✓	2
Senecio serpens		●	◐	50-150	✗	🟢	⚪	▁	N/A	Dry	N/A		✓	2
Herbaceous/Bulbs														
Allium schoenprasum	Chives	●	●	150-500	✓	🟢	🟣	✳	N/A	Meadow	N/A		✓	3
Crocus sativum	*Autumn Crocus*			50-150	✓	🟢	🟣	✳	N/A	Meadow	N/A		✓	3
Iris reticulata	*Iris*	●	◐	150-500	✓	🟢	🟣	✳	N/A	Dry	N/A		✓	1
Lavandula angustifolia	*Lavender*	●	◐	150-500	✓	🟢	🟣	◠	N/A	Dry	N/A		✓	1

Exotic Plant Selection

KEY:

●	◐	×					
Fully tolerant	Tolerates some	Not tolerant	Mounded or spreading	Oval	Spiky	Prostrate	Rounded

0 – Unknown
1 – Excellent
2 – Good
3 – Moderate
4 – Poor

Scientific name	Common name	Requirements				Characteristics			Ecology			Ecosystem services		Performance
Herbaceous/Bulbs continued		Sun	Shade	Minimum substrate depth (mm)	Irrigation required	Leaf colour	Flower or berry colour	Form	Conservation status	Ecosystem origin	Whangarei Ecological District	Bird food	Insect and/or lizard food	**Success ranking**
Ophiopogon japonicus	Mondo Grass	◐	●	150-500	✓	🟢	🟣		N/A	Open & Forest slopes	N/A		✓	1
Origanum vulgare	*Oregano*	●	●	150-500	✓	🟢	🩷		N/A	Dry	N/A		✓	1
Thymus vulgaris	*Thyme*	●	●	150-500	✓	🟢	🟣		N/A	Dry	N/A		✓	1
Grasses			●											
Lomandra tanika		●	●	150-500	✓	🟢	🟡		N/A	Dry	N/A		✓	2

3.3.8 Muehlenbeckia Case Study

One potential to increase biodiversity associated with living roofs and green walls is to focus on plants that provide habitat for flying native invertebrates.

Resistance is an attribute that Muehlenbeckia, amongst the most adaptable of New Zealand's native plants, demonstrates in its natural environments of coastlines and riverbeds (New Zealand Plant Conservation Network, 2018).

New Zealand has five species of *Muehlenbeckia*, most of which exhibit a climbing or sprawling growth habit. *Muehlenbeckia* plays an important ecological role as host for native copper butterflies. *Muehlenbeckia complexa* has been shown to adapt well to green wall and living roof situations and offers potential to provide a robust contribution to native biodiversity in such situations.

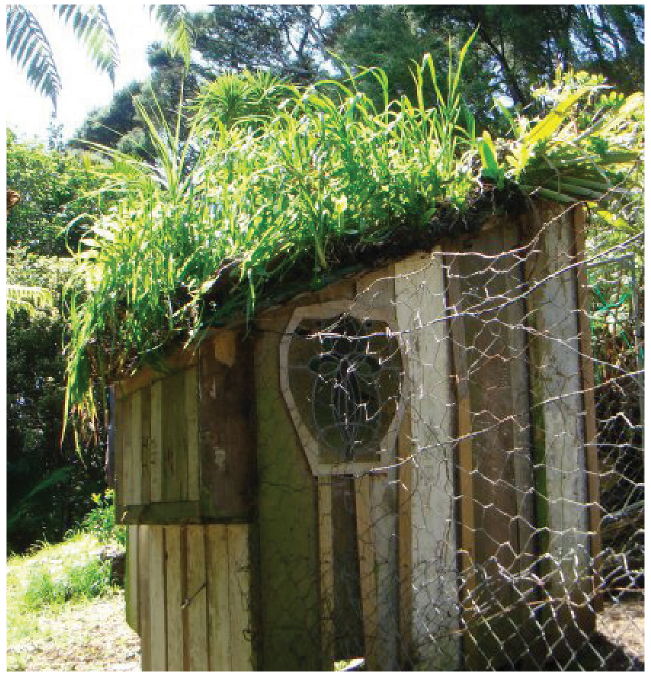


Figure 60: Living roof chicken house at Arohanui, Great Barrier Island

To Weed or Not to Weed?

As with any living system, a vegetated roof will provide conditions for weed establishment. The type and scale of weeds will vary and the extent of weed removal is dependent on the desired aesthetic. Many living roof weeds are small herbaceous weeds that will naturally die off each year and do not detract from the overall planted aesthetic.

Good nursery biosecurity measures are required to prevent the establishment of unwanted organisms and weeds on living roofs. Large rooted native plant seedlings such as pōhutukawa, cabbage tree, karo and flax (common adventive weeds found on New Zealand living roofs) should be removed to prevent their extensive root system compromising the waterproof layer.

Trampling over the roof to undertake weeding will compact the substrate, reducing air pockets, permeability and drainage capacity. It is important to minimise maintenance as much as possible and/or provide protected vegetation-free zones for access.

The smaller non-invasive weed species can be appreciated as a natural seasonal part of the living system.

Spontaneous Self-seeders

A mix of perennial weeds have been found to self-seed onto living roofs in New Zealand, many of which can add to the aesthetic of the roof, are not invasive, and/or die out annually over summer, so do not need to be weeded out (depending on the design aesthetic for the roof).

The following examples are found in Whangarei.

Cardamine hirsute
(Bittercress)

Helichrysum lueoalbum
(Jersey Cudweed)

Bellis perennis
(English Daisy)

Epilobium ciliatum
(Willow Weed)

Fumaria muralis
(Fumitory)

Fumaria muralis
(Lamium)

Euphorbia peplusbia
(Milkweed)

Anagallis arvensis
(Blue Pimpernel)

Plantago major
(Broad Leaf Plantain)

Prunella vulgaris
(Selfheal)

Sonchus sp.
(Sow Thistle)

Hydrocotyl moschata
(Hydrocotyl)

Taraxacum officinale
(Dandelion)

3.3.9 Substrate

The substrate that the vegetation on a living roof grows in needs to balance the engineering requirement of light weight and rapid permeability (roofs must not flood), with water and nutrient storage for plant growth, and cost.

The basic principle of the substrate is to keep it as light as possible, generally with a maximum soil or organic content of 20%. This low organic component allows for improved drainage, lighter substrate, and a more stable substrate that has a reduced need for 'top up' of new material.

There is a wide range of substrate types that can be used, depending on the tolerance of the roof loading and desired planting of the roof. From normal soil through to crushed brick, each will support different ranges and types of plants.

> "In New Zealand, the ideal substrate would be locally sourced and should meet the following criteria:
>
> - A saturated weight that is consistent with the structural loading able to be accommodated by the roof;
> - Hydraulic conductivity greater than 100 mm/hour at installation, to avoid ponding and potentially avoid the need for a drainage layer. This means plant roots maintain adequate aeration. Aeration is important, because many drought-tolerant plants are intolerant of continually wet and ponded root systems.
> - More than 20 mm moisture stored immediately after watering;
> - Moderate bearing strength (i.e. able to support foot traffic for maintenance without crumbling or overly compacting);
> - Minimal shrink/swell and slow development of hydrophobicity (water repellency) so the substrate absorbs water evenly and consistently;
> - Moderate ability to store and supply nutrients for plant growth without leaching high concentrations of nutrients.
>
> The most important aspect for consideration of substrate is the saturated weight. If a customised substrate is to be used where the saturated weight is not known, then tests should be carried out to determine that saturated weight loading. These tests can be undertaken by a number of scientific laboratories." (Simcock, R. personal communication, July 2017)

What is a Saturated Weight and Why is it Important?

The capacity of a substrate to hold water affects the volume of water it can retain and therefore make available to the plants on a living roof, and/or its detention ability (for stormwater drivers). In the case of a custom-designed substrate, the weight of the substrate on the structure can only be determined by undertaking a test of the weight of the substrate at full saturation (Fassman & Simcock, Moisture Measurements as Performance Criteria for Extensive Living Roof Substrates, 2012). This test can also help to determine how quickly the substrate will reach saturation, as that in turn impacts on the characteristics of the plants appropriate for the particular substrate. Tests can be done by a number of laboratory test companies in New Zealand.

3.3.10 Irrigation

Depending on the type of plants chosen, irrigation may be required, particularly in hot droughty Whangarei summers. Irrigation usually consists of a subsoil, low-volume, low-pressure drip irrigation system installed into the growing substrate (Crain, 2014). Irrigation fabric mats are also useful and distribute water throughout the mat via capillary action. Having the irrigation on an automatic and easily accessible controller is important.

3.3.11 Filter Layer

Sometimes incorporated into root barrier, this geotextile filter layer prevents fine particles from the substrate from clogging up the drainage layer.

3.3.12 Drainage Layer

It is important for living roofs, walls and facades to have good drainage to protect the plants and the building's structural integrity. Drainage systems need to be designed to remove surface and sub-surface water from the roof or wall and deal with extreme rainfall events. As such, drainage layers need to be highly porous, continuous and consistent over the whole roof (Fassman, Voyde, Simcock, & Wells, 2008).

Common drainage layers are made from a synthetic mat or a coarse aggregate. Living roof drainage mats usually have a root barrier geotextile attached. This layer can protect the waterproofing from damage by maintenance implements, such as spades, and can provide air circulation for the plant's root system. The substrate composition will also affect the flow of stormwater through the living roof system.

With the onset of modern living roof projects, a range of proprietary plastic drainage layers were developed that were an alternative to gravel or pumice. These systems have advantages for large projects as they reduce the weight and thickness of the system and allow for maximum water movement off the roof. For simple 'DIY' projects, the use of gravel or pumice type materials is a cheap and functional option.

The important element to ensure with any drainage layer, irrespective of type, is that they do not degrade and thereby lose their drainage capacity or create blockages in the system. They also need to be able to withstand the weights of installation activity.

3.3.13 Moisture Retention Layer

These layers are often incorporated into the drainage layer and allow for the storage of a small amount of water that then increases the availability of water to plants. These layers are most often used in situations where there is no intended irrigation provided to the system.

3.3.14 Membrane Protection

During construction of a living roof it is important to ensure that the waterproof membrane is protected from installation and construction activity. This can be achieved by either restricting all traffic on the membrane until the living roof components are added, either at once or staged (that then provide protection), or by placing some form of protective and robust mat (such as insulation) over the membrane.

3.3.15 Root Barrier

A root barrier is used to maintain the integrity of the waterproof membrane of a living roof (Snodgrass & McIntyre, 2010). It essentially provides a layer of material that reduces the potential of plant roots penetrating or impacting on the waterproof membrane. There are many different types of root barrier available. A separate sheet of geotextile fabric may be used, or something integrated into a modular system or with the proprietary drainage layer.

3.3.16 Leak Detection

A number of leak detection proprietary systems are available in New Zealand and are generally located next to the waterproof layer. These systems allow for testing to occur of the waterproof layer prior to installation of the living roof (essential as part of the flood testing of a roof), but can also be used as a permanent component that allows for quick detection and isolation of the area of any leak that might occur within the waterproof layer of the living roof. Such systems ensure that any remedial work in the future does not necessarily require removal of the whole living roof system. A 'warm' roof - a roof that has insulation above the waterproofing - requires a mesh grid system to be installed between the insulation and waterproof membrane, with the leak detection placed on top of the membrane, as it is non-conductive.

3.3.17 Waterproofing

There is a common concern that flat roofs leak in New Zealand. If a living roof is designed to meet the German FLL standards it will include a root barrier that will protect the waterproof layer. The living roof then protects and act as a barrier to UV and weather damage, thereby extending the roof life by two or three times. It is also noted that most waterproofing companies will leak-test the waterproof membrane prior to the living roof being installed.

There is a range of waterproofing systems and materials available in New Zealand for use on the roof deck. The important considerations include:

- Whether the material chosen has a proven track record for use in living roof scenarios;
- Ensuring the material has been tested and has passed the relevant standards;
- Ensuring there is a warranty (if required) in place;
- Choosing a material that is robust and will last as long as possible;
- Does it require a separate root barrier?

Butterflies and Bees

A living roof can add an attractive and ecologically beneficial feature to garden structures like sheds, garages, chook houses, and letter boxes. These domestic-scale projects are easy to install as long as some general principles are followed. Large-scale projects should be carried out only after advice from specialists.

Figure 61: Living roof garden shed at Chelsea Flower Show, London

Figure 62: Eco village, Torino, Italy (Reprinted with the permission of Renee Davies)

4. PHASE THREE: DESIGN - HUNDERTWASSER ART CENTRE LIVING ROOF

4.0 PHASE THREE: DESIGN HUNDERTWASSER ART CENTRE LIVING ROOF

"If we do not honour our past we lose our future. If we destroy our roots we can not grow."
Freidensreich Hundertwasser (1928-2000)

As discussed, the case study site for this research investigation was a real-world project. The Whangarei Art Museum Trust had successfully raised the estimated build costs for the Hundertwasser Art Centre and were finalising the design, final building consents and construction contract, with an estimated build start date of June 2018.

The Hundertwasser Art Centre will be the very last authentic living-roofed Hundertwasser building in the world and is intended to be a significant asset to Whangarei and the Northland Region (Deloitte, 2015). Hundertwasser always thought outside the box and rejected straight lines and authority. He expressed this philosophy through his architecture. His living roofs and tree tenants were more than just aesthetic features; these spaces were given back to nature where people could enjoy them as a guest of nature, just like walking through a forest (Muthesius, 2013).

The centre will be multi-functional, including a main gallery showcasing Hundertwasser's work, a contemporary Māori art gallery, café, cinema, and a student resource centre. The Wairau Māori Art Gallery will be the world's first gallery dedicated solely to contemporary Māori art. Wairau is the te reo Māori translation of 'one hundred waters' – the English translation of the German 'Hundertwasser'.

Having originally been approached to provide advice on the support methods for trees on the roof and subsequently highlighted areas to the project team, which required further consideration in terms of the holistic approach, I was commissioned to work with the project team on the design of the living roof.

4.1 Design Brief

As outlined in Phase Two, the Design Manual brief has as an important component, the philosophical musings and position of Hundertwasser (section 3.2.2 above). A primary goal is afforestation of the Hundertwasser Art Centre roof, to give this space back to nature. The creation of a forest was planned using mostly New Zealand native Northland-specific plants, including offshore island, threatened, endangered or rare species, and integrating those local species with fruiting trees, so one can wander through the forest and discover, pick and eat fruit. This forest was to be set randomly, wild, with spontaneous vegetation beneath the trees where new plants can self-seed, as happens in nature.

The design was to follow the Design Manual principles, design considerations and living roof

Figure 63: Te Kākano (the seed) folly has been built near the site of the Hundertwasser Art Centre in Whangarei - a stand-alone sculpture in the shape of a koru. A pre-requirement of the Hundertwasser Foundation in Vienna.

Figure 64: Drone photograph facing Hundertwasser Art Centre site

Figure 65: Drone photograph looking down on the Hundertwasser Art Centre site

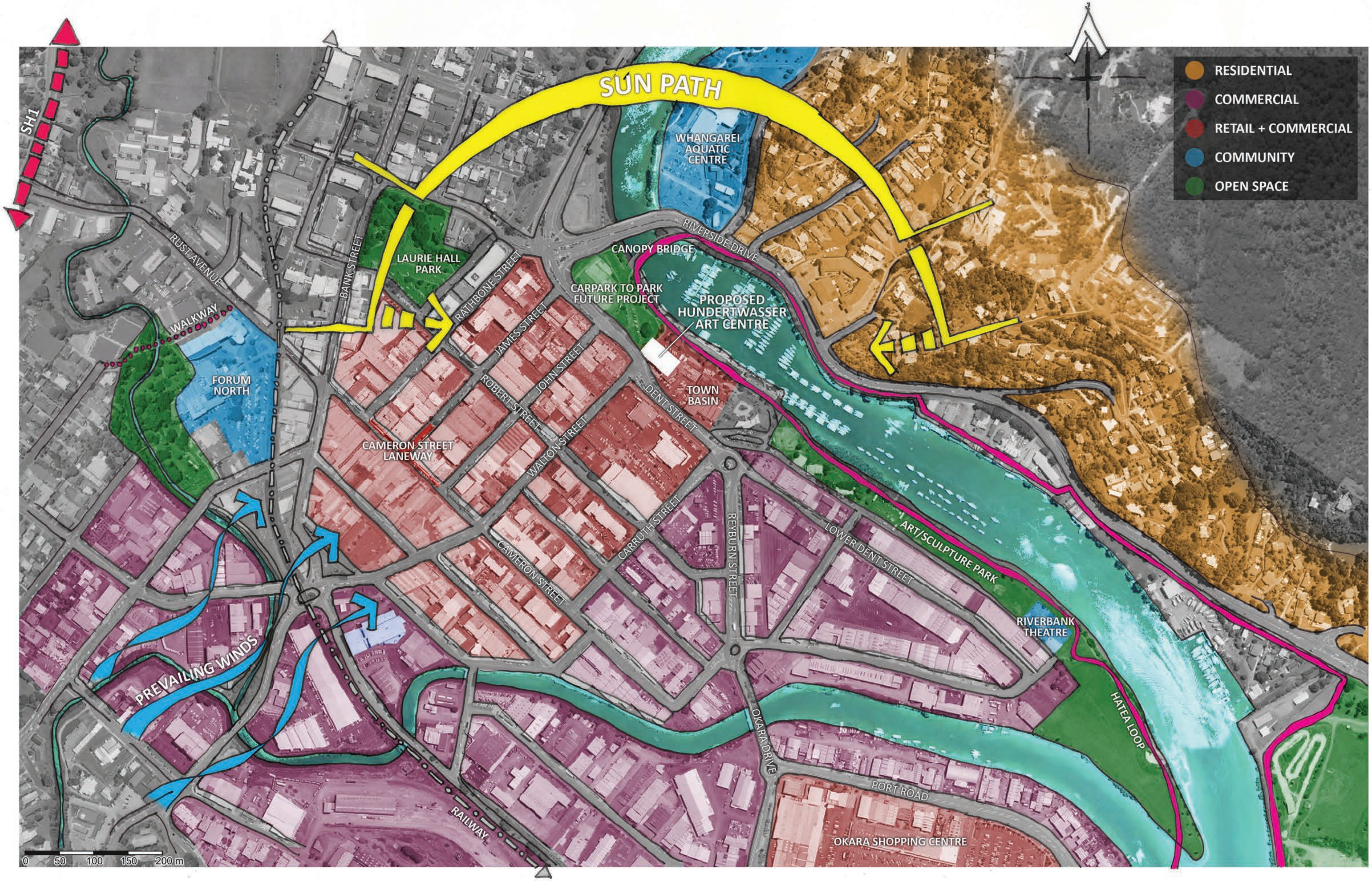


Figure 66: SIte Analysis

design components detailed in the guide to maximise the benefits on the built environment, humans and nature.

Titiro whakamuri hei arahi i nga uaratanga kei te kimihia.
Look to the past for guidance and seek out what is needed.

4.2 Site Analysis

The Hundertwasser Art Centre is in the Whangarei Town Basin, where it sits alongside the waterfront, between the Information Centre and the future park.

The area alongside the waterfront forms the Heritage Trail and Art Walk, with a number of sculptures commissioned from local artists, and currently houses the Whangarei Art Museum, Reyburn House Art Gallery and the Northland Society of the Arts. Cafes, restaurants, speciality shops, and private arts and craft galleries occupy many of the buildings at the Town Basin.

“The Whangarei City Centre Plan is structured around five key outcomes. These key outcomes form the vision of the city centre over the next thirty years” (Whangarei District Council, 2017, pp. 2-3). The intended outcomes are experience, **connectivity**, living, employment and education, and design. Within the Whangarei City Centre Plan, the Town Basin was highlighted as being disconnected from the city centre – **accessibility** and **permeability** being importance for design outcome. The Plan also highlighted the importance of mixed-use development, **diversity**, and **identity**, having spaces that are authentic for visitors.

With views of the Hatea River, the Whangarei Marina, the Canopy Pedestrian Bridge, and the future park, the roof of the Hundertwasser Art Centre presents the opportunity to capture iconic views of Whangarei.

The Hundertwasser Art Centre is at the intersection of Walton Street and Dent Street, two main roads in Whangarei, and the Hatea Loop, a 4.2 km walkway linking the Town Basin with surrounding destinations.

The prevailing wind comes from the southwest while the northern side of the building receives the most solar exposure.

4.3 The Plan

To increase the effectiveness of living roof design, the Design Manual informed the planting plan, highlighting, for example, offshore island plant options (see section 3.3.4) that may be successful on the Hundertwasser Art Centre living roof. In keeping with the living urbanism principles of **sustainability**, **identity** and **robustness**, the plants identified in the Manual are ones adapted to harsh local island conditions. The Manual’s Plant List (see section 3.3.7) also provided a number of species that had been trialled on other living roofs in New Zealand and been successful (Waitakere City Council, 2007). By proving species which may have a higher success rate, may provide some certainty of plant success and reduce risk of plant loss on the living roof in line with the principles of **robustness** and **diversity**. Plants were also chosen from the plant list that would provide food for birds and insects, increasing biodiversity and widening the ecosystem services provided by the Hundertwasser Art Centre living roof. The plant palette had a diverse mix of exotic fruiting trees and New Zealand natives that are adapted to the local ecological region. Focus was placed on species that are threatened and found on offshore islands, highlighting the special character and the unique location, and showcasing **identity** (see section 3.2.2) in the Hundertwasser Art Centre in Whangarei.

The planting used the Manual to inform the aesthetics of the living roof, where plants were chosen for their leaf and flower colour as well as form, to meet the concept of creating a woodland (forest) effect. The intention was to create a spontaneous feel to the planting with sightlines through and between the trunks of the forest trees. Groupings of offshore island nikau species (as their leaves don’t get so damaged in the wind) were interspersed within the overall forest tree species.

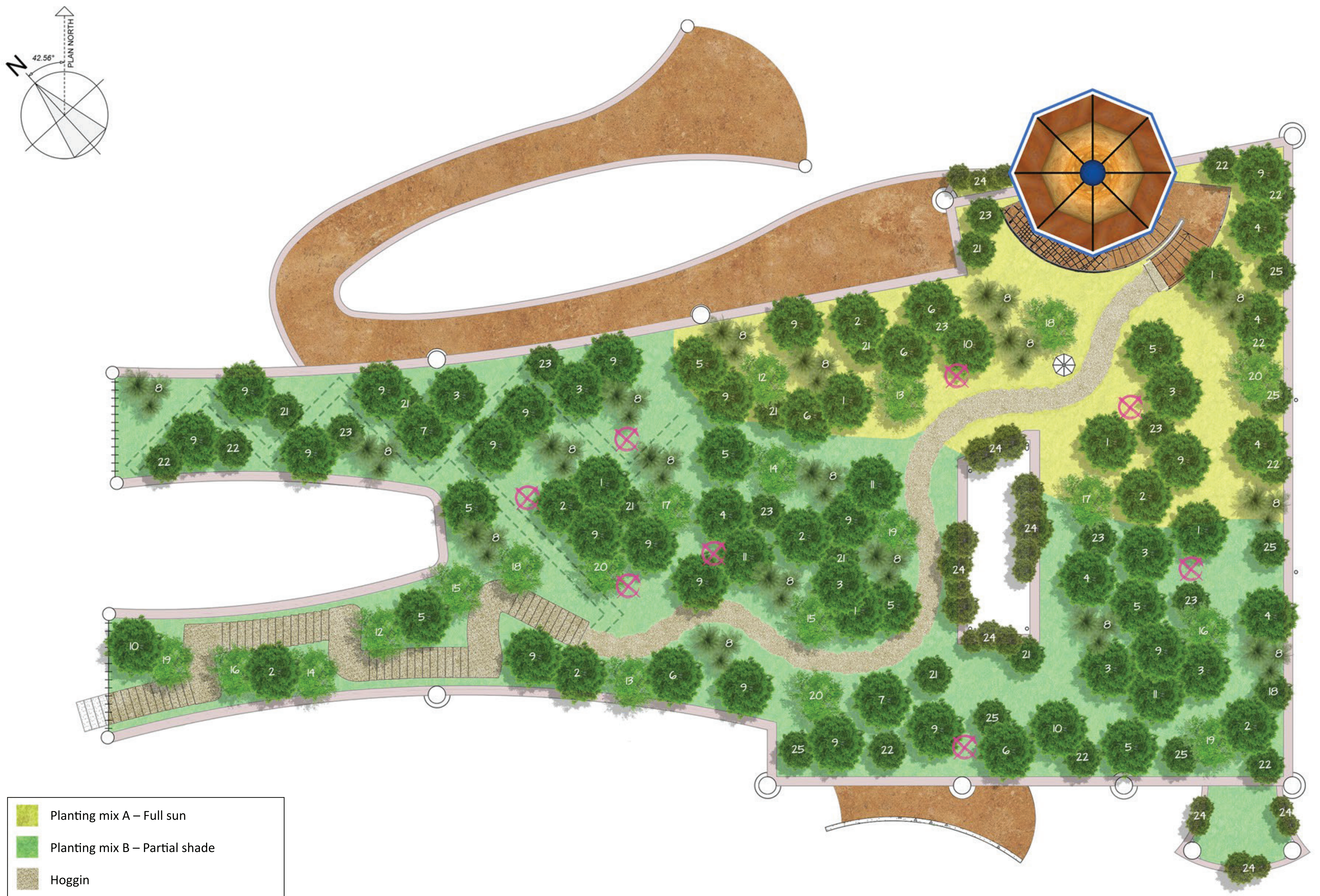
To ensure the roof creates a sense of place and **identity**, fruiting trees were included to reflect Hundertwasser’s philosophy, where visitors can discover and pick fruit from a tree.

A number of the original proposed plant species (by the project team) were replaced due to specific local conditions that might risk successful growth of those species. Replaced species included:

- *Myrtaceae species* (eg. feijoa, guava, manuka, kānuka, pōhutukawa and rata) were replaced due to the current risks associated with the myrtle rust disease and current unknown status of that situation;
- Fig – due to potential wind damage of branches and penetrating roots;
- Date palm – very difficult to source;
- Camelia – no fruit;
- Tōtara – too large, and replaced with more tropical-looking threatened native tree species.

To enhance even further the spontaneous nature of the living roof afforestation, the Design Manual and resulting plant palette identified a range of adventive local weed species that were likely to colonise the roof, and proposed that these not be weeded out, to allow for a natural progression and mixing of plant species as the roof planting develops and evolves naturally over time.

“The horizontal belongs to nature - the vertical belongs to men.”
- Hundertwasser, 1972



- 🟨 Planting mix A – Full sun
- 🟩 Planting mix B – Partial shade
- ▨ Hoggin
- ---- Chevron soil retention
- ++++ Gate/Fence
- ● Native woodland specimen tree
- ● Exotic woodland fruit tree
- ● New Zealand native shrub
- ✳ Nikau grove
- ⊗ Sculpture plinth and tree support anchor

Please note that canopy widths drawn are not reflective of final canopy cover which is expected to be ~90-100% cover of the roof – refer to cross sections and elevations

Native Woodland Specimen Trees:

1. *Alectryon excelsus* subsp. Grandis
   Three Kings titoki
2. *Corynocarpus laevigatusī*
   Karaka
3. *Elingamita johnsonii*
   Elingamita
4. *Pittosporum fairchildii*
   Fairchild's kohuhu
5. *Pennantia baylisiana*
   Three Kings Kaikomako
6. *Planchonella costata*
   Tawapou
7. *Nestegis apetala*
   Coastal maire, Bastard Ironwood (Norfolk Island)
8. *Rhopalostylis sapida*
   Nikau (Chatham Island)
9. *Sophora chathamica*
   Kowhai, Coastal Kowhai
10. *Vitex lucens*
    Puriri
11. *Strebulis smithii*
    Three Kings milk tree

Native Woodland Fruit Trees:

12. *Pyrus communis 'Doyenne du Comice'*
    Pear
13. *Pyrus communis 'Beurre Bosc'*
    Pear
14. *Prunus domestica 'Billington'*
    Plum
15. *Prunus domestica 'Burbank'*
    Plum
16. *Malus pumila 'Sunrise'*
    Apple (early season)
17. *Malus pumila 'Egremont russet'*
    Apple (mid season)
18. *Malus pumila 'Monty's surprise'*
    Apple (late season)
19. *Prunus persica var. nucipersica 'Nani's nectarine'*
    Nectarine
20. *Prunus persica 'Caravan peacherine'*
    Peach

New Zealand Native Shrubs:

21. *Veronica parviflora*
    Hebe parviflora
22. *Veronica speciosa* var. brevifolia
    Cheeseman
    Hebe brevifolia
23. *Veronica diosmifolia*
    Hebe diosmifolia
24. *Coprosma repens* 'Poor Knights'
    Coprosma repens 'Poor Knights'
25. *Griselinia lucida*
    Puka, Akapuka

Planting Mix A

26. *Astelia banksii*
    Coastal Astelia, Shore Kowharawhara
27. *Carex solandri*
    Forest Sedge, Solander's Sedge
28. *Carex testacea* - green
    Speckled Sedge, Trip Me Up
29. *Chionochloa flavicans*
    Snow Tussock
30. *Festuca coxii*
    Cox's fescue
31. *Lepidium oleraceum*
    Nau, Cooks scurvy grass
32. *Pimelea arenaria/Pimelea villosa*
    Sand Daphne, Autetaranga, Toroheke, Sand pimelea
33. *Pimelea prostrata* subsp. Prostrata
    Pinatoro, New Zealand Daphne, Strathmore Weed
34. *Xeronema callistemon*
35. *Pachystegia insignis*
    Marlborough Rock Daisy
36. *Hibiscus ricardii*

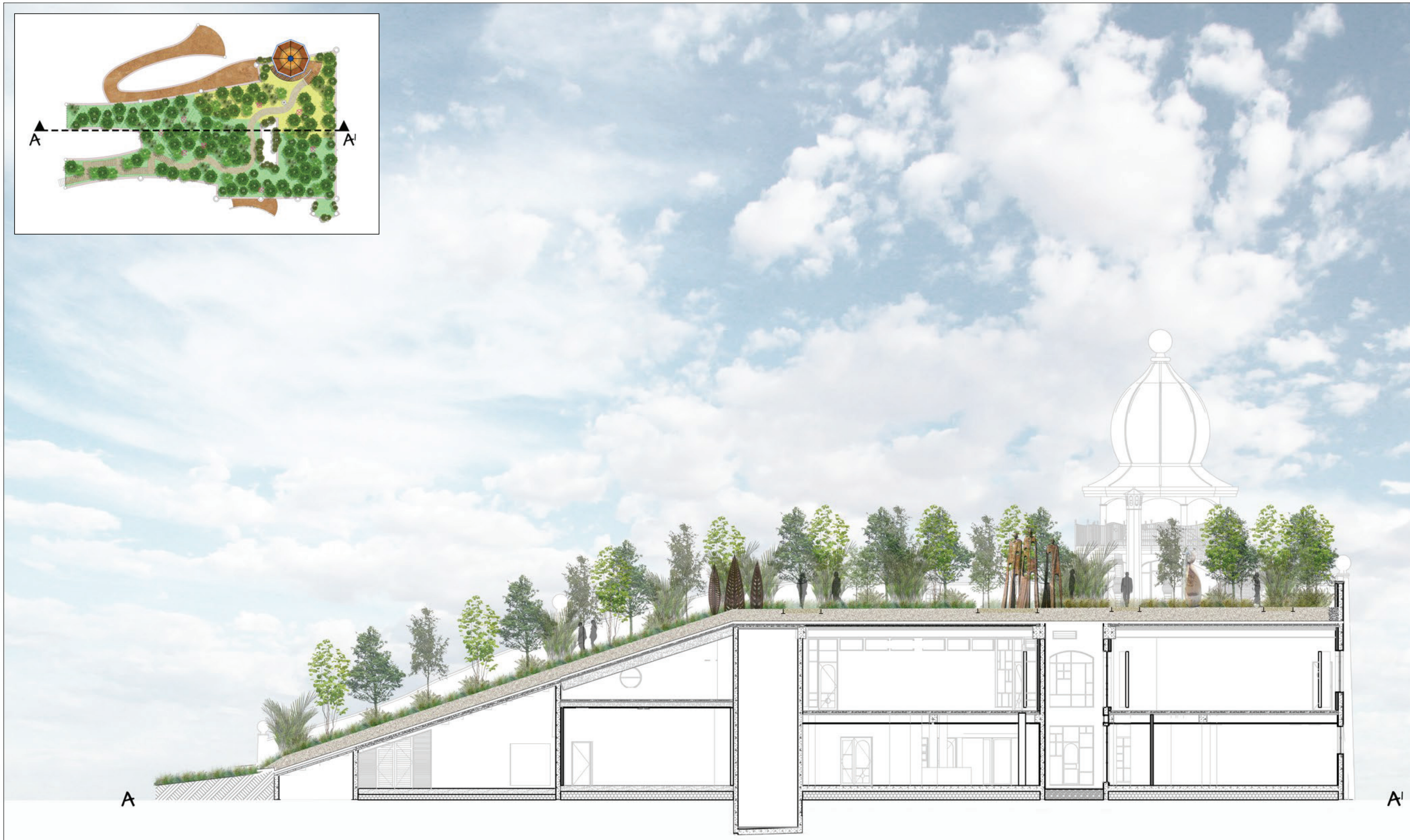
Planting Mix B

37. *Arthropodium* 'Matapouri Bay'
    'Matapouri Bay' Renga Lily, Rengarenga, Rock Lily
38. *Asplenium oblongifolium*
    Shining Spleenwort
39. *Astelia banksii*
    Coastal Astelia, Shore Kowharawhara
40. *Blechnum novae-zelandiae*
    Kiokio, Horokio, Palm Leaf Fern
41. *Carex solandri*
    Forest Sedge, Solander's Sedge
42. *Carex testacea* - green
    Speckled Sedge, Trip Me Up
43. *Chionochloa flavicans*
    Snow Tussock
44. *Festuca coxii*
    Cox's fescue
45. *Lepidium oleraceum*
    Nau, Cooks scurvy grass
46. *Pimelea arenaria/Pimelea villosa*
    Sand Daphne, Autetaranga, Toroheke, Sand pimelea
47. *Pimelea prostrata* subsp. Prostrata
    Pinatoro, New Zealand Daphne, Strathmore Weed
48. *Samolus repens*
    Sea Primrose, Shore Pimpernel
49. *Selliera radicans*
    Remuremu
50. *Xeronema callistemon*
51. *Pachystegia insignis*
    Marlborough Rock Daisy
52. *Hibiscus ricardii*
53. *Apium prostratum subsp. denticulatum*
    Chatham Island celery

Scale: 1:200 @ A3
1:100 @ A1
0 2 4 6 8 10m

Hundertwasser Art Centre with Wairau Maori Art Gallery
LIVING ROOF AFFORESTATION: PLAN

Figure 67: Living Roof Afforestation Concept Plan



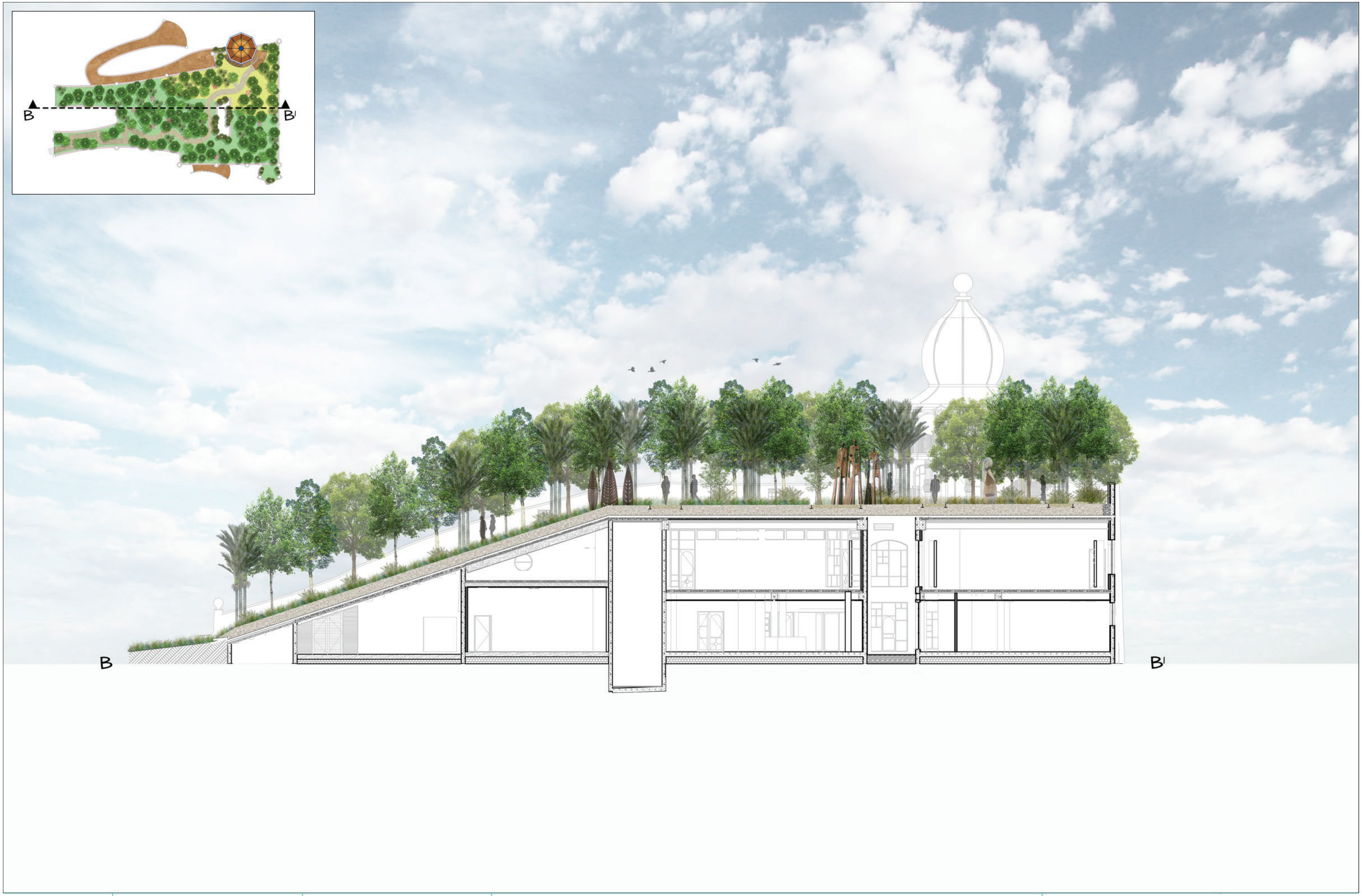
Scale: 1:200 @ A3
1:100 @ A1

0 2 4 6 8 10m

Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: CROSS SECTION A

Figure 68: Living Roof Afforestation Cross Section A



Scale: 1:200 @ A3
1:100 @ A1

0 2 4 6 8 10m

Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: CROSS SECTION B

Figure 69: Living Roof Afforestation Cross Section B

Scale: 1:100 @ A3
1:50 @ A1

0 1 2 3 4 5m

Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: CROSS SECTION C

Figure 70: Living Roof Afforestation Cross Section C

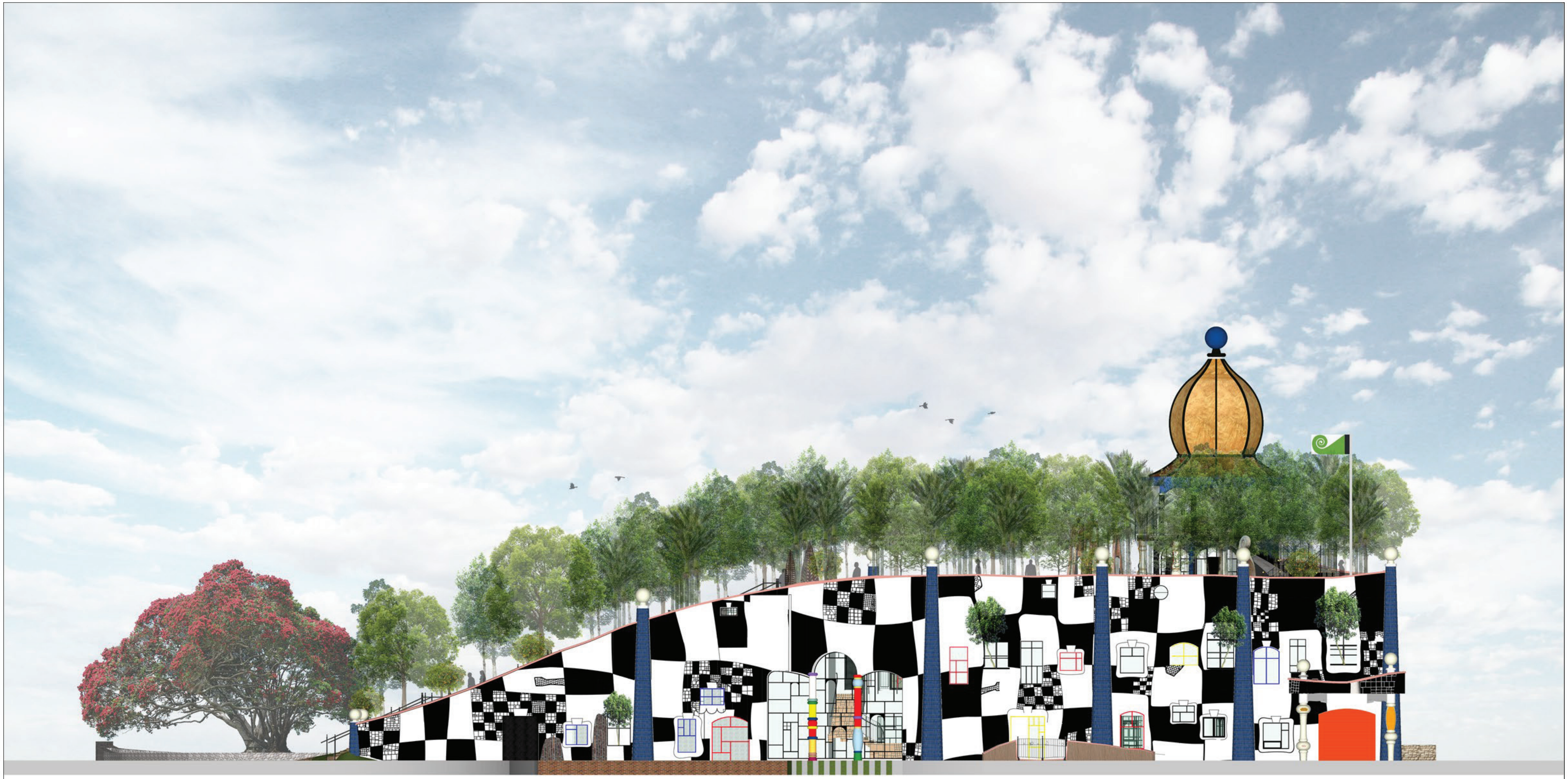
Scale: 1:100 @ A3
1:50 @ A1

0 1 2 3 4 5m

Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: CROSS SECTION D

Figure 71: Living Roof Afforestation Cross Section D



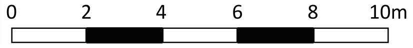
Scale: 1:200 @ A3
1:100 @ A1

Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: ELEVATION 1

Figure 72: Living Roof Afforestation Elevation 1

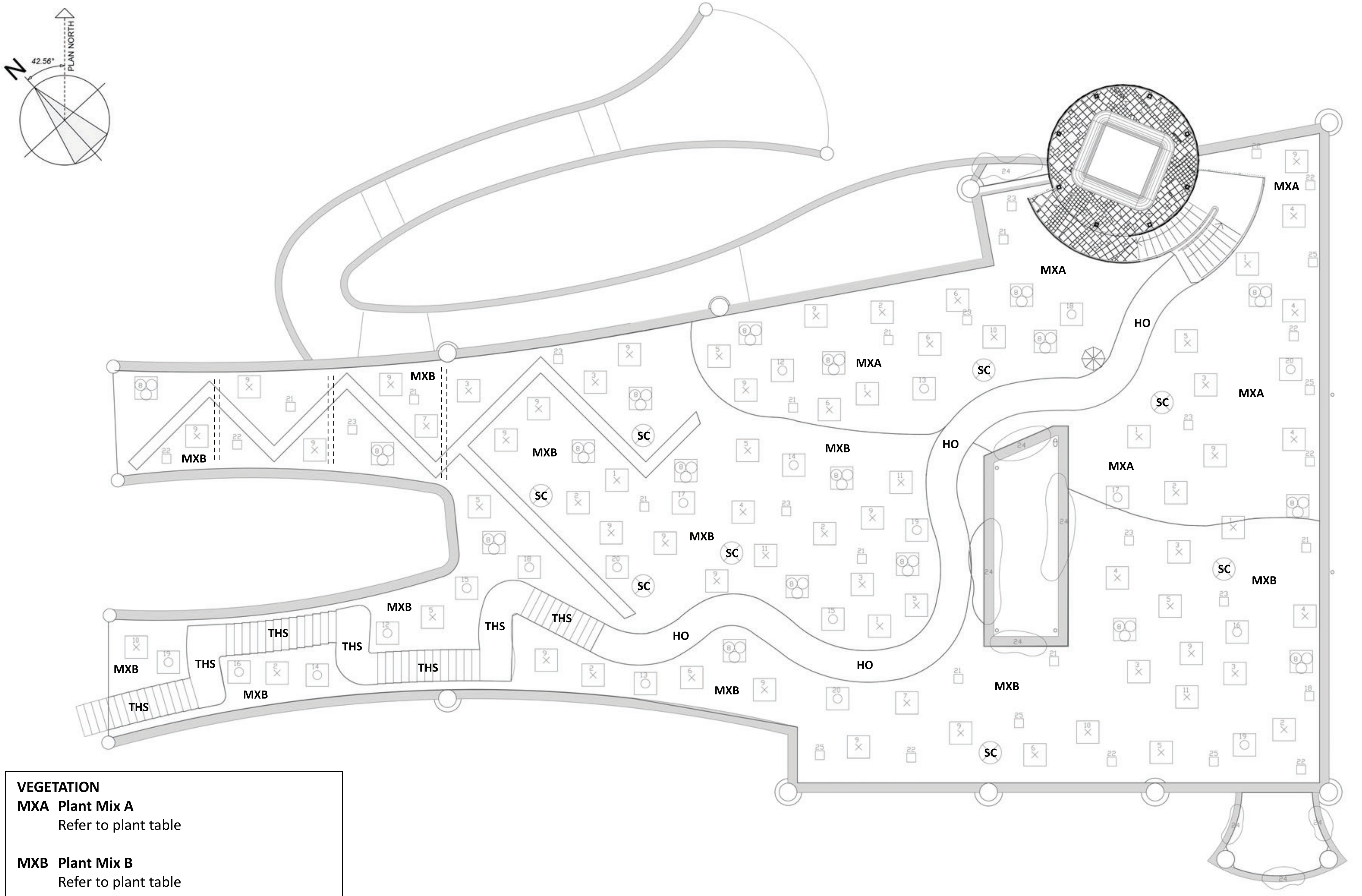
Scale: 1:200 @ A3
1:100 @ A1



Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: ELEVATION 2

Figure 73: Living Roof Afforestation Elevation 2



VEGETATION

MXA **Plant Mix A**
Refer to plant table

MXB **Plant Mix B**
Refer to plant table

SURFACE

HO **Hoggin**

TIMBER/HOGGIN STEPS

THS Timber and hoggin steps. To be detailed by HB Architects.

SCULPTURAL INSTALLATIONS
TO BE CONFIRMED

SC Māori artwork by artist to be co-ordinated by WAM personnel; base/paving detail construction and fixing to be advised.

Native Woodland Specimen Trees:

1. *Alectryon excelsus* subsp. Grandis
   Three Kings titoki
2. *Corynocarpus laevigatusī*
   Karaka
3. *Elingamita johnsonii*
   Elingamita
4. *Pittosporum fairchildii*
   Fairchild's kohuhu
5. *Pennantia baylisiana*
   Three Kings Kaikomako
6. *Planchonella costata*
   Tawapou
7. *Nestegis apetala*
   Coastal maire, Bastard Ironwood (Norfolk Island)
8. *Rhopalostylis sapida*
   Nikau (Chatham Island)
9. *Sophora chathamica*
   Kowhai, Coastal Kowhai
10. *Vitex lucens*
    Puriri
11. *Strebulis smithii*
    Three Kings milk tree

Native Woodland Fruit Trees:

12. *Pyrus communis 'Doyenne du Comice'*
    Pear
13. *Pyrus communis 'Beurre Bosc'*
    Pear
14. *Prunus domestica 'Billington'*
    Plum
15. *Prunus domestica 'Burbank'*
    Plum
16. *Malus pumila 'Sunrise'*
    Apple (early season)
17. *Malus pumila 'Egremont russet'*
    Apple (mid season)
18. *Malus pumila 'Monty's surprise'*
    Apple (late season)
19. *Prunus persica var. nucipersica 'Nani's nectarine'*
    Nectarine
20. *Prunus persica 'Caravan peacherine'*
    Peach

New Zealand Native Shrubs:

21. *Veronica parviflora*
    Hebe parviflora
22. *Veronica speciosa* var. brevifolia
    Cheeseman
    Hebe brevifolia
23. *Veronica diosmifolia*
    Hebe diosmifolia
24. *Coprosma repens* 'Poor Knights'
    Coprosma repens 'Poor Knights'
25. *Griselinia lucida*
    Puka, Akapuka

Planting Mix A

26. *Astelia banksii*
    Coastal Astelia, Shore Kowharawhara
27. *Carex solandri*
    Forest Sedge, Solander's Sedge
28. *Carex testacea* - green
    Speckled Sedge, Trip Me Up
29. *Chionochloa flavicans*
    Snow Tussock
30. *Festuca coxii*
    Cox's fescue
31. *Lepidium oleraceum*
    Nau, Cooks scurvy grass
32. *Pimelea arenaria/Pimelea villosa*
    Sand Daphne, Autetaranga, Toroheke, Sand pimelea
33. *Pimelea prostrata* subsp. Prostrata
    Pinatoro, New Zealand Daphne, Strathmore Weed
34. *Xeronema callistemon*
35. *Pachystegia insignis*
    Marlborough Rock Daisy
36. *Hibiscus ricardii*

Planting Mix B

37. *Arthropodium* 'Matapouri Bay'
    'Matapouri Bay' Renga Lily, Rengarenga, Rock Lily
38. *Asplenium oblongifolium*
    Shining Spleenwort
39. *Astelia banksii*
    Coastal Astelia, Shore Kowharawhara
40. *Blechnum novae-zelandiae*
    Kiokio, Horokio, Palm Leaf Fern
41. *Carex solandri*
    Forest Sedge, Solander's Sedge
42. *Carex testacea* - green
    Speckled Sedge, Trip Me Up
43. *Chionochloa flavicans*
    Snow Tussock
44. *Festuca coxii*
    Cox's fescue
45. *Lepidium oleraceum*
    Nau, Cooks scurvy grass
46. *Pimelea arenaria/Pimelea villosa*
    Sand Daphne, Autetaranga, Toroheke, Sand pimelea
47. *Pimelea prostrata* subsp. Prostrata
    Pinatoro, New Zealand Daphne, Strathmore Weed
48. *Samolus repens*
    Sea Primrose, Shore Pimpernel
49. *Selliera radicans*
    Remuremu
50. *Xeronema callistemon*
51. *Pachystegia insignis*
    Marlborough Rock Daisy
52. *Hibiscus ricardii*
53. *Apium prostratum subsp. denticulatum*
    Chatham Island celery

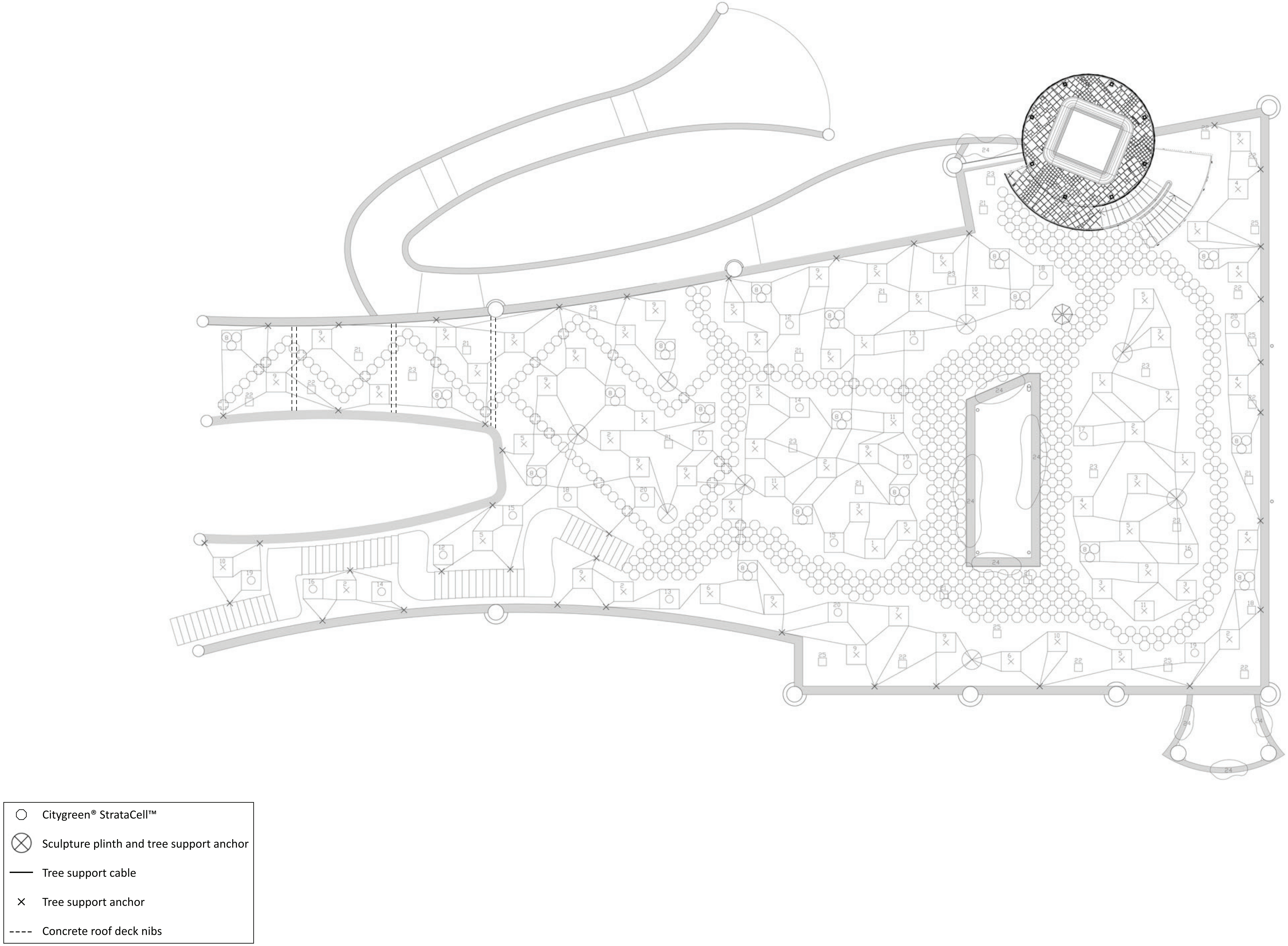
Scale: 1:200 @ A3
1:100 @ A1

0 2 4 6 8 10m

Hundertwasser Art Centre with Wairau Maori Art Gallery

LIVING ROOF AFFORESTATION: PLANTING PLAN

Figure 74: Living Roof Afforestation Planting Plan



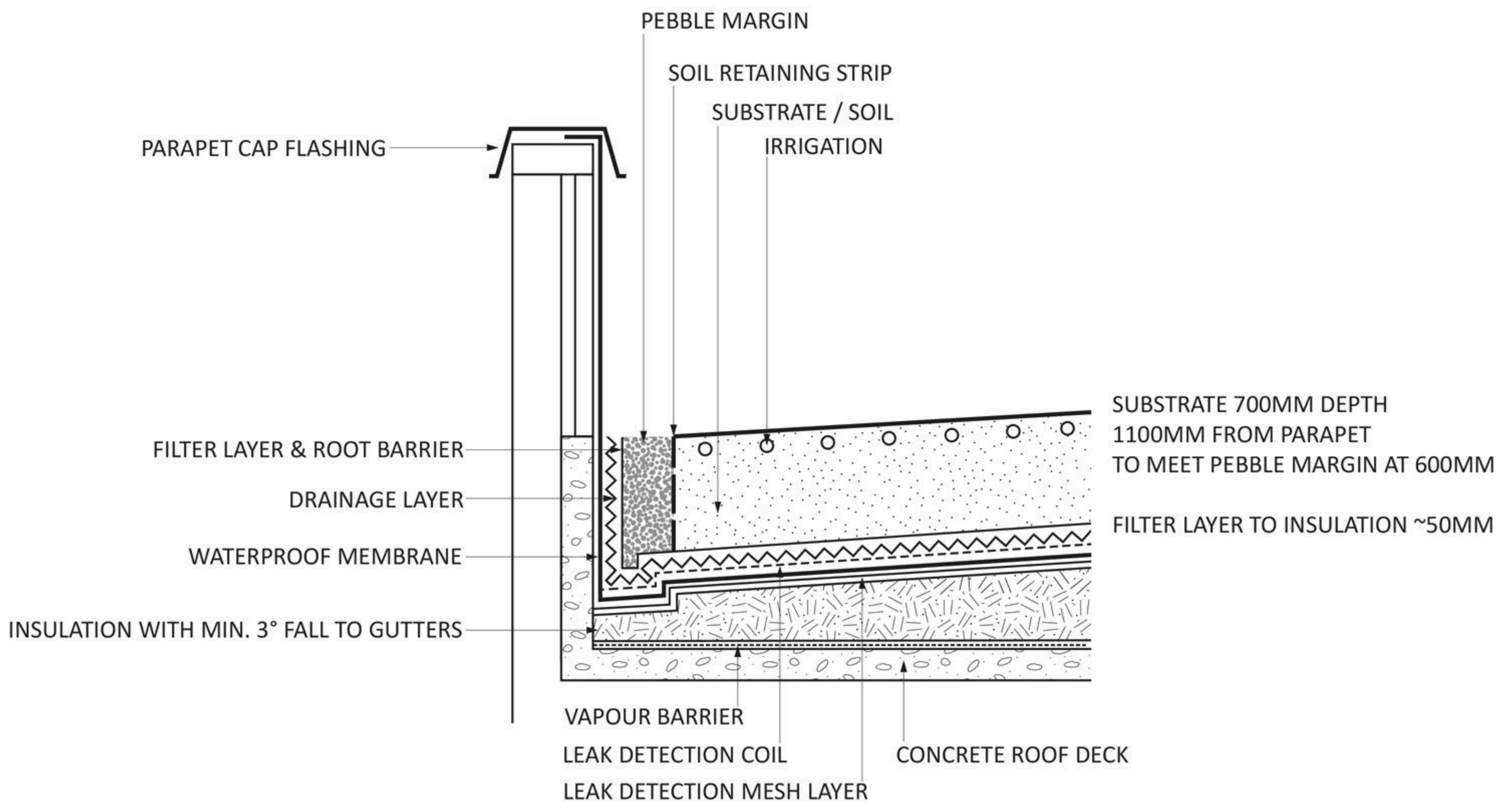
Scale: 1:200 @ A3
1:100 @ A1

0 2 4 6 8 10m

Hundertwasser Art Centre with Wairau Māori Art Gallery

LIVING ROOF AFFORESTATION TREE SUPPORT SYSTEM

Figure 75: Living Roof Afforestation Planting Plan Tree Support System



Hundertwasser Art Centre with Wairau Māori Art Gallery

Living Roof Afforestation Edge Detail

Figure 76: Living Roof Edge Concept Detail

Figure 77: Living Roof Plant Palette

Native Woodland Specimen Trees

Selection of New Zealand native trees appropriate to the local Whangarei environment are interspersed across the forest roof to echo a woodland environment.

Rhopalostylis sapida
Nikau Palm (Chatham Island)
(Not Threatened)

Alectryon excelsus subsp. Grandis
Titoki
(Threatened – Nationally Vulnerable)

Corynocarpus laevigatus
Karaka
(Not Threatened)

Elingamita johnsonii
Elingamita
(At Risk – Naturally Uncommon)

Pittosporum fairchildii
Fairchild's Kohuhu
(At Risk – Naturally Uncommon)

Pennantia baylisiana
Three Kings Kaikomako
(Threatened – Nationally Critical)

Planchonella costata
Tawapou
(At Risk – Relict)

Nestegis apetala
Coastal Maire, Bastard Ironwood (Norfolk Island)
(At Risk – Naturally Uncommon)

Sophora chathamica
Chatham Island Kowhai
(Not Threatened)

Vitex lucens
Puriri
(Not Threatened)

Strebulis smithii
Three Kings Milk Tree
(At Risk – Naturally Uncommon)

Exotic Woodland Fruit Trees

Deciduous fruiting trees contrast with the evergreen native woodland trees and provide autumn colour, textural change and opportunity for picking of fruit by those moving through the forest roof environment.

Pyrus communis **'Doyenne du Comice'**
Pear

Pyrus communis **'Beurre Bosc'**
Pear

Prunus domestica **'Billington'**
Plum

Prunus domestica **'Burbank'**
Plum

Malus pumila **'Sunrise'**
Early Season Apple

Malus pumila **'Egremont russet'**
Mid Season Apple

Malus pumila **'Monty's surprise'**
Late Season Apple

Prunus persica **var. nucipersica ' Nani's nectarine'**
Nectarine

Prunus persica **'Caravan peacherine'**
Peach

New Zealand Native Shrub Planting

A range of select New Zealand native shrubs to provide a limited range of mid-canopy species within the woodland/ forest ecosystem – chosen for dark glossy leaves or flower colour to enhance the woodland/forest character.

Veronica parviflora
Hebe parviflora
(Not Threatened)

Veronica speciosa var. brevifolia Cheeseman
Hebe brevifolia
(At Risk – Naturally Uncommon)

Veronica diosmifolia
Hebe diosmifolia
(Not Threatened)

Coprosma repens **'Poor Knights'**
Coprosma repens 'Poor Knights' (Not Threatened)

Griselinia lucida
Puka, Akapuka
(Not Threatened)

Planting Mix A

New Zealand Native 'Meadow' – full sun zones - A selection of New Zealand native grasses and herbaceous plants that form a tapestry of planting under the woodland trees to create the effect of a spontaneous woodland meadow. The particular species in this mix are located within the zones on the roof that receive full sun. *specific notes on microclimate planting considerations are covered in notes.

Hibiscus richardsonii
Native Hibiscus, Puarangi
(Threatened – Nationally Critical)

Astelia banksii
Coastal Astelia, Shore Kowharawhara
(Not Threatened)

Carex solandri
Forest Sedge, Solander's Sedge
(Not Threatened)

***Carex testacea* 'Green'**
Speckled Sedge, Trip Me Up
(Not Threatened)

Chionochloa flavicans
Snow Tussock
(Not Threatened)

Festuca coxii
Cox's Fescue
(At Risk – Naturally Uncommon)

Lepidium oleraceum
Nau, Cook's Scurvy Grass
(Threatened – Nationally Endangered)

Pimelea arenaria
Sand Daphne, Autetaranga, Toroheke, Sand Pimelea
(At Risk – Declining)

Pimelea prostrata
Pinatoro, New Zealand Daphne, Strathmore Weed
(Not Threatened)

Xeronema callistemon
Poor Knights Lily, Raupo Taranga, Xeronema
(At Risk – Naturally Uncommon)

Pachystegia insignis
Marlborough Rock Daisy, Marlborough Daisy
(Not Threatened)

Planting Mix B

New Zealand Native 'Meadow' – Partial shade zones and under large specimen trees - A selection of New Zealand native grasses and herbaceous plants that form a tapestry of planting under the woodland trees to create the effect of a spontaneous woodland meadow. The particular species in this mix are located within the zones on the roof that receive full sun. *Specific notes on microclimate planting considerations are covered in notes.

***Arthropodium* 'Matapouri Bay'**
Matapouri Bay Renga Lily, Rengarenga, Rock Lily
(Not Threatened)

Asplenium oblongifolium
Shining Spleenwort
(Not Threatened)

Astelia banksii
Coastal Astelia, Shore Kowharawhara
(Not Threatened)

Blechnum novae-zelandiae
Kiokio, Horokio, Palm Leaf Fern
(Not Threatened)

Carex solandri
Forest Sedge, Solander's Sedge
(Not Threatened)

***Carex testacea* 'Green'**
Speckled Sedge, Trip Me Up
(Not Threatened)

Dianella nigra
Turutu, New Zealand Blueberry, Inkberry
(Not Threatened)

Festuca coxii
Cox's Fescue
(At Risk – Naturally Uncommon)

Lepidium oleraceum
Nau, Cook's Scurvy Grass
(Threatened – Nationally Endangered)

Planting Mix B continued

New Zealand Native 'Meadow' – full sun zones - A selection of New Zealand native grasses and herbaceous plants that form a tapestry of planting under the woodland trees to create the effect of a spontaneous woodland meadow. The particular species in this mix are located within the zones on the roof that receive full sun. *specific notes on microclimate planting considerations are covered in notes.

Chionochloa flavicans
Snow Tussock
(Not Threatened)

Samolus repens
Sea Primrose, Shore Pimpernel
(Not Threatened)

Selliera radicans
Selliera, Remuremu, Bonking Grass
(Not Threatened)

Pimelea arenaria
Sand Daphne, Autetaranga, Toroheke, Sand Pimelea
(At Risk – Declining)

Pimelea prostrata
Pinatoro, New Zealand Daphne, Strathmore Weed
(Not Threatened)

Xeronema callistemon
Poor Knights Lily, Raupo Taranga, Xeronema
(At Risk – Naturally Uncommon)

Pachystegia insignis
Marlborough Rock Daisy, Marlborough Daisy
(Not Threatened)

Hibiscus richardsonii
Native Hibiscus, Puarangi
(Threatened – Nationally Critical)

Apium prostratum subsp. denticulatum
Chatham Island Celery
(At Risk – Naturally Uncommon)

4.3.1 Living Roof Afforestation Plan

Only the trees were demarcated on the planting plan. All under-planting (shrubs and plants) was shown as a solid 'yellow' colour notated on drawings as "Plant Mix A", or a solid 'green' colour for "Plant Mix B". On the roof, approximately 2,110 plants were included from the Mix A species list, as detailed in the Plant Palette, and 4,970 plants from Plant Mix B. As such, the entire roof would be covered in vegetation from edge to edge, meeting the concept of giving the space back to nature.

In the plan, the roof of the delivery entrance was shown as covered edge to edge with Plant Mix B (shown as a green block colour). This mix as detailed above comprised 17 plant species. In addition to these species, three *Coprosma repens* 'Poor Knights' were included from the Manual Plant List, as the species will creep and flow over the edges of the delivery entrance living roof and further improve the aesthetic when viewed from Dent Street.

The Manual detailed the need to consider access and maintenance of the plants. It is considered important to ensure maintenance staff will not compact the soil and damage the root ball of trees and shrubs when walking down the slope opposite the stairs. A zigzag chevron path using a StrataCell network was incorporated into the slope of the roof to help retain the soil on the 1-in-3 slope and provide a 'path' for maintenance purposes.

4.3.2 Plant Weights

The Manual informed the design around the weight of trees using the FLL guidelines. Then an over-estimation was made to allow for a decent-sized native at maturity (given constraints of the depth of soil). A 160 litre native tree (*Vitex lucens*, Pūriri, the most dense and therefore heaviest) of 2.4-3m height would have a fully saturated weight of 100-130kg maximum excluding the pot.

The design allowed for a specimen tree weight of 1,500 kg, which is mature weight (not planted weight). It is not envisaged that any of the native trees in a 700 mm depth of substrate would grow more than 10 metres in height. A maximum height needed to be set; accordingly, anything over 8 metres would be reviewed, in the first instance, for trimming back, to reduce above-ground load rather than removal.

Using the Manual to guide the weight of under-storey plants as well, an overall estimation was approximately 410.44kg per m2 for plants only, allowing for additional weight loading of plants over and above what would normally be allowed for on an intensive roof.

4.3.3 Paths/Access

The overarching concept highlighted as a design consideration in the Manual was to reflect a Hundertwasser living roof. As such, the incorporation of a permeable natural path using hoggin over substrate was appropriate, rather than concrete or paved walkways, as Hundertwasser did not use formalised paths on his living roofs. The use of hoggin also ensure**d accessibility,** creating a space that was accessibility to all.

Hoggin is a finely crushed limestone material that has a good colour match with pumice. It has been chosen as the material to use for the areas of the roof that would have most foot traffic, as it has a strong compaction that allows rainwater to naturally percolate through. Hoggin also provides slip resistance and is not muddy for the connections up the steep ramp. It has the feel of pumice without the associated crushing and slippery surface. It is less likely to move downhill on the slopes of the ramp where the slope is steep (1 in 4) compared to the 1 in 12 ramps that were reviewed in the auxiliary design investigation, refer Appendix 2. Plants can grow directly in the hoggin material and spread out over it and roots through it, blurring the connection between the forest and visitor pathway, creating a sense of **identity**.

4.3.4 Soil

Three blends of substrate have been made using pumice and CAN bark fines from Greenfingers in Kamo, Whangarei. The FLL method was used (15 cm cores with 125 holes of 5 mm diameter in base and 600 micron mesh at base) to measure maximum moisture capacity at 15 cm depth of media, representing a maximum weight (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V., 2008).

The mix has 20% v/v CAN fines (maximum level that can probably be sustained by the plants so as not to need to replace it), 10% v/v 1-3 mm zeolite (to help keep high organic matter content and chemical buffering) and pumice (with 2-4mm grade).

All mixes hold about the same amount of total water, 20-22 mm/100 mm depth.

4.3.5 Tree Supports

Ideally, in the afforestation of a roof, once planted and over time as the plants grow, the root systems will mesh together creating a natural support network and stability. As part of the site analysis, the effect of wind load on the living roof needs to be considered. Whangarei has approximately 22 days per year with wind gusts exceeding 63 km per hour (NIWA, 2013). These winds need to be considered alongside storm events where the winds reach ~125km/hr in a 1-in-25-year storm. Only four months ago Whangarei had 135 km/hr winds. Wind speeds alongside the fairly steep slope of the roof, being approximately 1-in-3.2, or 18.6 degrees, is a key design consideration. Public safety and building safety must be assessed and addressed for building consent to ensure trees have been adequately supported to avoid harm to both the public and the building.

To provide for some tree support during high winds and storm events, a tree support network was designed linking the trees across the roof to assist

Hundertwasser Art Centre with Wairau Maori Art Gallery

Living Roof Afforestation Perspective

Figure 78: Hundertwasser Living Roof Afforestation perspective

Hundertwasser Art Centre with Wairau Maori Art Gallery

Living Roof Afforestation Perspective

Figure 79: Hundertwasser Living Roof Afforestation perspective

the forest during the interim years while the tree roots become established and naturally interconnect, forming a connected root support system.

The tree support module was designed with a permeable and biodegradable fabric lining on the inside of the module to support substrate while the tree grows. This material will break down once placed on the roof to allow root penetration beyond the module so the forest roots can mesh together naturally.

The tree support modules would be made with mild steel, galvanised, with four eye bolts to allow for lifting and fixing tree support connections. The tree support wires would all be linked and sit below the soil level (between 70-100 mm below the earth surface of the living roof) and as such would not be visible.

Figure 80: Tree Support Module

4.3.6 Irrigation

As detailed in the Manual, irrigation is required for the plants, particularly in hot drought-prone Whangarei summers. This is a subsoil, low-volume, low-pressure drip irrigation system installed 70-100 mm into the growing substrate. Having the irrigation on an automatic controller, easily accessible would ensure success and survival of plants in times of drought.

4.3.7 Root Barrier + Filter Fabric

As detailed in the Manual, the geotextile filter layer prevents fine particles and roots from the substrate from clogging up the drainage layer and as such will be incorporated below the substrate level, above the drainage layer.

4.3.8 Drainage Layer

The Manual highlighted the importance for the living roof to have good drainage to protect the plants and the building's structural integrity. As the drainage system needs to remove surface and sub-surface water from the roof and deal with extreme rainfall events, a 50mm thick recycled polypropylene, free drainage layer was chosen to go across the entire roof.

4.3.9 Protection Layer

Referring to the Manual and the amount of rainfall in Whangarei, a moisture retention layer is not considered necessary for the Hundertwasser Art Centre living roof. A protection layer over the waterproof membrane was included to ensure that the waterproof membrane was protected from installation and construction activity.

4.3.10 Leak Detection

As the Hundertwasser Art Centre would be housing the largest Hundertwasser art collection from outside Vienna (YES Whangarei, 2018), a leak detection system was highlighted as an essential component, as detailed in the Manuals design objectives. The Hundertwasser Art Centre design had a warm roof with insulation on top of the roof structure and as such was a non-conductive surface. Leak detection would require a mesh grid system to be installed between the insulation and waterproof membrane, with the leak detection placed on top of the membrane.

4.3.11 Wider Site Landscaping

Wider site landscaping was also considered as part of this design project.

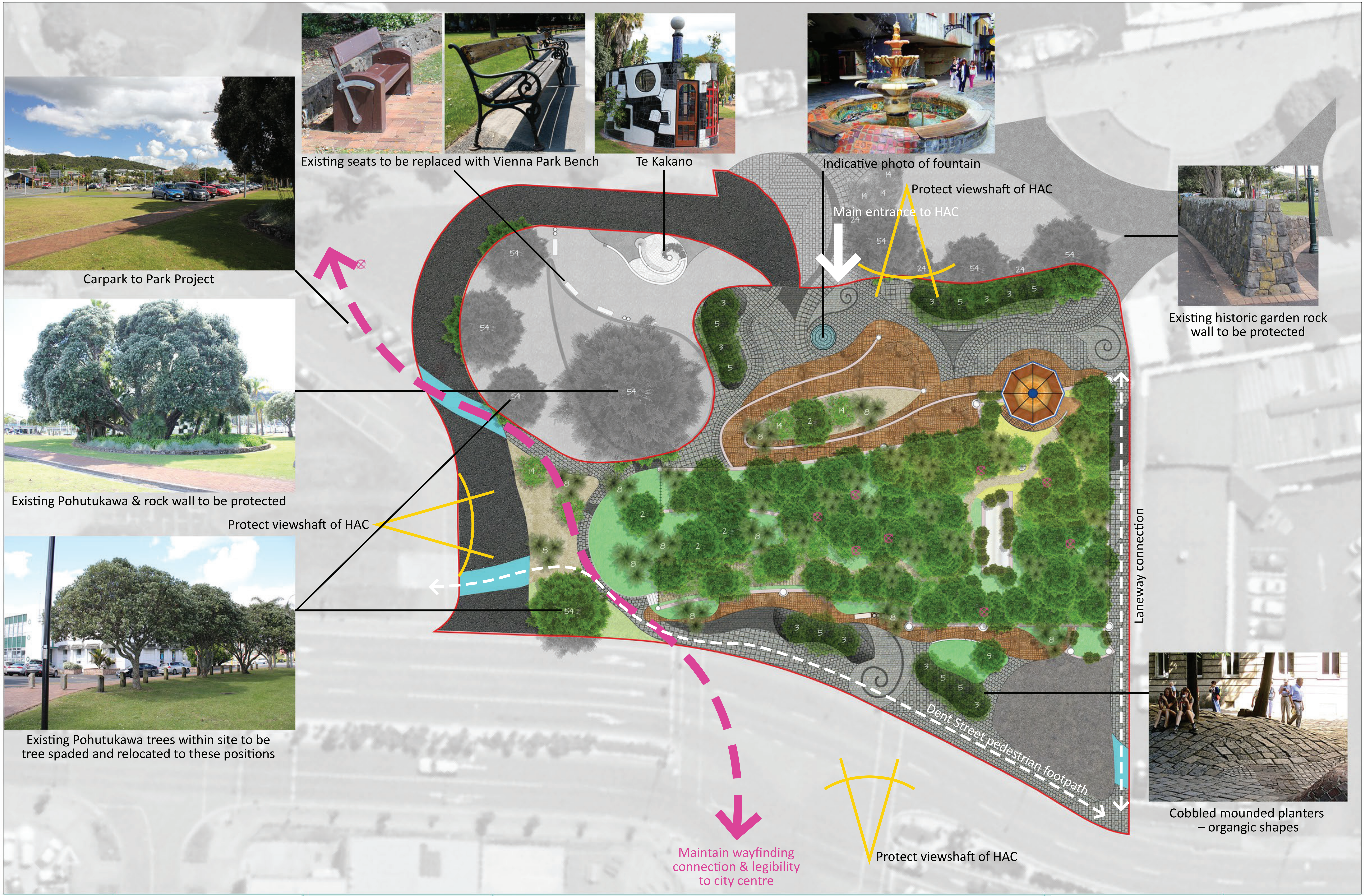
The living roof brief was followed through into the wider site landscaping, using the same plant palette, with more paving/cobbled landscaping to provide for the higher pedestrian use and to allow for small service vehicles. The introduction of paving in organic curved patterns, incorporating a koru design to reflect Hundertwasser's flag design (Harrel, 2015, p. 88), to ensure his philosophy was identifiable in the aesthetic of the landscape. The inclusion of cobbled organic shaped mounds for trees was incorporated, similar to that outside the Hundertwasser Haus in Vienna, Austria. These cobbled tree mounds would also function as raised seating areas, in addition to the inclusion of the Vienna Park Benches similar to that Hundertwasser had brought to Kaurinui. The trees chosen for the cobbled mounds were native species used on the living roof that were appropriate for the location and could cope with the amount of cobbled paving and heat generated from them.

To enhance even further the spontaneous nature of the living roof afforestation, the plant palette identified a range of adventive local weed species that were likely to colonise the roof, and proposed that these not be weeded out, to allow for a natural progression and mixing of plant species as the roof planting develops and evolves naturally over time.

The site landscaping narrative diagram detailed way-finding paths around the Hundertwasser Art Centre, with existing trees proposed to be relocated and a brief description of the type of paving, seating and planting to achieve a strongly Hundertwasser-inspired landscape.

Constraints:

- **Accessibility** - Needed consideration around building, including in between the existing arms of the building, as there were no windows in this location as it was a potential entrapment zone;
- **Robustness** - Significant pōhutukawa tree and surrounding rock wall - needed consideration and



Scale: 1:400 @ A3
1:200 @ A1

Hundertwasser Art Centre with Wairau Māori Art Gallery

SITE LANDSCAPE PLAN – NOTATED NARRATION

Figure 81: Site Landscape Concept Plan

Ground Level Planting Around Building:

2. *Corynocarpus laevigatusī*
   Karaka
3. *Elingamita johnsonii*
   Elingamita
5. *Pennantia baylisiana*
   Three Kings Kaikomako
8. *Rhopalostylis sapida*
   Nikau (Chatham Island)
9. *Sophora chathamica*
   Kowhai, Coastal Kowhai
14. *Prunus domestica 'Billington'*
    Plum
24. *Coprosma repens* 'Poor Knights'
    Coprosma repens 'Poor Knights'
54. *Metrosideros excelsa*
    Pohutukawa

Planting Mix A

26. *Astelia banksii*
    Coastal Astelia, Shore
    Kowharawhara
27. *Carex solandri*
    Forest Sedge, Solander's Sedge
28. *Carex testacea* - green
    Speckled Sedge, Trip Me Up
29. *Chionochloa flavicans*
    Snow Tussock
30. *Festuca coxii*
    Cox's fescue
31. *Lepidium oleraceum*
    Nau, Cooks scurvy grass
32. *Pimelea arenaria/Pimelea villosa*
    Sand Daphne, Autetaranga,
    Toroheke, Sand pimelea
33. *Pimelea prostrata* subsp. Prostrata
    Pinatoro, New Zealand Daphne,
    Strathmore Weed
34. *Xeronema callistemon*
35. *Pachystegia insignis*
    Marlborough Rock Daisy
36. *Hibiscus ricardii*

Planting Mix B

37. *Arthropodium* 'Matapouri Bay'
    'Matapouri Bay' Renga Lily,
    Rengarenga, Rock Lily
38. *Asplenium oblongifolium*
    Shining Spleenwort
39. *Astelia banksii*
    Coastal Astelia, Shore
    Kowharawhara
40. *Blechnum novae-zelandiae*
    Kiokio, Horokio, Palm Leaf Fern
41. *Carex solandri*
    Forest Sedge, Solander's Sedge
42. *Carex testacea* - green
    Speckled Sedge, Trip Me Up
43. *Chionochloa flavicans*
    Snow Tussock
44. *Festuca coxii*
    Cox's fescue
45. *Lepidium oleraceum*
    Nau, Cooks scurvy grass
46. *Pimelea arenaria/Pimelea villosa*
    Sand Daphne, Autetaranga,
    Toroheke, Sand pimelea
47. *Pimelea prostrata* subsp. Prostrata
    Pinatoro, New Zealand Daphne,
    Strathmore Weed
48. *Samolus repens*
    Sea Primrose, Shore Pimpernel
49. *Selliera radicans*
    Remuremu
50. *Xeronema callistemon*
51. *Pachystegia insignis*
    Marlborough Rock Daisy
52. *Hibiscus ricardii*
53. *Apium prostratum subsp.*
    denticulatum
    Chatham Island celery

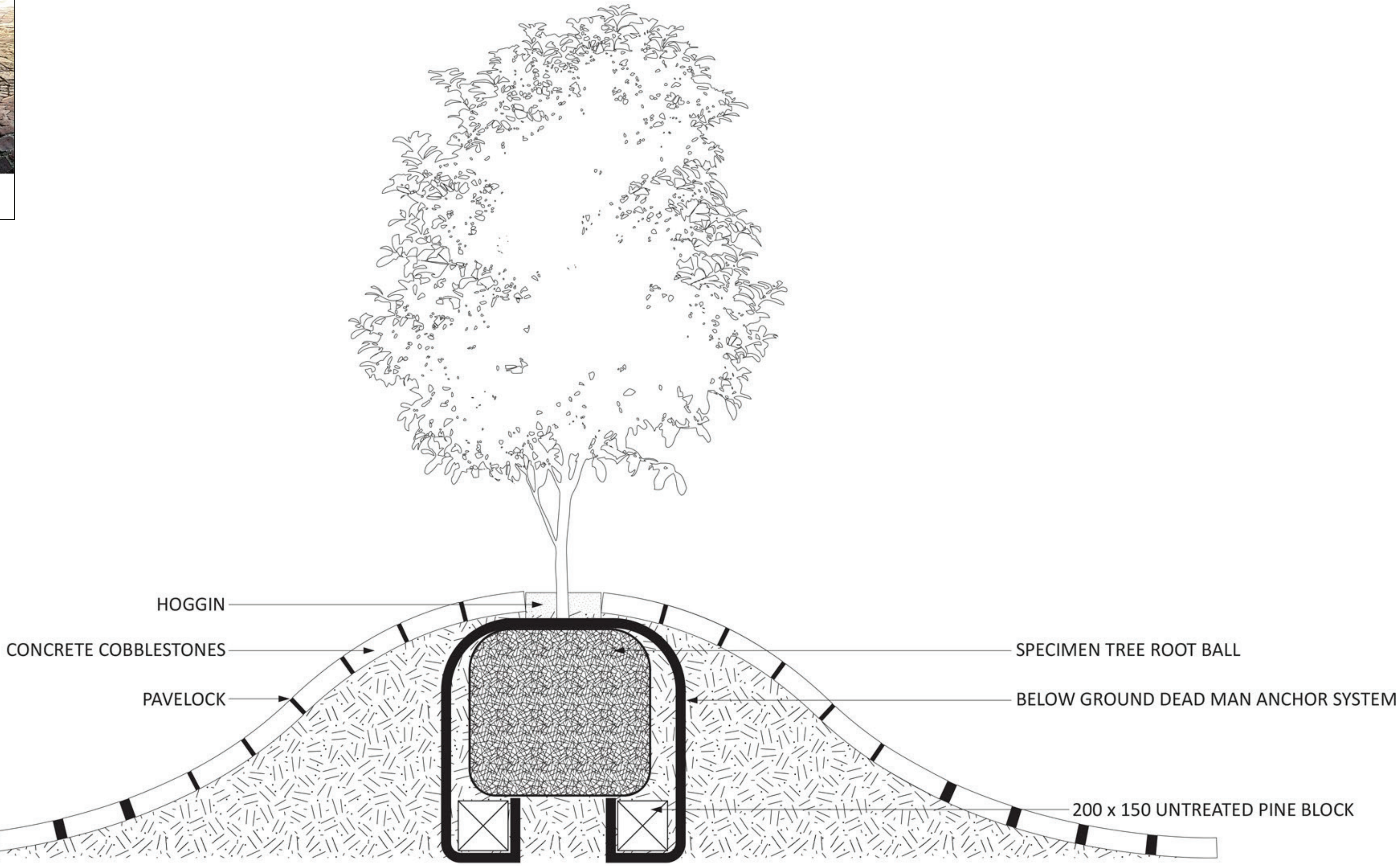
- ▬ Site Boundary
- ■ Asphalt
- ■ Dark Oxide Concrete
- ■ Hoggin
- ■ Coloured Concrete Pedestrian Path
- ■ Permeable Concrete Cobblestone
- ■ Mounded Cobbled Planters/Seats
- ■ Terracotta Tiles
- ■ Grass
- ■ Planting Mix A
- ■ Planting Mix B
- ● Native Specimen Tree
- ● Fruit Tree
- ● Native Shrub
- ✱ Nikau Palm Grove
- ⊗ Sculpture Location
- ◎ Hundertwasser Fountain
- ▭ Park Bench
- ∞ Rubbish & Recycling Bins
- ∘ Removeable Bollards

Scale: 1:400 @ A3
1:200 @ A1
0 4 8 12 16 20m

Hundertwasser Art Centre with Wairau Māori Art Gallery
SITE LANDSCAPE PLAN – MATURE VEGETATION

Figure 82 Site Landscape Plan

Photograph indicative of mounded cobble planter. Final layout to be confirmed on site.



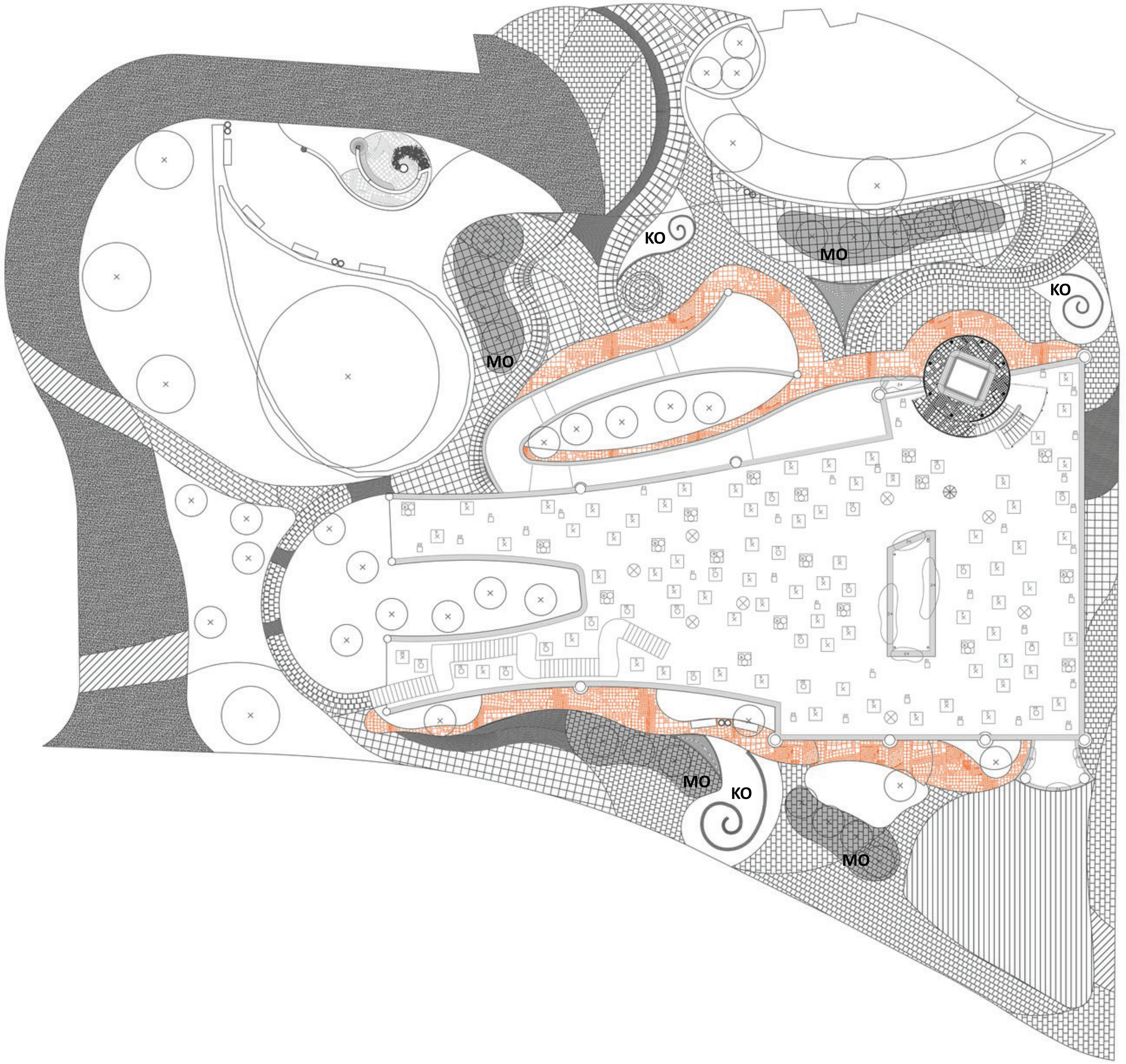
Hundertwasser Art Centre with Wairau Māori Art Gallery

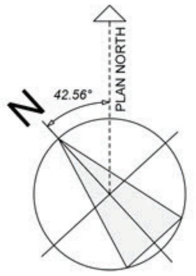
SITE LANDSCAPE DETAILS: MOUNDED COBBLE PLANTERS

Figure 83: Mounded Cobble Planters

Photograph indicative of koru paving finish (**KO**). Final layout to be confirmed on site.

Photograph indicative of mounded cobble planter (**MO**). Final layout to be confirmed on site.





- ▨ 400 x 400mm paver
- ■ 100 x 100mm paver
- ▦ 600 x 400mm paver
- ▦ 600 x 600mm paver
- 🟧 Hundertwasser style terracotta pavers
- ▨ Peter Fell Oxide Concrete ‘Blueberry’
- ▥ Peter Fell Oxide Concrete ‘621 Premium Charcoal’
- ▩ Asphalt

Scale: 1:400 @ A3
1:200 @ A1

0 4 8 12 16 20m

Hundertwasser Art Centre with Wairau Māori Art Gallery

SITE LANDSCAPE DETAILS: PAVING DETAIL

Figure 84: Paving Detail

	Botanical name	Māori and /or Moriori name	Common name	Current conservation status (2012)	Approximate planted size	M^2 area	Maximum plant weight (kg per plant)	Quantity	Total plant weight (kg)	Planting considerations notes
Ref:	**Native Woodland Specimen Trees. A selection of New Zealand native trees appropriate for the local Whangarei environment are interspersed across the forest roof to echo a woodland environment.**									
1	*Alectryon excelsus subsp. Grandis*	Tiktoki	Three Kings titoki	Threatened - Nationally Vulnerable	160litre	As per planting plan	1,500	8	12,000	
2	*Corynocarpus laevigatus*	Karaka, Kōpī	Karaka	Not Threatened	160litre		1,500	6	9,000	
3	*Elingamita johnsonii*		Elingamita	At Risk - Naturally Uncommon	160litre		1,500	3	4,500	
4	*Pittosporum fairchildii*		Fairchild's Kohuhu	At Risk - Naturally Uncommon	160litre		1,500	7	10,500	
5	*Pennantia baylisiana*		Three Kings Kaikomako	Threatened - Nationally Critical	160litre		1,500	8	12,000	
6	*Planchonella costata*	Tawapou	Tawapou	At Risk - Relict	160litre		1,500	6	9,000	
7	*Nestegis apetala*	Maire	Coastal maire, Bastard Ironwood (Norfolk Island)	At Risk - Naturally Uncommon	160litre		1,500	2	3,000	
8	*Rhopalostylis sapida*	Nikau	Nikau (Chatham Island)	Not Threatened	160litre		3,000	18	54,000	Planted in groups of 3 within modules to create grove. Each Nikau estimated at 1,000kg with total weight per module of 3,000 kg
9	*Sophora chathamica*	Kowhai	Kowhai, Coastal kowhai	Not Threatened	160litre		1,500	17	25,500	
10	*Vitex lucens*	Puriri	Puriri	Not Threatened	160litre		1,500	3	4,500	
11	*Strebulis smithii*		Three Kings Milk Tree	At Risk - Naturally Uncommon	160litre		1,500	2	3,000	
	Subtotal							**80**	**147000**	
Ref:	Tree Tenants									
1	*Alectryon excelsus subsp. Grandis*	Tiktoki	Three Kings Titoki	Threatened - Nationally Vulnerable	160litre	As per tree tenant details	1,500	5	7,500	Refer to specific plant shaping guide for each individual tree tenant
	Subtotal							**5**	**7,500**	
Ref:	**Exotic Woodland Fruit Trees. Deciduous fruiting trees contrast with the evergreen native woodland trees and provide autumn colour, textural change and opportunity for picking of fruit by those moving through the forest roof environment.**									
12	*Pyrus communis* 'Doyenne du Comice'		Pear	N/A	160litre	As per planting plan	1500	2	3000	
13	*Pyrus communis* 'Beurre Bosc'		Pear	N/A	160litre		1500	2	3000	
14	*Prunus domestica* 'Billington'		Plum	N/A	160litre		1500	2	3000	
15	*Prunus domestica* 'Burbank'		Plum	N/A	160litre		1500	2	3000	
16	*Malus pumila* 'Sunrise'		Apple (early season) budded onto M793 root stock	N/A	160litre		1500	2	3000	
17	*Malus pumila* 'Egremont russet'		Apple (mid season) budded onto M793 root stock	N/A	160litre		1500	2	3000	
18	*Malus pumila* 'Monty's surprise'		Apple (late season) budded onto M793 root stock	N/A	160litre		1500	2	3000	
19	*Prunus persica var. nucipersica* 'Nani's nectarine'		Nectarine (on peach root stock 3-4 metres)	N/A	160litre		1500	3	4500	
20	*Prunus persica* 'Caravan peacherine'		Peach (self fertile)	N/A	160litre		1500	3	4500	
	Subtotal							**20**	**3000**	
Ref:	**New Zealand Native Shrub Planting. A selection of New Zealand native shrubs to provide a limited range of mid-canopy species within the woodland/forest ecosystem – chosen for dark glossy leaves or flower colour to enhance the woodland/forest character.**									
21	*Veronica parviflora*		Hebe Parviflora	Not Threatened	PB40	As per planting plan	30	8	240	
22	*Veronica speciosa var. brevifolia Cheeseman*		Hebe Brevifolia	At Risk - Naturally Uncommon	PB40		30	8	240	
23	*Veronica diosmifolia*		Hebe Diosmifolia	Not Threatened	PB40		30	7	210	
24	*Coprosma repens* 'Poor Knights'		Coprosma Repens 'Poor Knights'	Not Threatened	PB40		30	13	390	
25	*Griselinia lucida*		Puka, Akapuka	Not Threatened	PB40		30	6	180	
	Subtotal							**42**	**1,260**	

Figure 85: Plant Schedule

	Botanical name	Māori and /or Moriori name	Common name	Current conservation status (2012)	Approximate planted size	M^2 area	Maximum plant weight (kg per plant)	% mix	M^2 of plant per mix	Quantity	Total plant weight (kg)	Planting considerations notes
Ref:	**Planting Mix A - New Zealand Native 'Meadow' – full sun zones. A selection of New Zealand native grasses and herbaceous plants that form a tapestry of planting under the woodland trees to create the effect of a spontaneous woodland meadow. The particular species in this mix are located within the zones on the roof that receive full sun. *specific notes on microclimate planting considerations are covered in notes. Area of 166.36 m2**											
26	*Astelia banksii*	Kowharawhara	Coastal Astelia, Shore Kowharawhara	Not Threatened	PB5	166.36	15	20	34	340	5100	
27	*Carex solandri*		Forest Sedge, Solander's Sedge	Not Threatened	PB5	166.36	15	5	9	90	1350	
28	*Carex testacea* 'Green'		Speckled Sedge, Trip Me Up	Not Threatened	PB5	166.36	15	20	34	340	5100	
29	*Chionochloa flavicans*		Snow Tussock	Not Threatened	PB5	166.36	15	5	9	90	1350	
30	*Festuca coxii*		Cox's Fescue	At Risk - Naturally Uncommon	PB5	166.36	15	10	17	170	2550	
31	*Lepidium oleraceum*		Nau, Cooks Scurvy Grass	Threatened - Nationally Endangered	PB5	166.36	15	5	9	90	1350	
32	*Pimelea arenaria / Pimelea villosa*	Autetaranga, Toroheke	Sand Daphne, Autetaranga, Toroheke, Sand Pimelea	At Risk - Declining	PB5	166.36	15	5	9	90	1350	
33	*Pimelea prostrata subsp. Prostrata*		Pinatoro, New Zealand Daphne, Strathmore Weed	Not Threatened	PB5	166.36	15	10	17	170	2550	
34	*Xeronema callistemon*		Poor Knights Lily, Raupo Taranga, Xeronema	At Risk - Naturally Uncommon	PB5	166.36	15	5	9	90	1350	Grouped in 3's to 5's for mass grouping for impact of flowering
35	*Pachystegia insignis*		Marlborough Rock Daisy	Not Threatened	PB5	166.36	15	5	9	90	1350	
36	*Hibiscus richardsonii*	Puarangi	Native Hibiscus, Puarangi	Threatened – Nationally Critical	PB5	166.36	15	10	17	170	2550	To be seeded onto roof in addition to planted specimens
				Subtotal				100	173	1730	25950	
Ref:	**Planting Mix B – New Zealand Native 'Meadow' – semi or part shade zones. A selection of New Zealand native grasses and herbaceous plants that form a tapestry of planting under the woodland trees to create the effect of a spontaneous woodland/forest meadow. The particular species in this mix are located within the zones on the roof that have a degree of shading at different times of the day. *specific notes on microclimate planting considerations are covered in notes.**											
37	*Arthropodium* 'Matapouri Bay'	Rengarenga	Matapouri Bay' Renga lily, Rengarenga, Rock lily	Not Threatened	PB5	415.75	15	10	42	420	6300	
38	*Asplenium oblongifolium*		Shining Spleenwort	Not Threatened	PB5	415.75	15	5	21	210	3150	To be located on site under evergreen shade trees and in particularly shady locations on roof
39	*Astelia banksii*	Kowharawhara	Coastal Astelia, Shore Kowharawhara	Not Threatened	PB5	415.75	15	5	21	210	3150	
40	*Blechnum novae-zelandiae*	Kiokio, Horokio	Kiokio, Horokio, Palm Leaf Fern	Not Threatened	PB5	415.75	15	5	21	210	3150	To be located on site under evergreen shade trees and in particularly shady locations on roof
41	*Carex solandri*		Forest Sedge, Solander's Sedge, Maori sedge	Not Threatened	PB5	415.75	15	5	21	210	3150	
42	*Carex testacea* 'Green'		Speckled Sedge, Trip Me Up	Not Threatened	PB5	415.75	15	10	42	420	6300	
43	*Dianella nigra*	Turutu	Turutu, New Zealand Blueberry, Inkberry	Not Threatened	PB5	415.75	15	10	42	420	6300	
44	*Festuca coxii*		Cox's fescue	At Risk - Naturally Uncommon	PB5	415.75	15	5	21	210	3150	
45	*Lepidium oleraceum*		Nau, Cook's Scurvy Grass	Threatened - Nationally Endangered	PB5	415.75	15	5	21	210	3150	
46	*Pimelea arenaria / Pimelea villosa*	Autetaranga, Toroheke	Sand Daphne, Autetaranga, Toroheke, Sand Pimelea	At Risk - Declining	PB5	415.75	15	5	21	210	3150	
47	*Pimelea prostrata subsp. Prostrata*		Pinatoro, New Zealand Daphne, Strathmore Weed	Not Threatened	PB5	415.75	15	5	21	210	3150	
48	*Samolus repens*	Mākoako	Sea Primrose, Shore Pimpernel	Not Threatened	PB5	415.75	15	5	21	210	3150	
49	*Selliera radicans*	Remuremu	Selliera, Remuremu, Bonking Grass	Not Threatened	PB5	415.75	15	5	21	210	3150	Interspersed amidst all planting as low growing suckering cover under all herbaceous, shrub and tree species
50	*Xeronema callistemon*	Raupō Taranga	Poor Knights Lily, Raupo Taranga, Xeronema	At Risk - Naturally Uncommon	PB5	415.75	15	5	21	210	3150	Grouped in 3's to 5's for mass grouping for impact of flowering
51	*Pachystegia insignis*		Marlborough Rock Daisy	Not Threatened	PB5	415.75	15	5	21	210	3150	
52	*Hibiscus richardsonii*	Puarangi	Native Hibiscus, Puarangi	Threatened – Nationally Critical	PB5	415.75	15	5	21	210	3150	
53	*Apium prostratum subsp. denticulatum*		Chatham Island celery	At Risk - Naturally Uncommon	PB5	415.75	15	5	21	210	3150	

protection measures put in place;
- Historic rock wall north of Hundertwasser Art Centre to be protected, retain some of the existing pōhutukawa where possible/appropriate;
- Relocate pōhutukawa (tree spade) proposed to be removed as part of the development to the wider landscape where appropriate;
- **Permeability** - With surrounding streets and Council future street amendments, adjoining the proposed Council car park, to park, Town Basin, The Loop walkway and art trail, and importantly the city centre (and Walton Street connection);
- Future Council maintenance requirements - Needed to be integrated into design; and
- Addressing Dent Street barrier.

Opportunities:
- **Identity** - Consider and incorporate the cultural narrative;
- **Identity** - Creation of a sense of place and belonging that reflects the Hundertwasser Art Centre and cultural narrative of the space and its inhabitants and visitors: place-making;
- **Permeability** - Provision of view shafts of the Hundertwasser Art Centre as a landmark building;
- Identity and robustness - Opportunity for sculptures to be incorporated;
- **Accessibility** and **concentration** - Cobbled mounded tree planters (inspired by similar treatment outside Hundertwasser Haus in Vienna) to be cobbled and function as informal, organic-style seating area, shade for users; and
- Incorporation of new seating - inspired by Vienna Park benches.

Design Objectives:
- **Permeability** and **Legibility** - Maintain view shafts of the Hundertwasser Art Centre as a landmark building;
- Maintain way-finding connection and **legibility** to city centre;
- **Accessibility** - Maintain **permeability** and **accessibility** to, around and into the Hundertwasser Art Centre;
- **Identity** - Consider and incorporate the cultural narrative;
- **Accessibility** and **concentration** - Implement seating at key points surrounding the Hundertwasser Art Centre;
- **Legibility** - Create safe and legible entry points;
- **Identity** and **legibility** - Design contextually appropriate wider landscaping;
- **Permeability** and **identity** - Giver users/visitors the best experience by framing and enhancing views of the Hundertwasser Art Centre, the Basin and Te Kakano;
- **Permeability** - Connect the Hundertwasser Art Centre landmark building with surrounding streets, adjoining park, Town Basin, The Loop walkway and art trail, and the city centre;
- **Legibility** - Make safe and legible nodes at the Hundertwasser Art Centre entry, Dent Street/Walton Street (city centre view shaft) and adjoining park/Loop connect - new and existing entry points;
- **Identity** - Allow for the Hundertwasser Fountain and connection into wider landscaping;
- **Diversity**, **concentration** and **sustainability** - Plant densely in between existing arms of the Hundertwasser Art Centre building, with Plant Mix B and specimen native trees, to discourage this area as a place to congregate, due to potential **accessibility** issues.

Beyond the Hundertwasser Art Centre Living Roof and immediate surrounds, what could be designed to further connect people to the built environment and nature?

Figure 86: Existing situation

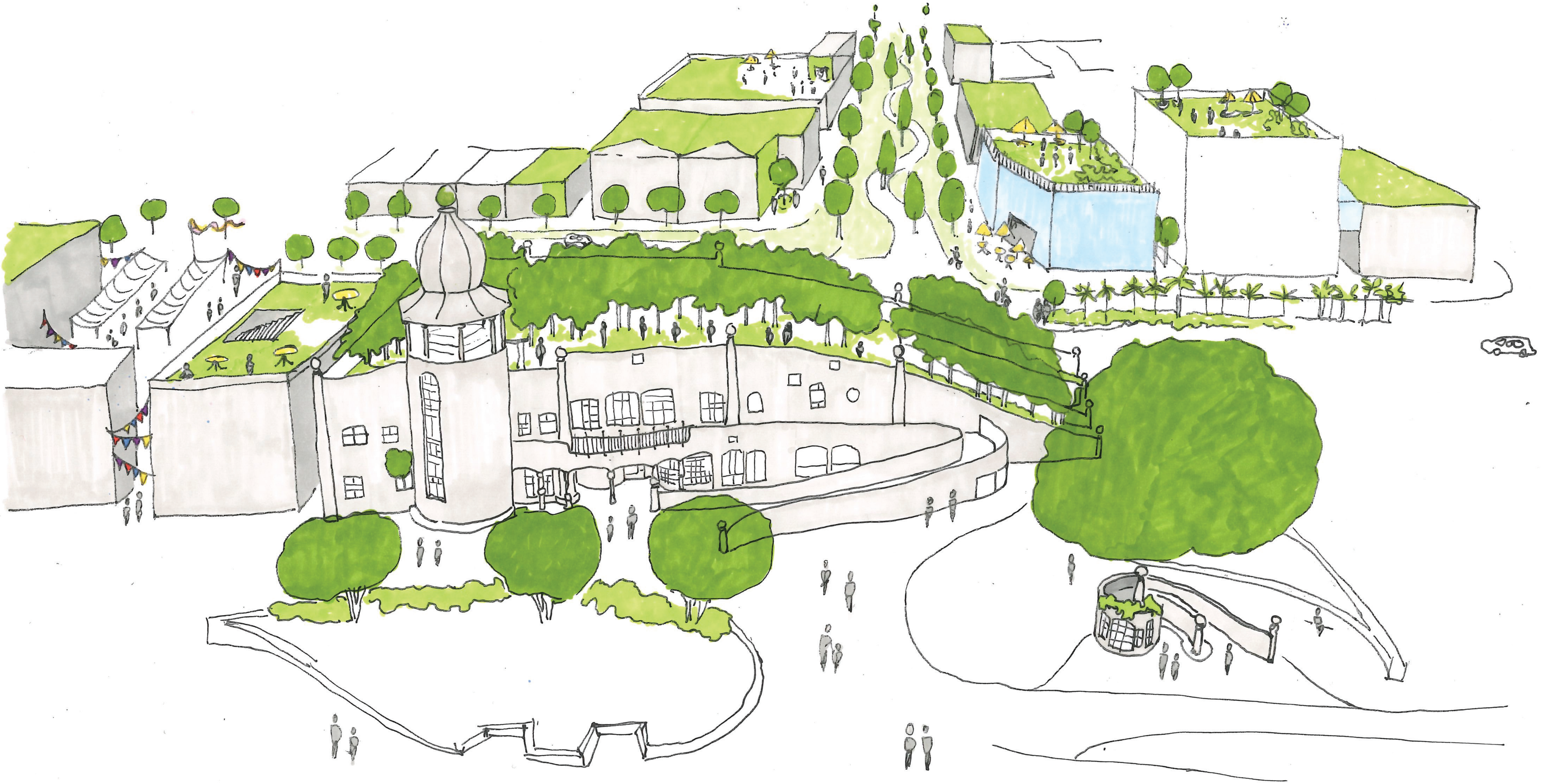


Figure 87: Potential wider development

Figure 88: Existing situation

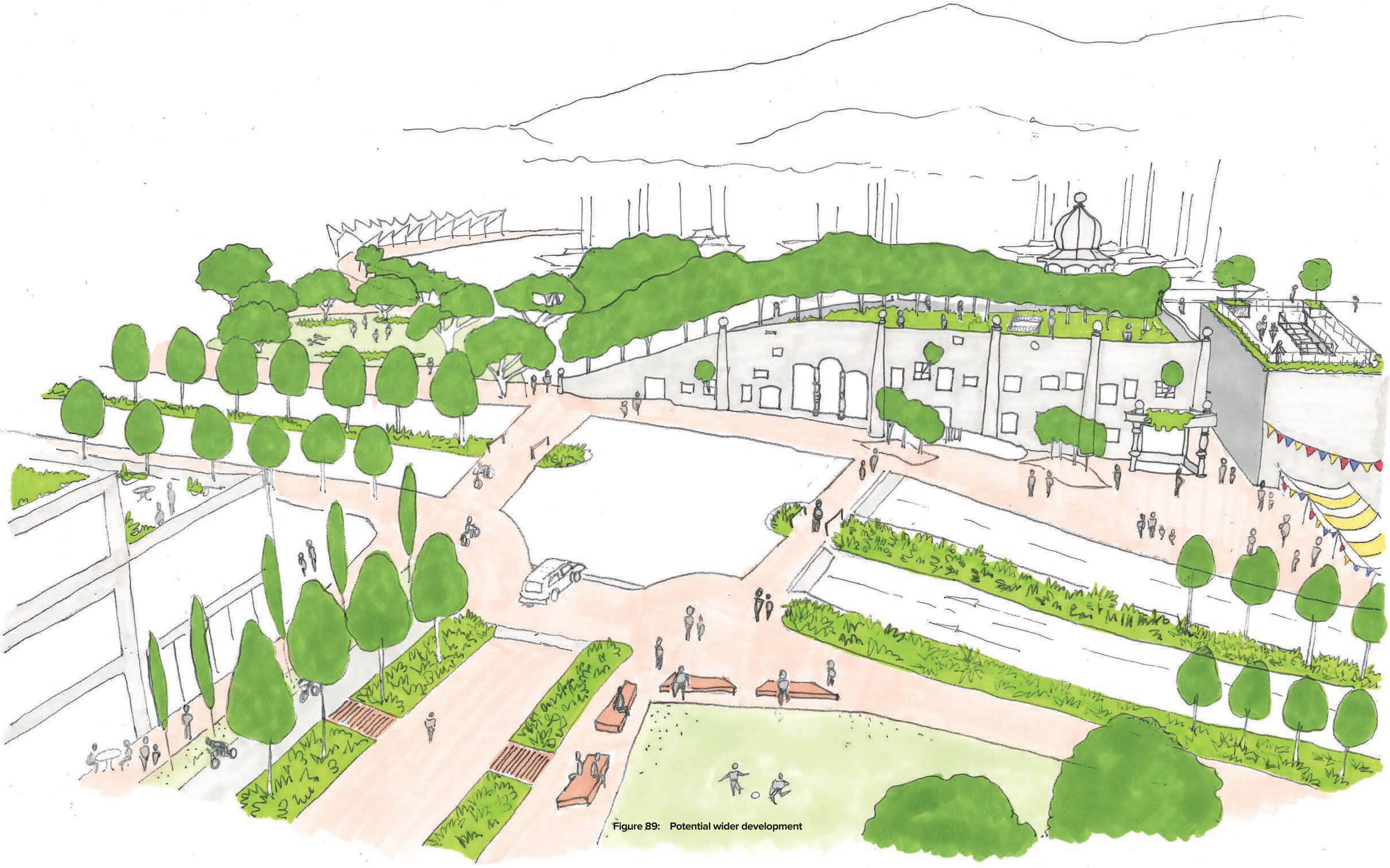


Figure 89: Potential wider development

5. CONCLUSION.
KUPU WHAKATEPE

5.0 CONCLUSION. KUPU WHAKATEPE

This research aimed to answer the question "How could the development of a Living Roof Design Manual increase the effectiveness of living roof design?" The question gave rise to four main objectives across three phases of research. The first two objectives were to: (i) outline the types, relevance and benefits of living roofs informed by the literature; and then (ii) identify key living roofs in Europe and New Zealand, and analyse their design characteristics in terms of living urbanism design principles. As discussed, these principles, drawn from urbanism and green infrastructure, were utilised both as an analytical tool and as a means for improving the effectiveness of living roofs.

Analysis of literature and case studies provided an understanding of the design characteristics that can enhance or restrict the effectiveness of living roof design. This led to, and helped to address, the third objective: (iii) to develop a Living Roof Design Manual. This Manual, based on the findings from Phase One, was populated with Northland-specific data, to inform design considerations with the aim of enhancing benefits for humans, the built environment and nature.

The fourth objective was to (iv) utilise the Design Manual at the proposed Hundertwasser Art Centre site, exploring how such a manual may influence the design response, improve the effectiveness of design, to help reveal the potential that living roofs present to improve urban landscapes and people's lives.

5.1 Current Situation

The relationship between people, buildings and nature is increasingly important as over 55% of humans live in urban areas and urbanisation is occurring at an unprecedented rate (United Nations, 2018). As cities have more hard surfaces, less green space and less permeable areas, this pattern reinforces the disconnect from nature while also creating more surface runoff, flash flooding, and interrupted or damaged ecological systems and processes. While cities are not inherently bad, global sustainability and human wellbeing challenges must be resolved in cities. A blend between built form and nature is needed - of healthy spaces and places that are good for hearts and minds as well as ensuring functionality. Green infrastructure is being used around the world as a toolkit for integrating people with built form and nature. Currently, living roofs are rarely included in developments in New Zealand, and where they are, most are being designed in isolation, resulting in living roofs that do not achieve their potential effectiveness.

5.2 Theory

As stated, in order to understand this situation and identify strategies to address it, a literature review was conducted. The review of theories of urban design, landscape architecture and green infrastructure generated a theoretical framework that urban design was the bridge and intersection between landscape architecture and planning. Green infrastructure is the system that delivers ecological services and quality of life benefits for people; while landscape architecture engages people to nature and places; urban design engages people to spaces and activities. The key authors are Kevin Lynch; Matthew Carmona; Jane Jacobs; Ian McHarg; Bill Hillier; Edmund Bacon; Edward Relph; and Jan Gehl. The principles deemed relevant to this investigation in terms of increasing the effectiveness of design are those of living urbanism being permeability, legibility, concentration, diversity, sustainability, identity, accessibility and robustness.

A landscape design philosophy - the link or sensory connection of humans to the built environment and nature - was described in this research as living urbanism. The decision to develop a Living Roof Design Manual incorporating living urbanism principles was informed by the writing of Kevin Lynch, Matthew Carmona; Jane Jacobs; and Ian McHarg on the image of a city and nature. The Manual looked beyond the component layers of a living roof to reveal the landscape and urban design principles that articulate the potential benefits and thereby improve the effectiveness of the design. This research acknowledges that the living roof will form part of the wider landscape, environment and community, to essentially create a 'sense of place' in the built form. Using the living urbanism principles as a foundation highlighted design interventions and approaches that provide options to optimise the benefits of a living roof.

5.3 Precedents

Twenty living roof case studies from Europe and New Zealand were analysed using the framework and principles of living urbanism. This approach allowed for a critique that encompasses the human dimension, as well as normative technical aspects. For example, in the case of New Zealand, several studies highlighted a lack of **permeability**, with limited or no visual connection to the roof or access. The majority of New Zealand living roofs studied did not reflect a high level of **diversity**, where communities can engage with the space and understand the multitude of benefits living roofs can provide. Lack of **identity** was also demonstrated, where cultural and natural narratives had not been recognised, resulting in a space that was disconnected and did not reflect the character of the place. As such, it was recognised that the living roof spaces studied in New Zealand had not yet addressed **accessibility**, **permeability**, **diversity** or **identity**, resulting in places that feel disconnected and as such may not be viewed as worthwhile contributions to urban form. The European studies showed a clear social narrative, creating a sense of place and encouraging people to connect with the living roof.

This analysis lead to Phase Two, where the aim was to address the apparent gap in achieving effectiveness through the development of a Living Roof Design

Manual. To address the unrealised benefits of living roofs in New Zealand, it was suggested that a living urbanism approach could be used in the design of living roofs that would enhance the ability to create spaces that connect people to the built environment and nature.

5.4 Question

In light of the previously stated significance and the existing knowledge, this research posed the question: “How could the development of a Living Roof Design Manual increase the effectiveness of living roof design?”

5.5 Site

The Hundertwasser Art Centre site is located in the Whangarei Town Basin and sits alongside the waterfront, beside the Hatea River and Dent Street, between the Information Centre and a future Council park. The living roof area is approximately 950 m², where the north-western portion of the roof is at ground level and slopes up at a 1-in-3 gradient to a flat roof deck level. The site previously housed the Northland Regional Council building, which was demolished to make way for the construction and piling of the new Art Centre. The Hundertwasser Art Centre building will be the last authentic living-roofed Hundertwasser building in the world housing a main gallery showcasing Hundertwasser’s work, a contemporary Māori art gallery, café, cinema and student resource centre. The living roof was designed to be an open park with contemporary Māori sculptures and a ‘live load’ of 200 people. This real-world project presented an opportunity to design a living roof that maximises the benefits for the local community and visitors to connect with the built environment of Whangarei city - a building designed to reflect both Hundertwasser’s architectural style and the nature and the unique ecology of this part of New Zealand.

The surrounding land is relatively flat and overlooks the marina and Parihaka mountain. The area alongside the waterfront forms the Heritage Trail and Art Walk, with a number of sculptures commissioned from local artists, and currently accommodates the Whangarei Art Museum, Reyburn House Art Gallery and the Northland Society of the Arts. Cafes, restaurants, speciality shops, private arts and craft galleries comprise the majority of the buildings at the Town Basin. The Hundertwasser Art Centre is at the intersection of Walton Street and Dent Street, two main roads in Whangarei, and the Hatea Loop, a 4.2 km walkway linking the Town Basin with surrounding destinations.

5.6 Site analysis

Three phases of research were undertaken to inform an iterative design process:

Phase One: Theory and Precedents

- Phase One outlined living roof typologies and benefits on humans, the built environment and nature. This section highlighted key findings that informed specifics for the Living Roof Design Manual, such as the use of locally relevant species to improve biodiversity and also create a sense of identity on the living roof. To increase the effectiveness of the design, the importance of creating a general and locally-specific plant list was emphasised. Plants that have succeeded on living roofs elsewhere in New Zealand were highlighted, alongside locally specific species that could be trialled.
- Alongside this research, living roofs in Europe and New Zealand were analysed critically through the lens of living urbanism, in terms of design characteristics and the effectiveness of the living roofs and benefits achieved. These characteristics created the foundation for the Living Roof Design Manual in Phase Two, a set of living urbanism design-led principles to help better integrate living roofs into urban landscapes. **Accessibility**, **identity**, **legibility** and **sustainability** were found to be lacking in New Zealand living roofs. These principles were translated into components of a living roof design that requires consideration to enhance its effectiveness.

Phase Two: Living Roof Manual

- The research findings in Phase One informed the creation of a Living Roof Design Manual. This tool was populated with data specific to Whangarei, to inform design considerations to improve benefits realised for humans, the built environment and nature. The Manual proposed that using living urbanism design-led principles would help designers integrate living roofs better into New Zealand’s urban landscapes to maximise benefits and the effectiveness of the design. As part of this phase, the research explored site analysis considerations, potentially appropriate exotic and native plants that might be suitable for Whangarei, and on-going considerations in terms of maintenance, which could inform the design response and future aesthetics of the roof.

Phase Three: Hundertwasser Art Centre Living Roof Design

- The third phase utilised the Manual for development of the proposed Hundertwasser Art Centre site, to help reveal the potential that living roofs present to improve urban landscapes and people’s lives. The afforestation of the Hundertwasser Art Centre roof created a space for people to have a sensory connection to the built environment and nature. Utilising the living urbanism design principles, the roof aimed to create a space that would be permeable, concentrate space for nature and people, be diverse and sustainable, displays a local identity with **indigeneity** of species and cultural narrative, including Māori sculptures, and would be **accessible**, **robust** and **legible**.

5.7 Design/strategy

This research project was an opportunity to develop a Manual that would increase the effectiveness of living roof design and utilise it in a real-world project. The design of the living roof, utilising living urbanism design-led principles, helped to integrate the building into the wider landscape and maximise benefits. The use of native trees on the roof further highlighted the landmark building in Whangarei Town Basin. This use of native vegetation with such height can connect the people of Whangarei to the roof, even if just visually. The height, form and use of native trees would create a sense of **identity** with the majority of species commonly found in the region. From a wider perspective, the visually and physically accessible living roof can provide a catalyst for the community, to promote and foster better understanding and use of living roofs locally. It was designed to contribute to making Whangarei a more resilient, liveable and loved city that promotes wellbeing – providing a space that would promote a sensory connection for people to the built environment and nature.

The design of the roof used a living urbanism approach to maximise the benefits. The use of indigenous plant species with local offshore island uniqueness, alongside incorporating the rarest tree in the world, *Pennantia baylisiana* from the Three Kings Island, all contributed to creating a sense of **identity**. An examination of the New Zealand situation and the enclosed New Zealand case studies suggested this as a unique approach and one not seen in any previous living roof or green space in the public realm. In addition to this, the incorporation of Māori contemporary sculptures on the roof, bringing art beyond the walls of the gallery space below, further highlighted the **identity** of the building being an art centre housing New Zealand's only contemporary Māori gallery, and its locale within Whangarei and Aotearoa. This feature is unusual, and no examples of this were seen in either the European or New Zealand precedents.

In terms of overseas precedents, it has similarities in terms of **permeability**, **legibility**, **concentration**, **accessibility** and **robustness**. It is different however, in terms of identity, linking the character of the place and its inhabitants, both cultural and natural with the incorporation of contemporary Māori sculptures and incorporation of threatened indigenous plants.

The use of meandering paths throughout the roof for **accessibility**, with blurred planted edges, places to explore and touch nature alongside more than one entry onto the roof, was intended to create a sense of **permeability** alongside **legibility** and **concentration**. Introducing curved paths would create a space where people slow down and connect to the landscape, rather than use it as a thoroughfare. The positioning of sculptures slightly visible ahead would draw people along paths to points that open up in the tree canopy. The paths on the roof connect to the edges of the building, providing places where the canopy is more open to display views of the broader Whangarei riverside, back towards the central city, over the sloping ramp towards a future urban park and down a light well into the building - all showcasing **diversity**. The space on the roof was designed to allow different movements or circulation, sculptures can be changed and at the same time trees will grow and canopy spread will alter the character and feel of the roof environment. This design brings robustness to the roof. The sculptures were placed at junction points that lead to another path, landmark or vista, creating an understandable place, creating **legibility**.

Alongside a place for people to connect through art and education, the design included a range of plant species, food-producing trees such as plums and early, mid- and late-season apples, connecting people to nature, seasons and permaculture. The use of Northland-specific plants and fruiting trees maximised the living roof potential in terms of **sustainability**. The plant list in the Manual provided a guide to ensure plant species on the living roof were a combination of regionally specific species and natives that had been successful on other living roofs in New Zealand. The use of the plant list and known success rates reduced an element of risk of plant survival on the roof and as such increased the effectiveness of the design.

The incorporation of 600 mm and 700 mm of substrate on the roof lead to a reduction in insulation required on the warm roof, thereby reducing the cost of that element. Vegetating the majority of the roof should result in a large increase in biomass, where the existing site does not provide much vegetated cover. It would also reduce stormwater runoff, as the existing site is mainly paved or roof, and made provision for habitat and food sources for birds and invertebrates. The use of the Manual to inform the design has created a sustainable space that would protect and enhance the area's natural features, ecosystem and water quality, and should enhance cultural and heritage values.

Utilising the Manual and taking a living urbanism approach the designed landscape attempted to blend beauty and function. The multifaceted outcomes that the design intended to deliver addresses non-human life within the city and extends to engagement with human processes. This process has demonstrated that the development of a Living Roof Design Manual that incorporates living urbanism design-led principles can improve the effectiveness of living roof design.

5.8 Final word

In summary, the investigation aimed to increase the effectiveness of living roof design through the development of a Living Roof Design Manual. It is hoped that, with the use of the living urbanism design-led principles, living roofs can be better integrated into our urban landscapes and benefits maximised. The project aimed to demonstrate how landscape architecture intersects and blends with the disciplines of urban design and planning throughout the urban fabric of cities - that interstitial spaces, such as roofs, can be landscaped and create a sensory connection for people with the built environment and nature.

Thinking beyond just one system or building or intervention within the urban fabric, the ambition is for this living roof project to become the catalyst for spreading the living urbanism principles beyond its four walls - inspiring all New Zealanders with the potential of city spaces. Living roofs create sanctuaries in the city. Places and spaces like the Hundertwasser Art Centre living roof would be a step towards humanising New Zealand's urban environments - recognising the need for connection with nature to be embedded in all elements of the city so that people can experience, daily, those moments of inspiration, respite and wonder that are triggered by sensory connections with plants and animals, and with one another. It is envisaged that, in using a living urbanism approach to designing living roofs, people can be connected to nature, with hearts and minds - an often forgotten vital element of happiness and wellbeing.

5.9 Further research

Throughout this project, the costs of living roofs have been highlighted. Further research would be beneficial on the costs for installation and on-going maintenance, especially in terms of a cost-benefit analysis considering benefits achieved. That analysis would be useful in understanding the economic implications of designing accessible living roofs, where this project has highlighted increased costs from the incorporation of a lift to the roof and the 1-in-4 sloped ramp to ground level. Although not researched as part of this project, the additional cost of retaining soil and trees alongside the installation of a lift adds significantly to the construction costs of the project. Further research on the cost-benefits of adding another level of marketable floor space at roof level would be valuable in understanding the benefits of living roofs. Since living roofs aim to produce value for a range of stakeholders (building owner, neighbouring businesses, local community), research would be useful into how diverse stakeholder interests may be considered in legislation or acknowledgment of feasibility.

Finally, utilising the living urbanism approach to analysing existing living roofs could also allow us to understand the strengths and weaknesses of existing projects, to inform future interventions to improve the multitude of benefits realised and, importantly, for designing new living roofs. As such, the living urbanism approach was a core component of the Living Roof Design Manual, to enhance benefits realised for people, the built environment and nature. However, further research is needed moving from the qualitative to the quantitative – by comparing principles of living urbanism on a scale to measure benefits and effectiveness of living roofs.

6. BIBLIOGRAPHY.
TOHUTORO

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APPENDIX 1.
CASE STUDIES (UNABRIDGED)

Urquharts Bay Toilets

Location:
Urquhart Bay Road, Urquhart Bay, Whangarei Heads

Client:
Whangarei District Council

Living Roof Designers:
Zoë Avery and Renée Davies

Architect:
Chris Howell, Main 4 Architects

Living Roof Type:
Semi-Intensive

Development Type:
Public

Build:
New Build

Building Type:
Public Toilet Block

Living Roof Brief:
Native living roof with appropriate species for the location, adjoining Bream Head Scenic Reserve

Project Drivers:
Aesthetics, Biodiversity/Habitat creation, and Roof longevity.

Living Roof Design:
Vegetation
- *Sellieria radicans*
- *Coprosma acerosa*
- *Pimelia prostrata*
- *Muehlenbeckia complexa*
- *Disphyma australe*
- *Apium prostratum*
- *Leptospernun nanum*
- *Arthropodium Cirratum* Matapouri Bay ‘Renga Renga Lily’

Substrate depth:
250-300mm

Substrate composition:
20% Organic matter, 70% Pumice, 10% Zeolite

Drainage system:
VersiDrain drainage system

Waterproof membrane:
Living Roof root resistant waterproof membrane

Irrigation:
EcoBlanket capillary living roof irrigation and timer.

Living Roof Construction:
Built-in-place living roof system

Right: Living Roof at Urquharts Bay, Whangarei Heads

Roof structure:
Wood

Slope of roof:
8 Degrees

Describe roof access:
No access provided, limited for maintenance with clip station for harness.

Climate evaluation:
- Full Sun
- High Winds/coastal location

Size:
36m^2

Completion:
2013

Cost:
Everything above waterproofing ~ \$275/m^2

Buckleton Beach Shed

Location:
Buckleton Beach, Tawharanui

Client:
G & J Cremer

Living Roof Designer:
Renée Davies

Living Roof Type:
Semi-Intensive

Development Type:
Private

Build:
New Build

Building Type:
Residential garage/boat shed

Living Roof Brief:
A semi-intensive living roof located on a new boat shed building with the planting taking inspiration from its coastal location and from known successful NZ natives that have been used as living roof plants to create a native living roof which has botanical and visual links with the adjacent coastal garden design.

Project Drivers:
Aesthetics and stormwater management

Living Roof Design:
Vegetation

- *Festuca coxii*
- *Coprosma acerosa*
- *Leptospermum flavescens 'Little bun'*
- *Libertia ixioides*
- *Pimelea prostrata*
- *Leptospermum flavescens 'Pink beauty'*
- *Muehlenbeckia axillaris*
- and area of lawn

Substrate depth:
200mm

Substrate composition:
20% Organic matter, 70% Pumice, 10% Zeolite

Drainage system:
Plazadeck drainage system

Waterproof membrane:
Nuralite living roof waterproof membrane

Irrigation:
Above ground dripper irrigation

Living Roof Construction:
Built-in-place living roof system

Roof structure:
Concrete

Slope of roof:
less than 3 Degrees

Describe roof access:
Limited for maintenance

Climate evaluation:
- Full Sun
- High Winds, coastal site

Site considerations:
Views from deck of house down onto the living roof. Client desire for some lawn area.

Size:
45m²

Completion:
August 2011

Below and right:
Living roof at Buckleton Beach, Tawharanui

NZI Building

Location:
1 Fanshawe Street, Auckland

Client:
IAG

Living Roof Designer:
Greenroofs Ltd

Architect:
Jasmax

Contractor:
Scarbro

Living Roof Type:
Extensive

Development Type:
Commercial

Build:
New Build

Building Type:
Commercial Office Space

Living Roof Brief:
Roof top garden adjacent to staff outdoor area. Used to reduce stormwater runoff plus any runoff from the roof to be used for flushing toilets. The building achieved a 5 star Green Star rating for sustainable design from the New Zealand Green Building Council.

Project Drivers:
Aesthetics, Workplace productivity, Recreation, Stormwater management, and Water quality

Living Roof Design:
Vegetation

- *Sedum Lydium Pigwee*
- *Sedum Coccine*
- *Sedum Ternatum*
- *Sedum Weistephener*
- *Sedum Tricolor*
- *Sedume reflexum*
- *Sedum Azure*
- Exotic ice plant

Planters included:
Yucca faxoniana, Dietes Grandiflora, Ophiopogon planiscapus, *Draecaena draco* and *Sedum spurium coccineum*

Substrate depth:
50-75mm

Substrate composition:
20% Organic matter, 70% Pumice, 10% Zeolite

Drainage system:
Plazadeck

Right: Living Roof at NZI Centre, Auckland

Waterproof membrane:
Nuralite waterproof membrane

Irrigation:
Sprinklers included with a battery timer – added retrospectively

Living Roof Construction:
Built-in-place living roof system

Roof structure:
Wood

Slope of roof:
0-5 Degrees

Describe roof access:
Permanent access via lift or staircase – for internal use only, i.e. staff and area that can be booked out by staff for entertaining clients

Climate evaluation:

- Full Sun
- High wind environment

Size:
350m²

Completion:
May 2009

Cost:
Everything above waterproofing ~$200/m² and included one year's maintenance visits

Mt Difficulty Winery

Location:
Mt Difficulty Winery, Bannockburn, Central Otago

Client:
Mt Difficulty Wines

Living Roof Designer:
Stormwater360 – Greg Yeoman

Architect:
Red Rooster Design

Living Roof Project Manager/Contractor:
Stormwater360

Living Roof Type:
Extensive

Development Type:
Commercial

Build:
New Build

Building Type:
Wine Barrel Store

Living Roof Brief:
The brief for the new barrel store in Bannockburn, Cromwell was to create a temperature controlled and environmentally conscious space that would fit into the surrounding Central Otago landscape. The resulting building is an earth-toned, exposed aggregate, pre-cast panel construction buried back into the hillside with a vegetated living roof covering the complete 900m2 building footprint. The barrel store is located at the base of the hillside below the restaurant and wine tasting cellar door.

Temperature control is a vital component of wine making and was a key factor in the design. In an effort to keep the temperature at the correct constant temperature the building is set into the earth hillside at the back sides and a 150mm deep vegetated roof was installed on the insulated roof slab. The resulting energy requirement has been reduced primarily to only requiring energy input to artificially increase or reduce the temperature for the winemaking process.

Process water from the winemaking process is irrigated onto the roof through sprinklers reducing loading on the onsite wastewater plant.

Rocky outcrops were strategically placed onto the living roof to successfully encourage habitat for the local Cromwell geckos.

Project Drivers:
Aesthetics, Stormwater management - process water, Energy conservation, Roof longevity, Habitat creation

Living Roof Design:
Vegetation

- *Poa cita*
- *Ffestuca coxii*
- *Festuca novae-zelandiae*
- *Carex testacea*

Right and Below:
Mt Difficulty Winery Living Roof and Wine Barel Store

- *Carex buchananii*
- *Thymus vulgaris* (locally sourced Thyme)
- *Stonecrop sedum*

Approximately 14,000 plants in total.

Substrate depth:
150mm

Substrate composition:
Lightweight pumice based proprietary media

Drainage system:
LiveRoof modules

Waterproof membrane:
TPO

Irrigation:
Spray irrigators using mix of process and fresh water

Living Roof Construction:
Modular tray living roof system

Roof structure:
Reinforced Concrete slab + warmroof

Slope of roof:
~2 Degrees

Describe roof access:
Walk-on access from hillside, with balustrading at front edges. No heights restraints required.

Climate evaluation:

- Full Sun
- Exposed

Site considerations:
Rabbit protection required consideration

Size:
900m^2

Completion:
March 2012

Cost:
Everything above waterproofing ~\$300/m^2

Waitakere Civic Building

Location:
Henderson, Auckland

Client:
Former Waitakere City Council (now Auckland Council)

Living Roof Designer:
Renée Davies & Landcare Research

Architect:
Architectus

Living Roof Project Manager/Contractor:
Canam (main contractor) & Greenroofs Ltd (substrate installation and planting)

Living Roof Type:
Extensive

Development Type:
Commercial

Build:
New Build

Building Type:
Government Office

Living Roof Brief:
Waitakere City Council's original vision for the development of the living roof was:

- To demonstrate the range of sustainable benefits of living roof technology.
- To create a living roof which is specific to the New Zealand situation, and at least in part, reflective of plant species found in the Waitakere environment.
- To create an organic patchwork of plants which will move and change over the years with competition and natural growth styles.
- To provide splashes of colour variation through leaf colour, texture and seasonal flowering.
- To ensure a multitude of outcomes are achieved for stormwater, habitat and amenity.
- To provide a robust, well-researched and documented process for plant selection, including substrate make-up, and monitoring to provide useful and innovative input into living roof technology specific to New Zealand.

Project Drivers:
Aesthetics, improved biodiversity, improved air and water quality, stormwater management, support of green products and systems, thermal performance, Urban Heat Island Effect mitiagtion

Living Roof Design:
Vegetation

- *Acaena microphylla*, NZ bidibid
- *Calystegia soldanella*, Sand convolvulus
- *Coprosma acerosa*, Sand coprosma
- *Dichondra repens* 'piha', Mercury bay weed
- *Disphyma australe*, New Zealand iceplant
- *Festuca coxii*, Native tussock
- *Leptostigma setulosa*
- *Libertia peregrinans*, NZ iris
- *Muehlenbeckia axillaris*
- *Muehlenbeckia complexa*
- *Muehlenbeckia ephendroides*

Right: Waitakere Civic Building extensive living roof
Right below: Mixture of native species on mounds
Photos reprinted with permission by Renée Davies

- *Pimelea prostrata*, NZ daphne
- *Selliera radicans*

Substrate Depth:
50-130mm

Substrate Composition:
20% 4-8mm grade expanded clay (Hydrotech), 30% 4-8mm grade pumice, 20% Perry's garden mix or Living Earth garden mix, 30% 1-3mm or 1-2mm grade pumice

Drainage System:
Rigid drainage boards

Waterproofing:
Standard waterproof membrane

Irrigation:
No irrigation installed initially. Modifications have been undertaken to the design (including installation of ecoblanket irrigation for harsh summer droughts and introduction of mounds).

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~2 Degrees

Roof Access:
Limited for maintenance

Climate Evaluasation:
- Full sun
- Exposed

Site Considerations:
Plants chosen to withstand the harsh conditions of the roof, must be native preferrably from the Waitakere Ecological District.

Size:
500m²

Completion:
August 2006

Potter's Children Garden Entrance

Location:
102 Hill Road, The Gardens, Auckland

Client:
Auckland Botanic Gardens

Living Roof Designers:
Jack Hobbs and Ed Snodgrass

Architect:
Adams De La Mere Architects and Landscape Architects

Living Roof Type:
Extensive, timber roof

Development Type:
Public

Build:
New Build

Building Type:
Public entranceway

Living Roof Brief:
An extensive living roof is located on the entranceway to the Childrens Garden at the Auckland Botanic Gardens. The planting on this living roof has been designed for maximum visual impact utilising plants of outstanding form and colour. All of the plants are exotic but are known to thrive on living roofs with shallow substrate.

Project Drivers:
Aesthetic, improved air and water quality.

Living Roof Design:
Vegetation
- *Aloe aristata*
- *Aloe humilis*
- *Bromeliad neoregelia* 'Night Sky'
- *Echeveria elegans*
- *Gazania sp.*
- *Iris sp.*
- *Lampranthus sp.*
- *Ornithogalum dubium*
- *Senecio serpens*

Substrate Depth:
110mm

Substrate Composition:
20% v/v Organic matter, 70 % Pumice, 10% Zeolite

Drainage System:
Maccaferri Plazadeck/Nuraflow drainage mat

Waterproof Membrane:
Nuralite 3PV & 3PG waterproofing membrane system

Irrigation:
Conventional above-ground jets

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
225 x 50mm tongue & groove 'Lawsons' cypress sarking fixed to beams with 2/100 x 3.75 FH nails per board

Roof Access:
Limited for maintenance

Site Considerations:
As the entrance to a children's garden, the "funky", somewhat outrageous look was desired to draw the attention of children. The roof slopes towards the road and the proximity of viewing platforms (in the form of large, flat boulders) means that the roof is visible from the road and within the children's garden.

Size:
12.9m²

Completion:
July 2010

Cost:
Not disclosed

Comments:
Following planting, the large Echeveria lost their orange flower spikes and were replaced with numerous 'pups'. The Echeveria grew better at the lower, wetter end of the roof while the Aloe grew better at the higher, drier end. The Ornithogalum failed to flower in 2012 and the leaf and flower size was a third of the expected size, indicating the low fertility of the living roof substrate.

> **"Just living is not enough…**
> **one must have sunshine,**
> **freedom, and a little flower."**
>
> **Hans Christian Andersen.**

Potter's Children Garden Toilet Block

Location:
102 Hill Road, The Gardens, Auckland

Client/Partner:
Auckland Botanic Gardens

Living Roof Designers:
Jack Hobbs and Ed Snodgrass

Architect:
Adams De La Mere Architects and Landscape Architects

Living Roof Type:
Extensive, timber roof

Development Type:
Public

Build:
New Build

Building Type:
Public toilet block

Living Roof Brief:
A extensive living roof is located on the roof of the Childrens Garden toilet block at the Auckland Botanic Gardens. The planting on this green roof has been designed to showcase native plants and complement adjacent native landscaping.

Project Drivers:
Aesthetic, improved air and water quality

Living Roof Design:
Vegetation

- *Austrofestuca sp*
- *Austrostipa stipoides*
- *Chionochloa rubra*
- *Coprosma acerosa* 'Hawera'
- *Libertia peregrinans*
- *Muehlenbeckia complexa*
- *Poa cita*
- *Xeronema callistemon*

Substrate Depth:
110mm

Substrate Composition:
20%v/v Organic matter, 70 % Pumice, 10% Zeolite

Drainage System:
Maccaferri Plazadeck/Nuraflow drainage mat

Waterproof membrane:
'Nuralite' 3PV & 3PG waterproofing membrane system for green roof

Irrigation:
Conventional above-ground jets

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
225x50mm tongue & groove ‘Lawsons’ cypress sarking fixed to beams with 2/100x3.75 FH nails per board

Slope of Roof:
15°

Roof Access:
Limited for maintenance

Site Considerations:
To fit the aesthetic of the surrounding landscape, this living roof was planted with similar and complimentary plants.

Size:
29.9m²

Completion:
July 2010

Comments:
This living roof forms part of a treatment train; rainfall is discharged to a swale planted with sedges and rush that then drains into a pond.

The tussocks and Libertia were immediately visible while the Muehlenbeckia and Coprosma blended into the substrate. The use of the high visibility plants was imperative for this public site and was achieved through clustering and the contrasting plant colour and texture.

The plants on the native roof required less maintenance than the exotic entrance roof as there were no dead seed heads to be removed.102 Hill Road, The Gardens, Auckland

Wiles Ave Studio

Location:
Wiles Avenue, Auckland

Client:
Robyn Simcock and Stuart Smith

Living Roof Design:
Robyn Simcock

Project Manager/ Contractor:
Stuart Smith

Research:
Dr Robyn Simcock

Living Roof Type:
Extensive (lightweight)

Development Type:
Private residential

Build:
New build

Building Type:
Studio

Project Brief:
The herb garden was shifted to the roof, as this is one of the few sunny places on the section. The roof is also overlooked by a bedroom and neighbour's decks, so needs to be relatively aesthetically attractive; about one quarter to one third of the roof should be suitable for growing annual crops such as lettuces and coriander. The studio is a wood workshop with noisy equipment, so the living roof helps supress noise (it has double glazing and thick insulation). The living roof is at shoulder height for the neighbours, so plants were selected for the boundary that needed very little maintenance, were dense and tidy, and discouraged children from trying to get onto the roof (use of low Bromeliads).

Project Drivers:
Aesthetics, food production, sound proofing, stormwater management

Living Roof Design:
Rosemary, Thyme varieties (including *T. vulgaris*, and emerald thyme) Oreganum, Bergamont, Calendula, Blue Salvia, Chives, Sage, Lettuce, Coriander, Dianthus, Geranium, *Lavender angustifolia* (has performed poorly), Bromeliads, *Sedum mexicanum*

Substrate Composition:
20%v/v Organic matter, 70 % Pumice, 10% Zeolite

Drainage System:
ANS Modular drainage system with 20 mm deep cup retention cell depth made from recycled HDPE plastic overlaid with 5 mm thick bioblanket filter layer (recycled polyethylene and hemp) that promotes even water distribution and water retention. The cups interlock creating a stable platform that stays put (not prone to wind unlike the lightweight rolled products)
Waterproof Membrane:
Standard waterproof membrane

Irrigation:
A small water tank on the adjacent car port collects roof runoff from the two storey dwelling main house. The water tank is connected by a hose and allows hand watering.

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Wood 190 x 45 mm rafters at a maximum of 480 mm centres; extra rafters were added and little additional cost as the spans are short

Slope of Roof:
5°

Roof Access:
Limited for maintenance

Climate Evaluation:
Morning Sun NE aspect, low wind, afternoon light shade from adjacent trees (palms and pittosporum)

Site Considerations:
Planting that discourages people from climbing onto the roof from neighbouring section as roof is at about shoulder height. The roof has areas that are regularly replaced, and some areas with fertiliser added to encourage plant growth so water runoff quality is elevated in nutrients. Runoff is split into a rain chain that feeds a pot plant, and a perforated pipe that runs along a garden with citrus trees

Size:
22m^2

Completion:
August 2016 but plants are added to over time

Wiles Ave Carport

Location:
Wiles Avenue, Auckland

Client:
Robyn Simcock and Stuart Smith

Living Roof Design:
Robyn Simcock

Project Manager/ Contractor:
Stuart Smith

Research:
Dr Robyn Simcock

Living Roof Type:
Extensive (lightweight)

Development Type:
Private residential

Build:
New build

Building Type:
Residential carport and bike shed

Project Brief:
A roof to test native and non-native plants and demonstrate techniques to manage drought stress and stratify a roof by microclimate.

Project Drivers:
Aesthetics, food production, sound proofing, stormwater management

Living Roof Design:
Vegetation- Mix of native and exotic species
Areas with very thin media and afternoon sun are planted with:

- *Sedum ternatum*
- *Sedum reflexum (syn. Sedum rupestre)*
- *Sedum spurium*
- *Sedum rubroctintum* 'jellybeans'
- Bromeliads (notably *B. neoregelia* 'Red of Rio')
- *Lampranthus* (iceplant)
- *Kalanchoe*

Areas with thin substrate but afternoon shade are planted with natives:

- *Xeronema callistemon*, Poor Knight's lilly
- *Astelia banksii*
- *Collespermum hastatum*
- *Acaena sp.*
- *Dichondra brevifolia*

Areas with deeper substrate (over the bike shed) are planted with natives:

- *Athropodium bifurcatum* 'Matapouri Bay
- *Coprosma repens* 'Poor Knights'
- *Hebe obtusata*
- *Doodia australis*
- *Acaena*

- *Selliera radicans*
- *Fuschia procumbens*

Substrate Depth:
20-200mm

Substrate Composition:
20% v/v Organic matter, 70 % Pumice, 10% Zeolite

Drainage System:
ANS Modular drainage system with 20 mm deep cup retention cell depth made from recycled HDPE plastic overlaid with 5 mm thick bioblanket filter layer (recycled polyethylene and hemp) that promotes even water distribution and water retention. The cups interlock creating a stable platform that stays put (not prone to wind unlike the lightweight rolled products.

Waterproof Membrane:
Standard waterproof membrane

Irrigation:
A small water tank on the roof collects runoff from the two storey dwelling main house and water can be bucketed from this onto parts of the roof. Special native plants on the roof are watered by hand as required in summer.

Living Roof Construction:
Built-in-place living roof system but edges of the roof were grown as modular trays, and these were flipped out to provide instant cover

Roof Structure:
Wood 190 x 45 mm rafters at a maximum of 480 mm centres; extra rafters were added and little additional cost as the spans are short

Slope of Roof:
3°

Roof Access:
Limited for maintenance

Climate Evaluation:
Variable sun due to shading from main house and adjacent buildings at different times of the day; quite protected from wind

Site Considerations:
Matching plants to shade and substrate depth

Size:
$39m^2$

Completion:
August 2016 but ongoing as the centre of the roof is being transitioned from wildflowers to permanent vegetation

Right: Living roofs of Hundertwasser Haus Plochingen
Photo Zoë Avery

Hundertwasser Haus Plochingen

Location:
Plochingen, Germany

Client:
Werner Moll

Architects:
Friedensreich Hundertwasser and Heinz M. Springman

Living Roof Design:
Friedensreich Hundertwasser

Living Roof Type:
Extensive and intensive

Development Type:
Commercial and Residential

Build:
New build

Building Type:
Commercial (16 units) and Residential (64 units)

Living Roof Design:
Vegetation- Mix of native and exotic species

Right: Living roofs of Hundertwasser Haus Plochingen
Below: Access stairs to plaza living roof

Substrate Depth:
200-400mm

Substrate Composition:
Unknown

Drainage System:
Unknown

Waterproof Membrane:
Standard waterproof membrane

Irrigation:
Not known

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
3°

Roof Access:
Residental and Commercial access
Stairs

Climate Evaluation:
Full sun and wind

Size:
~200m²

Completion:
August 1994

Nine Houses, Earth House Estate Lttenstrasse

Location:
Dietikon, Switzerland

Architect:
Peter Vetsch, Vetsch Architektur

Living Roof Type:
Intensive

Development Type:
Private residential

Build:
New build

Building Type:
Residential (9 units)

Living Roof Design:
Vegetation- Mix of native and exotic species

Substrate Depth:
400 - 800mm

Substrate Composition:
Unknown

Drainage System:
Unknown

Waterproof Membrane:
Root-resistant Polymer bitumen vapour barrier

Irrigation:
Not known

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Sprayed-concrete domes, recycled glass insulation foam (250mm thick)

Slope of Roof:
~18°

Roof Access:
Residental access
Slopes

Climate Evaluation:
Full sun and wind

Size:
~4000m^2

Completion:
1993

Therme Vals

Location:
Vals, Graubunden Canton, Switzerland

Architect:
Peter Zumthor, with Marc Loeliger, Thomas Durisch and Rainer Weitschies

Living Roof Type:
Extensive

Development Type:
Commercial

Build:
New build

Building Type:
Commercial Pool

Living Roof Design:
Vegetation- Mix of native grass species

Substrate Depth:
50 - 100mm

Substrate Composition:
Unknown

Drainage System:
Unknown

Waterproof Membrane:
Unknown

Irrigation:
Not known

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~2°

Roof Access:
In part access from hotel to hand rail - remaining no access to public
Slopes

Climate Evaluation:
Full sun and wind

Size:
~1972m^2

Completion:
1996

Katstrup Power Plant

Location:
Kastrup Power Plant at Copenhagen International Airport, Denmark

Client:
City of Copenhagen

Living Roof Type:
Extensive

Development Type:
Government - powerplant

Build:
New build

Building Type:
Government

Living Roof Design:
Vegetation- Mix of succulent species

Substrate Depth:
50mm

Substrate Composition:
Unknown

Drainage System:
Unknown

Waterproof Membrane:
Unknown

Irrigation:
Not known

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~22°

Roof Access:
Inaccessible
Slopes

Climate Evaluation:
Full sun and wind

Size:
~1200m^2

Completion:
2005

8 - House

Location:
Richard Mortensen vej 81, Copenhagen, Denmark

Client:
St. Frederikslund Holding

Architect:
Bjarke Ingels Group - BIG

Living Roof Designer:
KLAR

Project Drivers:
Aesthetics, urban heat island effect, visual identity

Living Roof Type:
Extensive and Semi-intensive

Development Type:
Mixed Use - Residential

Build:
New build

Building Type:
Residential & Commercial

Living Roof Design:
Vegetation- Mix of succulent species and some trees

Substrate Depth:
50 - 400mm

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
30°

Roof Access:
Inaccessible
Slopes

Climate Evaluation:
Full sun and wind

Size:
~1700m^2 of extensive and 1m^2 x 100 semi-intensive gardens

Completion:
December 2010

Birkegade Penthouses

Location:
Birkegade 4-6, Copenhagen, Denmark

Client:
A/B Birkegade

Architect:
PLOT= JDS+BIG, EKJ

Project Drivers:
To create the ‘missing garden’ at the top of an existing housing block in association with 3 penthouses - Aesthetics

Living Roof Type:
Semi-intensive

Development Type:
Residential

Build:
New build

Building Type:
Residential

Living Roof Design:
Vegetation- grass

Substrate Depth:
50 - 100mm

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
30°

Roof Access:
Accessible
Slopes + Stairs

Climate Evaluation:
Full sun and wind

Size:
900m^2

Completion:
2011

The City Dune - Urban Space

Location:
Bernstorffgade 50, Copenhagen, Denmark

Client:
SE Bank & Pension

Landscape Architect:
SLA

Project Drivers:
Aesthetics, Public Space provision and Stormwater management

Living Roof Type:
Intensive

Development Type:
Commercial

Build:
New build

Building Type:
Commercial

Living Roof Design:
Vegetation- specimen trees

Substrate Depth:
~800mm

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
30°

Roof Access:
Accessible
Slopes + Stairs

Climate Evaluation:
Full sun and wind

Size:
7,300m^2

Completion:
July 2010

National Archives

Location:
Kalvebod Brygge 32, Copenhagen, Denmark

Client:
OPP Pihl Arkivet A/S

Architect:
PLH Arkitekter

Landscape Architect:
Schonherr A/S

Project Drivers:
Provide pedestrian throughsite link, Aesthetics and Stormwater management

Living Roof Type:
Intensive

Development Type:
Government

Build:
New build

Building Type:
Government - State Archives

Living Roof Design:
Vegetation- specimen trees

Substrate Depth:
~800mm

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~2°

Roof Access:
Accessible
Slopes + Stairs

Climate Evaluation:
Full sun and wind

Size:
7,000m^2

Completion:
2009

Tivoli Congress Centre & Hotel

Location:
Arni Magnussons Gade 2, Copenhagen, Denmark

Client:
Hansen Hotel Group

Landscape Architect:
SLA

Project Drivers:
Public Space for use by locals and hotel guests, Aesthetics and Accessible to all

Living Roof Type:
Intensive

Development Type:
Commercial

Build:
New build

Building Type:
Commercial - Hotel

Living Roof Design:
Vegetation- specimen trees

Substrate Depth:
~800mm

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~2°

Roof Access:
Accessible
Slopes + Stairs

Climate Evaluation:
Full sun and wind

Size:
7,000m^2

Completion:
May 2010

Emporia Shopping Centre

Location:
Malmö district of Hyllie, Sweden

Client:
Sten & Ström

Architect:
Wingårdhs Arkitektkontor

Landscape Architect:
Landskapsgruppen Öresund AB

Project Drivers:
Public Space for use by shoppers and workers, Aesthetics

Living Roof Type:
Semi-intensive and Extensive

Development Type:
Commercial

Build:
New build

Building Type:
Commercial - shopping mall

Living Roof Design:
Vegetation- sedums, prairie grass and specimen trees

Substrate Depth:
~800mm

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~2°

Roof Access:
Accessible
Slopes + Stairs

Climate Evaluation:
Full sun and wind

Size:
27,000m^2

Completion:
2012

Augustenborg Botanical Roof Garden - Scandinavian Green Roof Institute

Location:
Ystadvägen 56, Malmö, Sweden

Client:
Scandinavian Green Roof Association (not for profit)

Project Drivers:
Education (seminars and courses, providing consultancy support to member organizations), Research and Promotion of living roofs and facades throughout Scandinavia

Living Roof Type:
Extensive, Semi-intensive and Intensive

Development Type:
Government - Education

Build:
Retrofit

Building Type:
Government - Education

Living Roof Design:
Vegetation- sedums, low ground plants and specimen trees

Substrate Depth:
varies

Substrate Composition / Drainage System / Waterproof Membrane / Irrigation:
Unknown

Living Roof Construction:
Built-in-place living roof system

Roof Structure:
Concrete

Slope of Roof:
~2°

Roof Access:
Accessible - open to public
Stairs + boardwalk

Climate Evaluation:
Full sun and wind

Size:
9,500m^2

Completion:
2001

APPENDIX 2.
EXPLORATION OF ACCESSIBILITY; WYNYARD QUARTER, AUCKLAND

Wynyard Quarter design interventions

EXPLORATION OF ACCESS

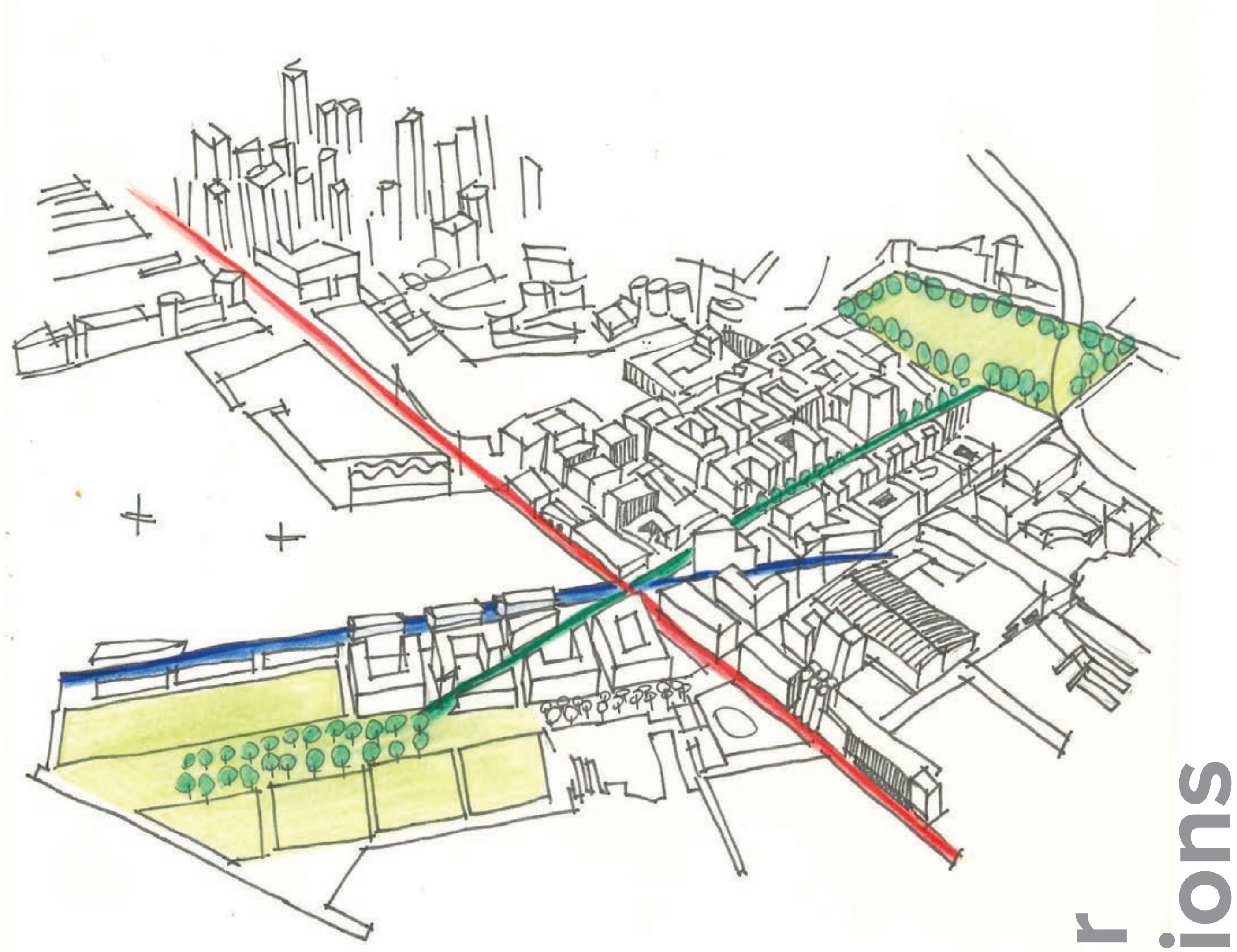
Point Precinct, Wynyard Quarter, Auckland Waterfront

I explored access at a site in Wynyard Quarter, Point Precinct, on Auckland's waterfront. This area, being the birthplace of Auckland, is steeped in history of trade, industry and fishing. Being a dynamic time for the Auckland Waterfront area with the redevelopment of Wynyard Quarter, I aimed to apply my design intervention of living roofs on the new Point Precinct which includes a 4.5hectare urban park. This site being part of Auckland's largest urban revitalisation project of approximately 37 hectares with nearly three kilometres of coastal frontage.

The waterfront landscape is distinctly different from other parts of the city and affords special amenity and function being characterised by marine, commercial and industrial activities. Historically the area contained a diverse range of businesses and industry from boat builders, flourmills, gas works, and sawmills to the now more common, taverns.

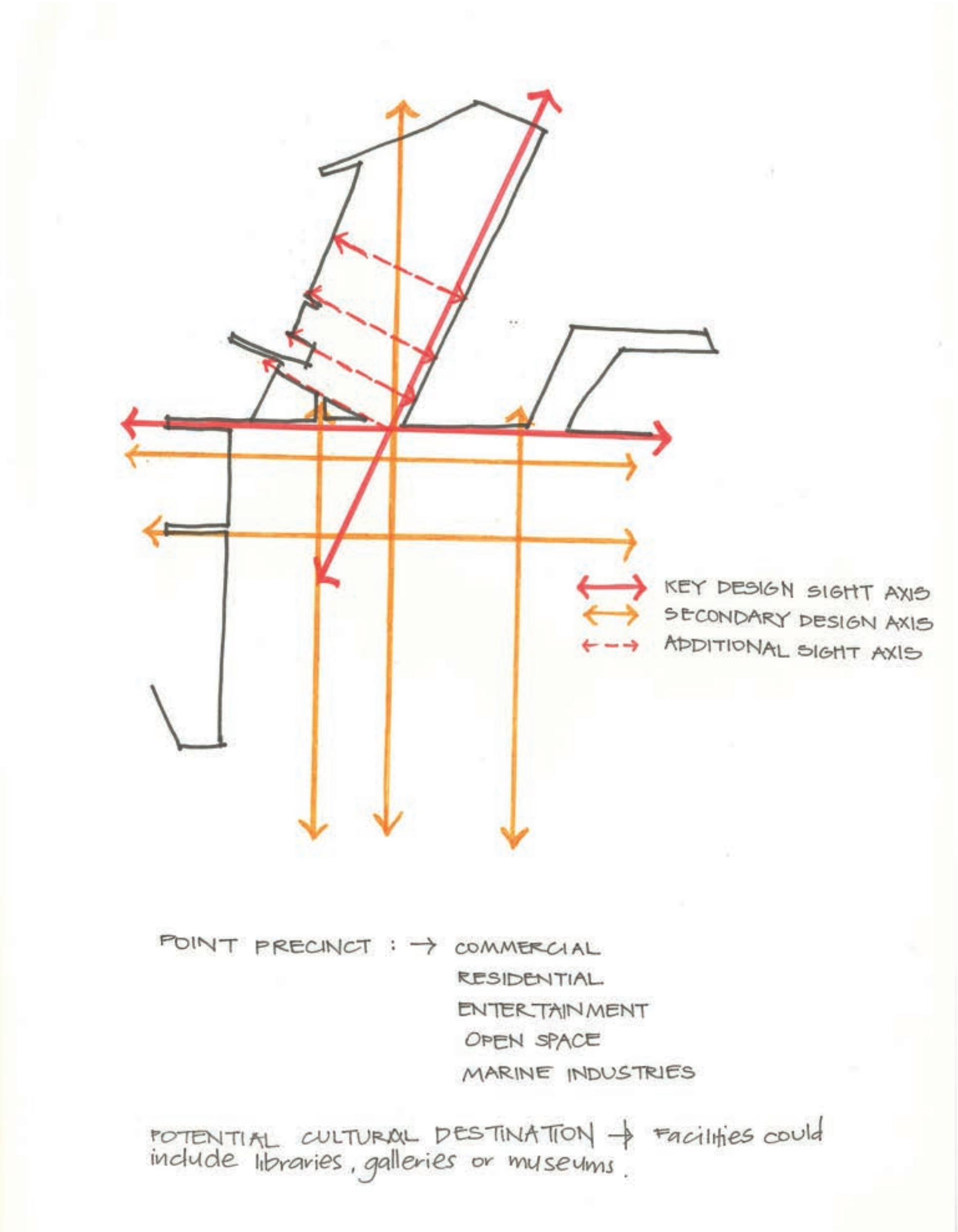
Auckland Waterfront and the community have indicated their goals for this distinct district is:

- A blue-green waterfront
- A public waterfront
- A smart working waterfront
- A connected waterfront
- A liveable waterfront (Waterfront Auckland, 22-23)

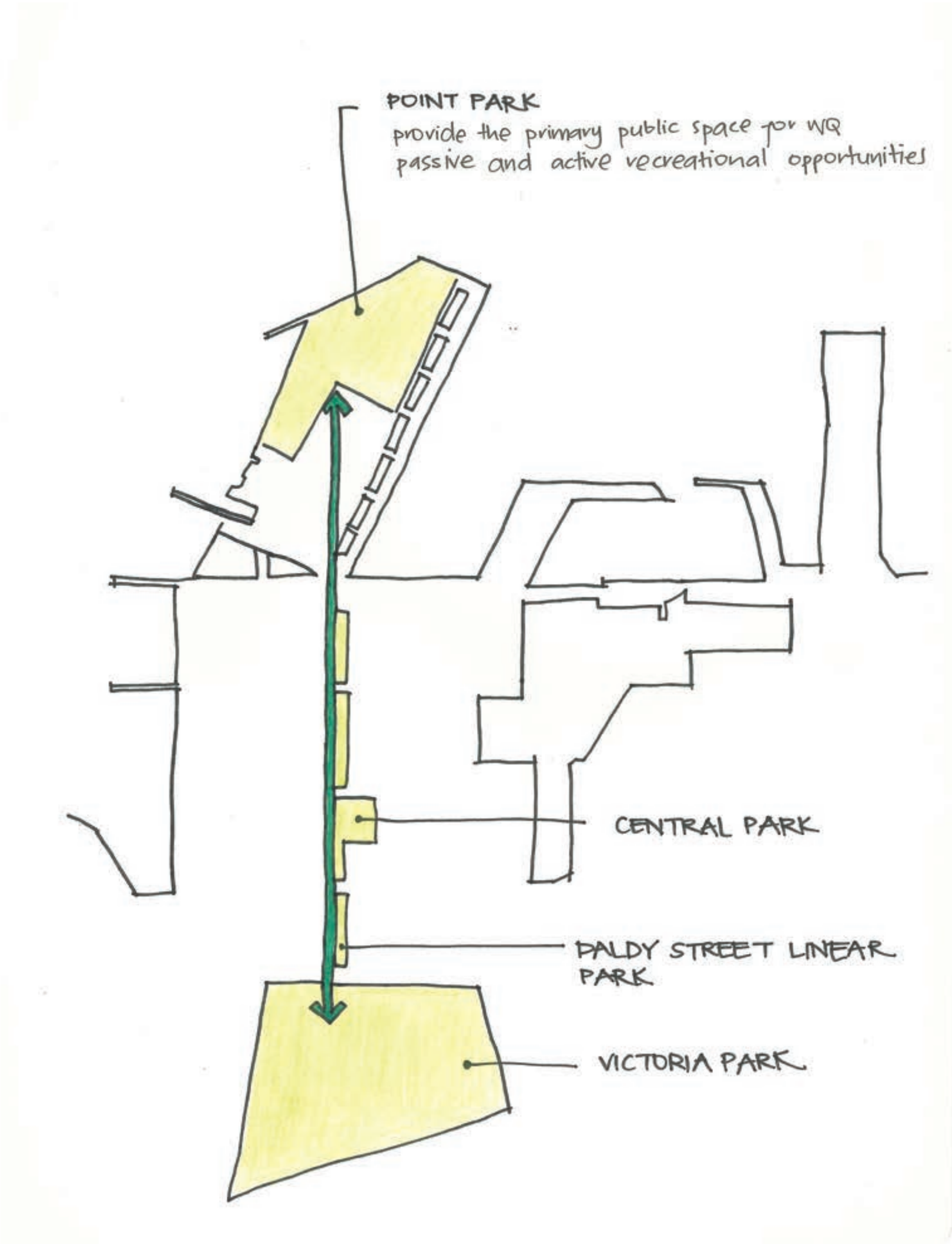


4 key urban design concepts:

1. The Waterfront Axis
2. The Park Axis
3. The Wharf Axis
4. Waterfront Precincts

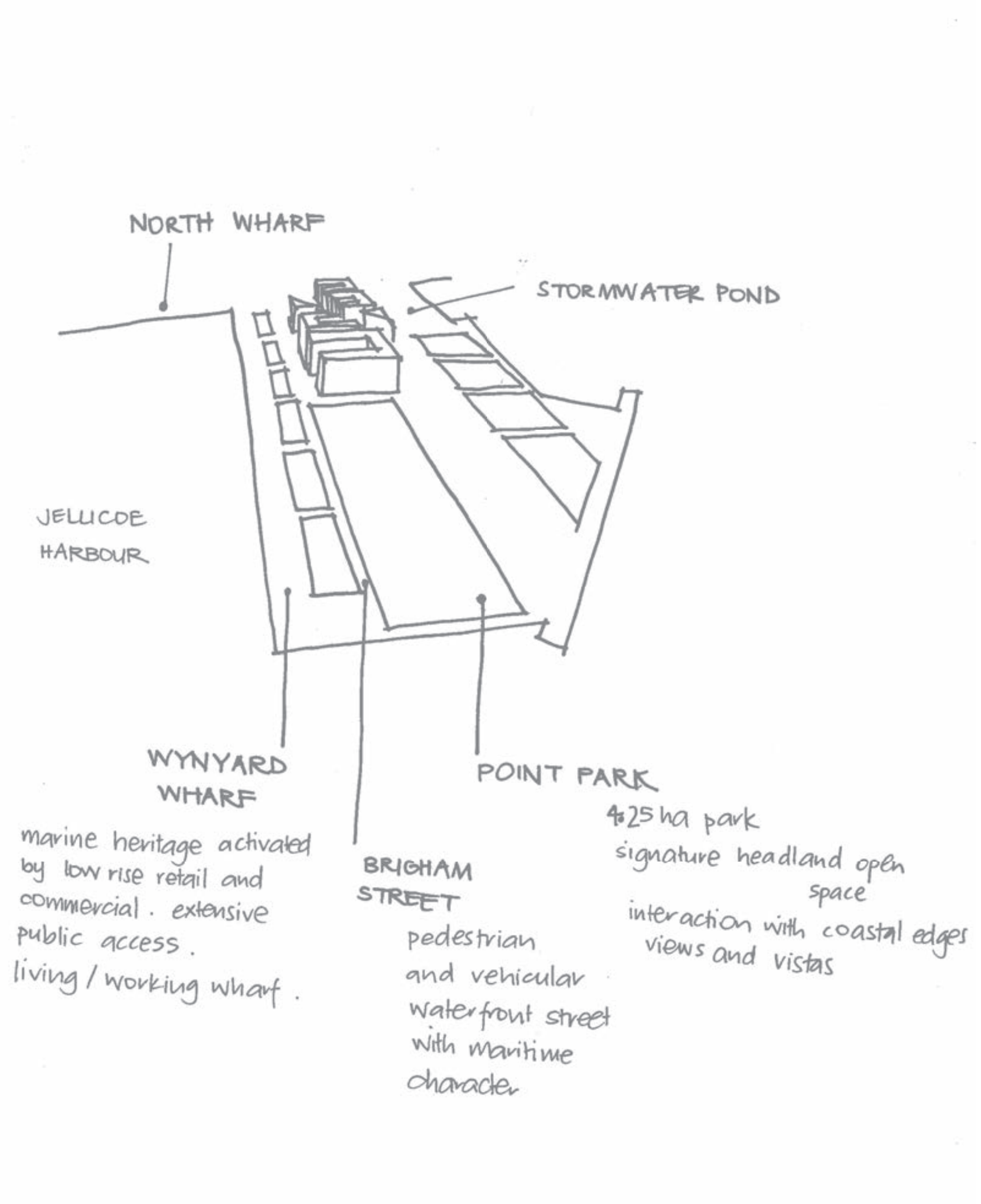


legibility . diversity . sustainability . accessibility .

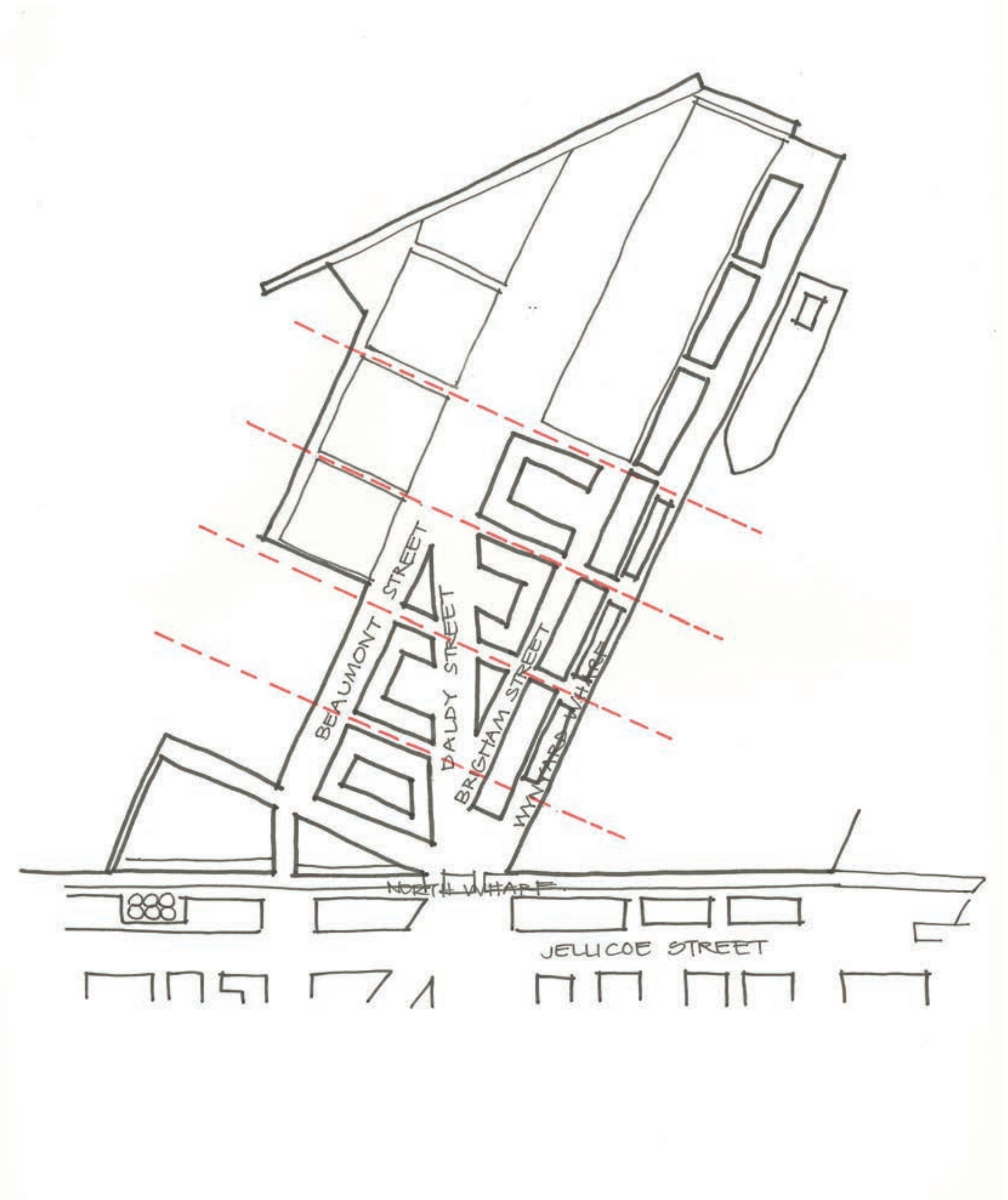


permeability . concentration . identity .

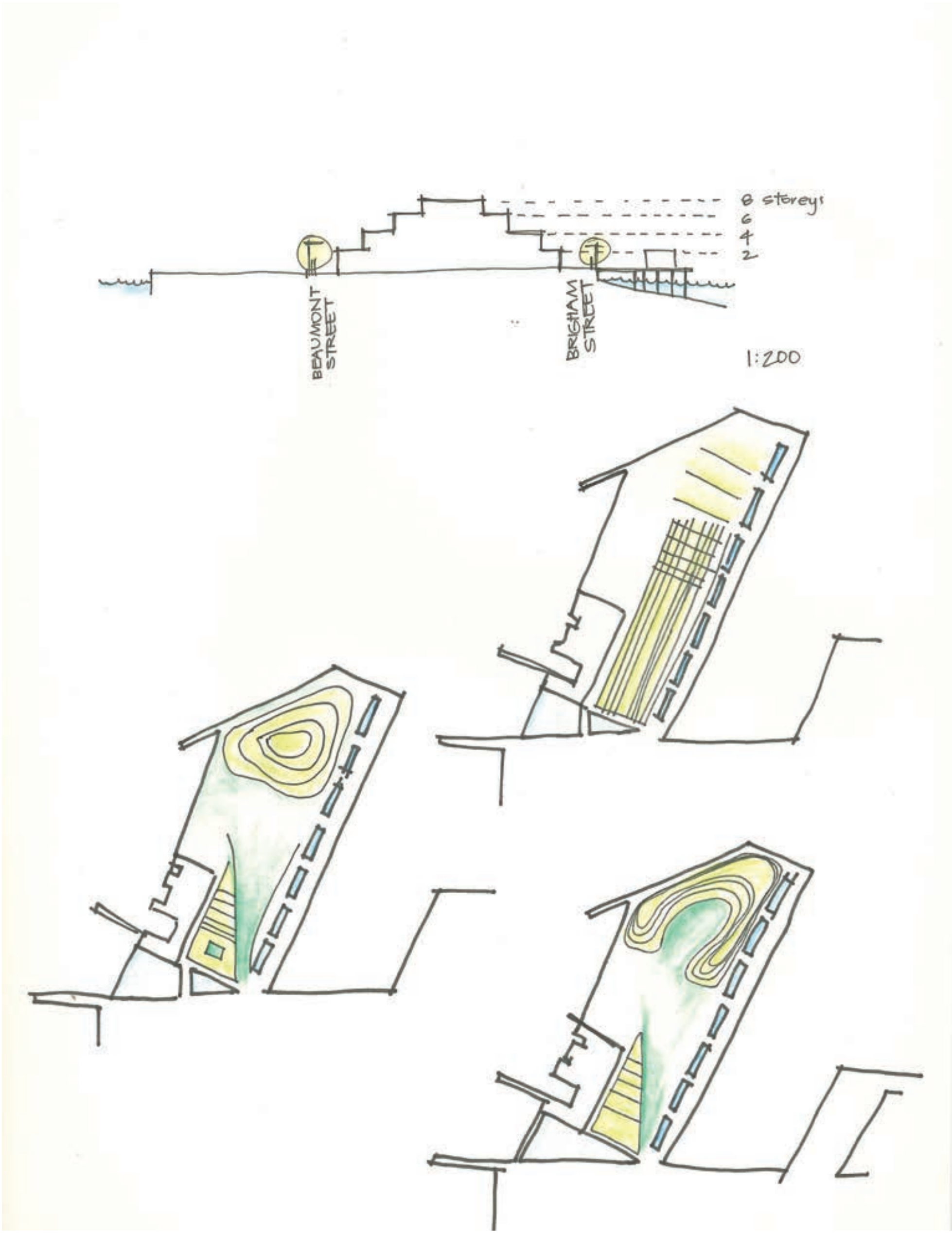
Intervention Intention
My intention was to utilise the existing Waterfront Auckland designs and building envelopes, densities and mixed use building typologies established in the Unitary Plan, and investigate different configurations of these buildings. This design intervention was undertaken whilst maintaining the urban design paths that have been established along the waterfront, parks (connecting Victoria Park to Point Park), the wharf and key design axis.



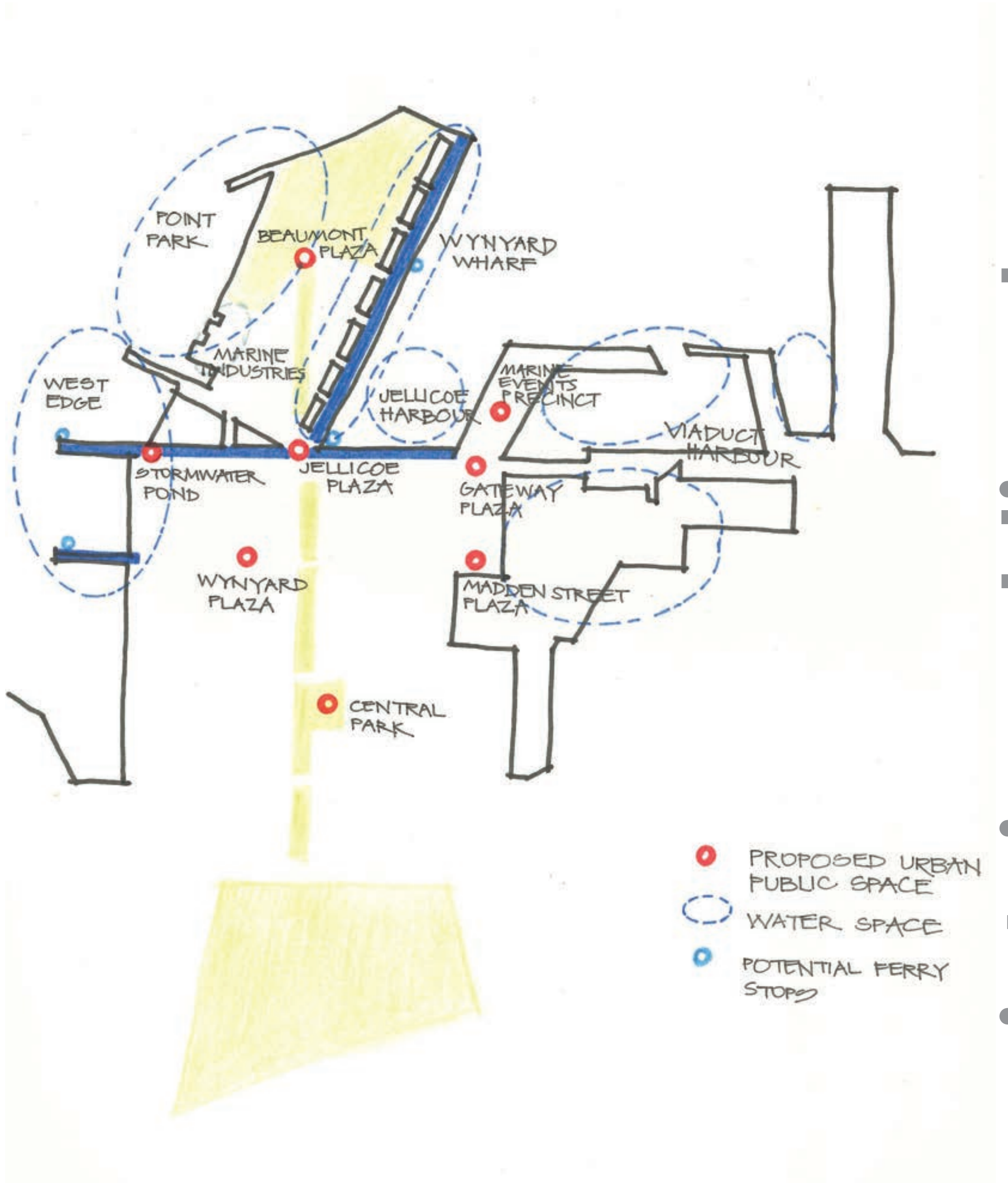
current design .



secondary axis .



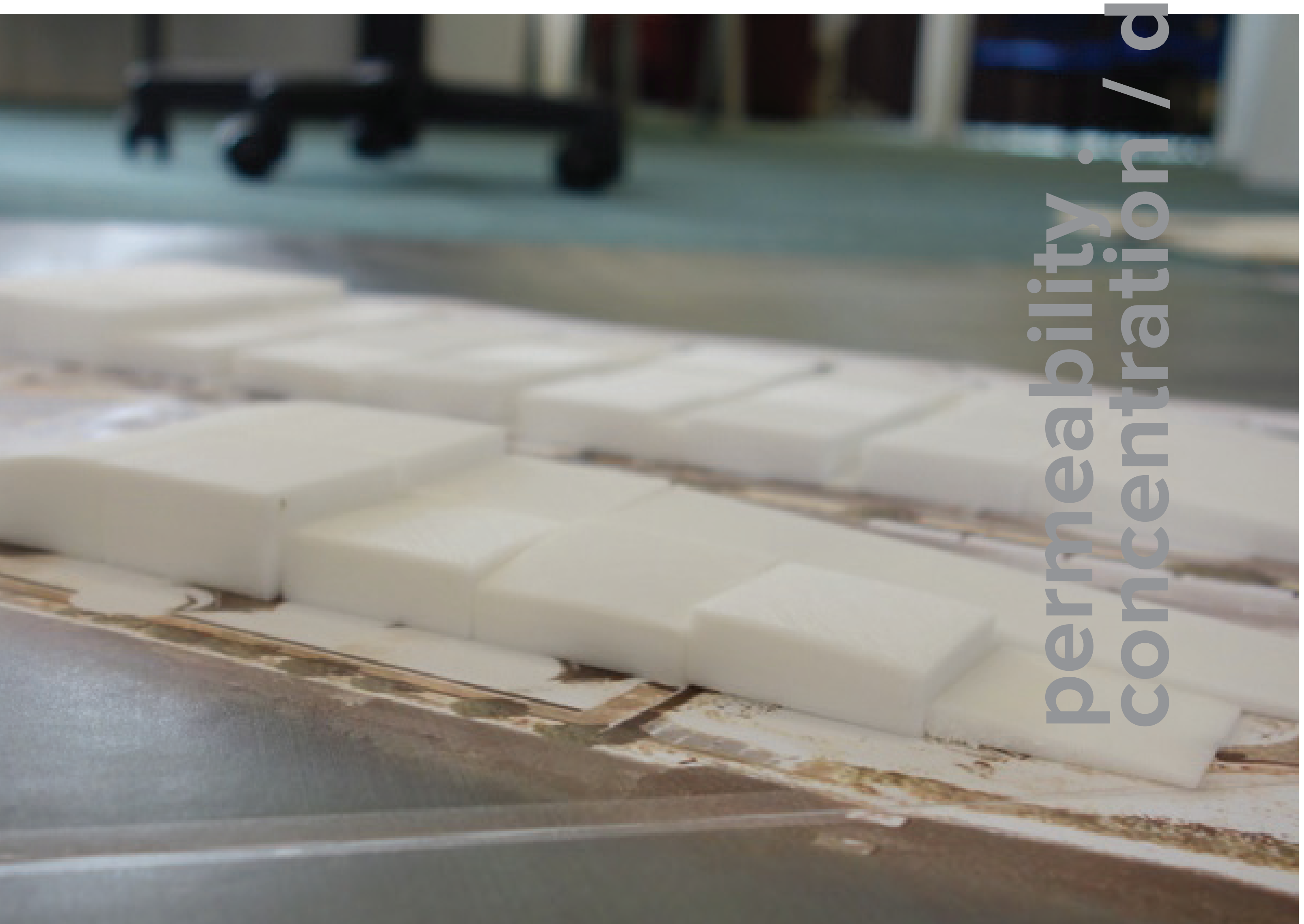
configuration investigations .
maintain axis .

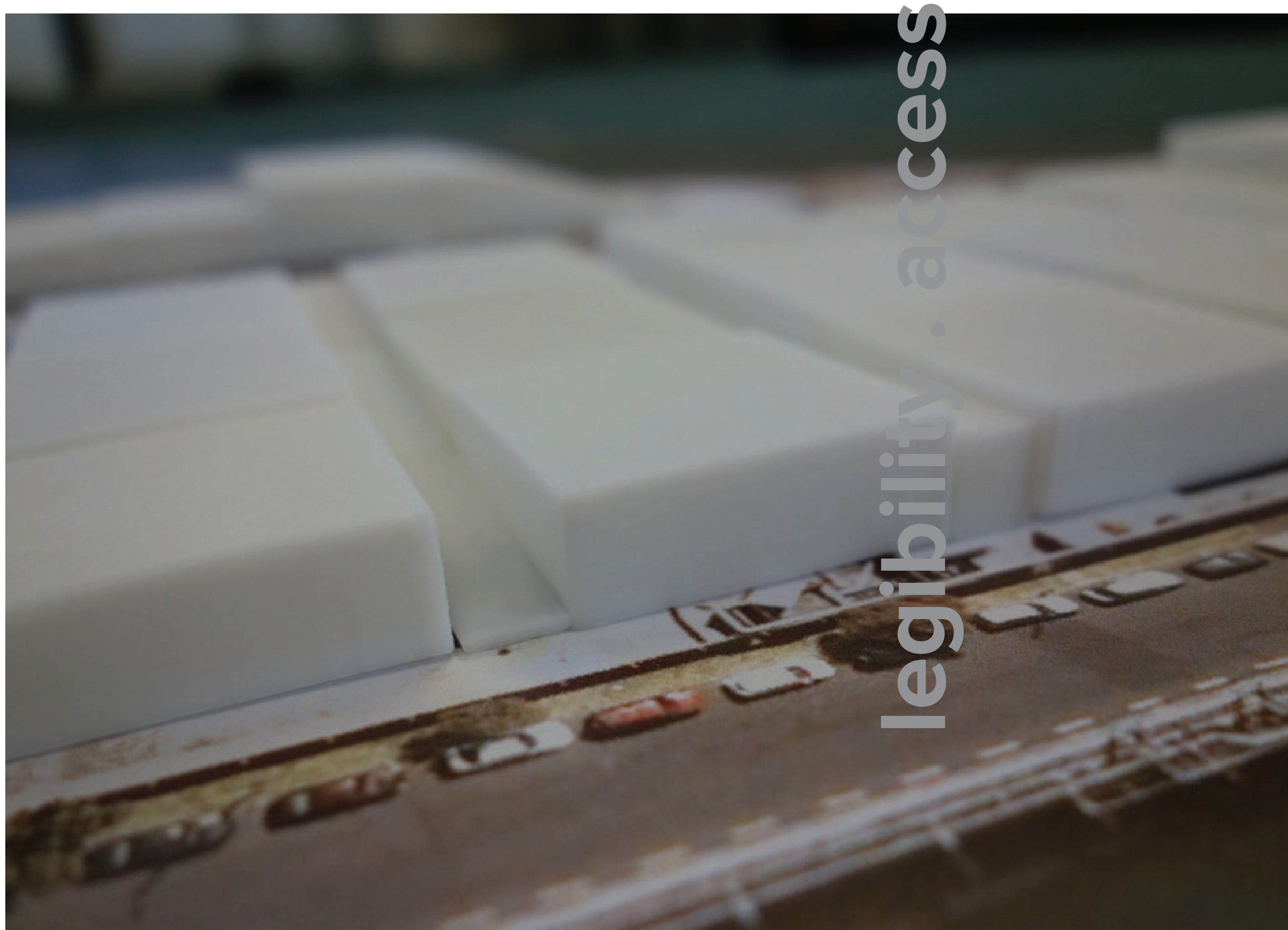


maintain public urban space focal points .

3d printed blocks of different area densities relevant to the Point Precinct anticipated commercial, retail, mixed use and residential use were used to explore building envelopes and potential living roof space

Different types of access investigated, such as ramps, stairs and lifts



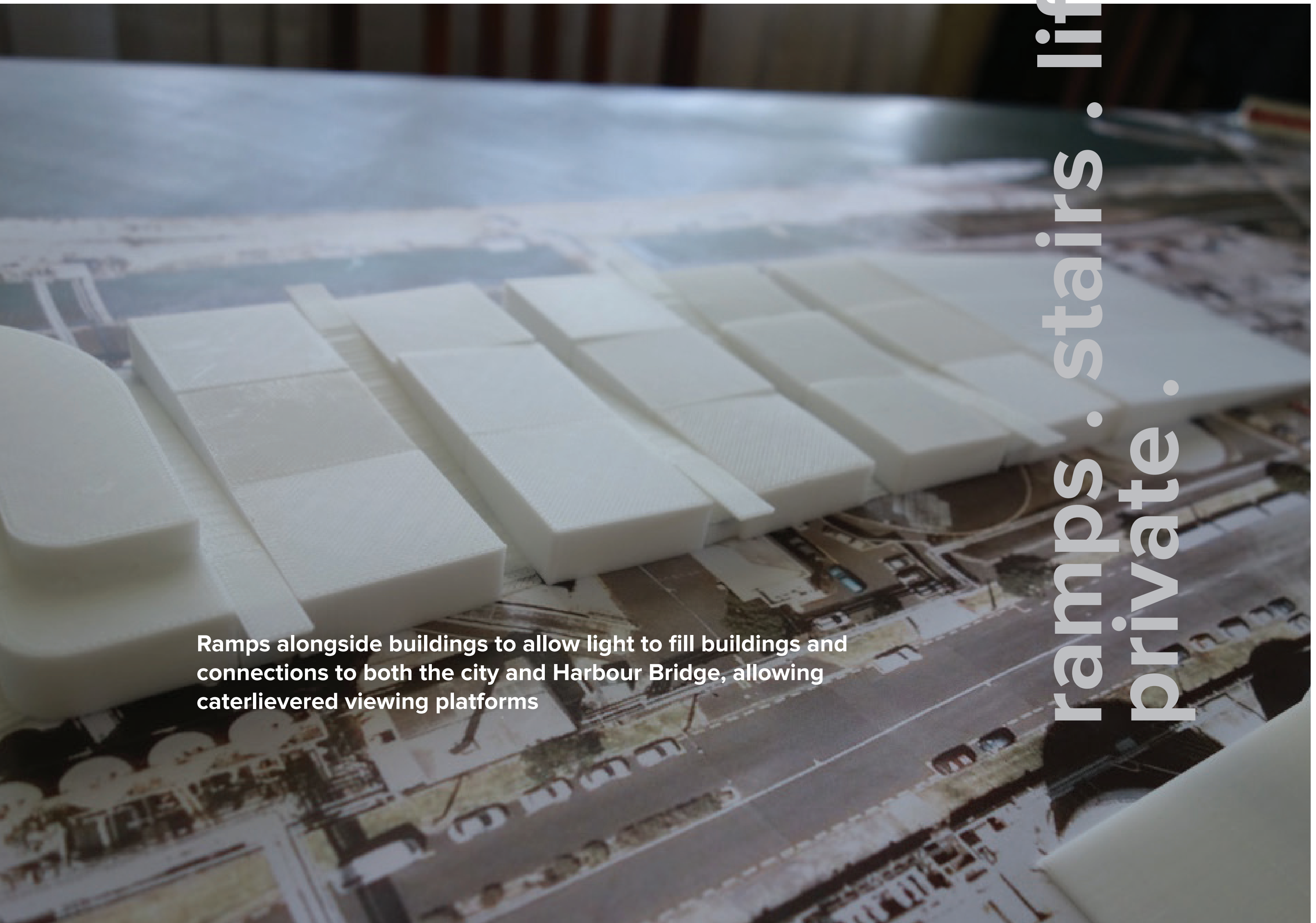


permeability .
concentration / density .

legibility . accessibility . identity .

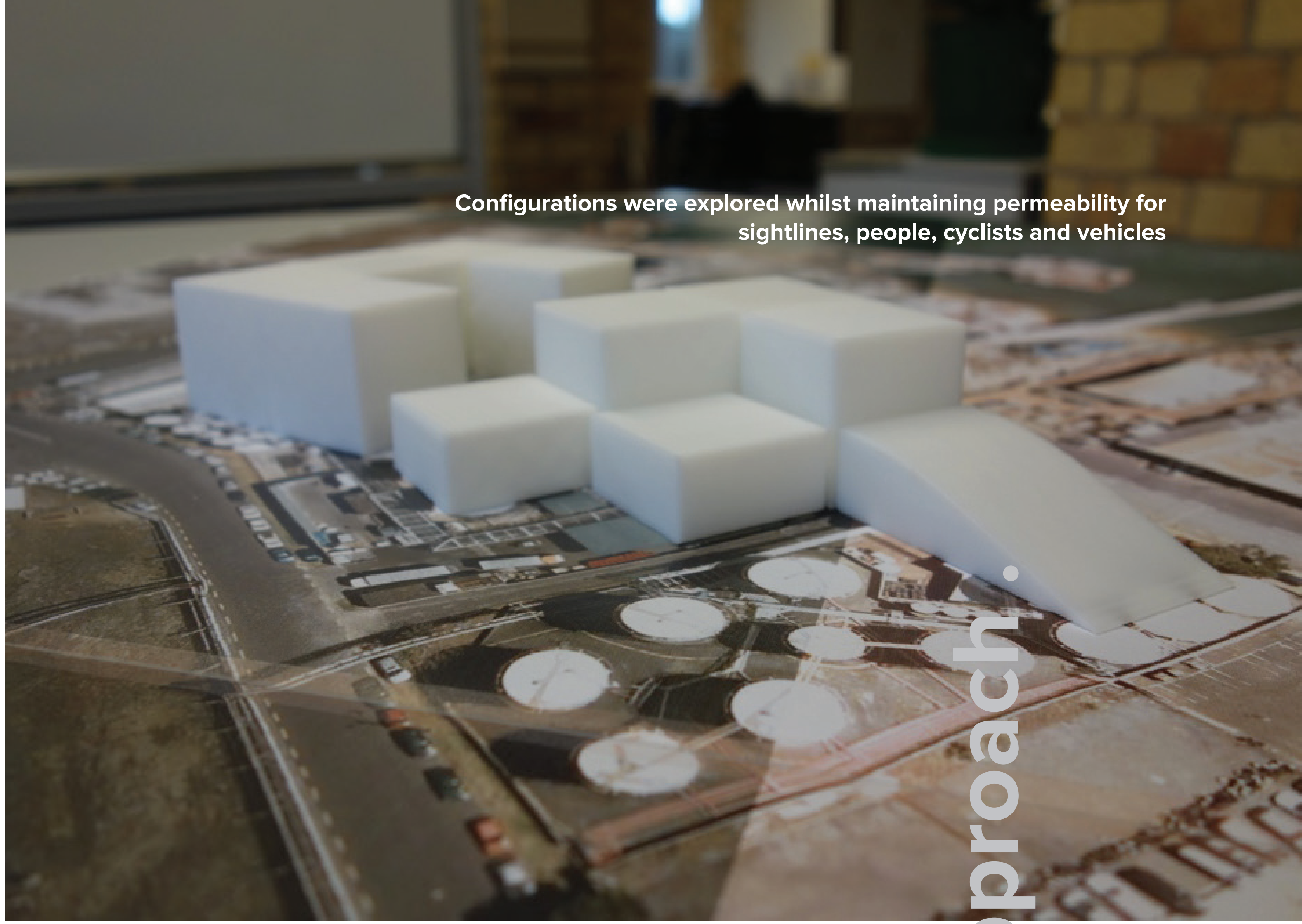
ramps . stairs . lifts . public vs private .

Connecting the ground plane to the roof plane, blurring private vs public use, buildings becoming park space

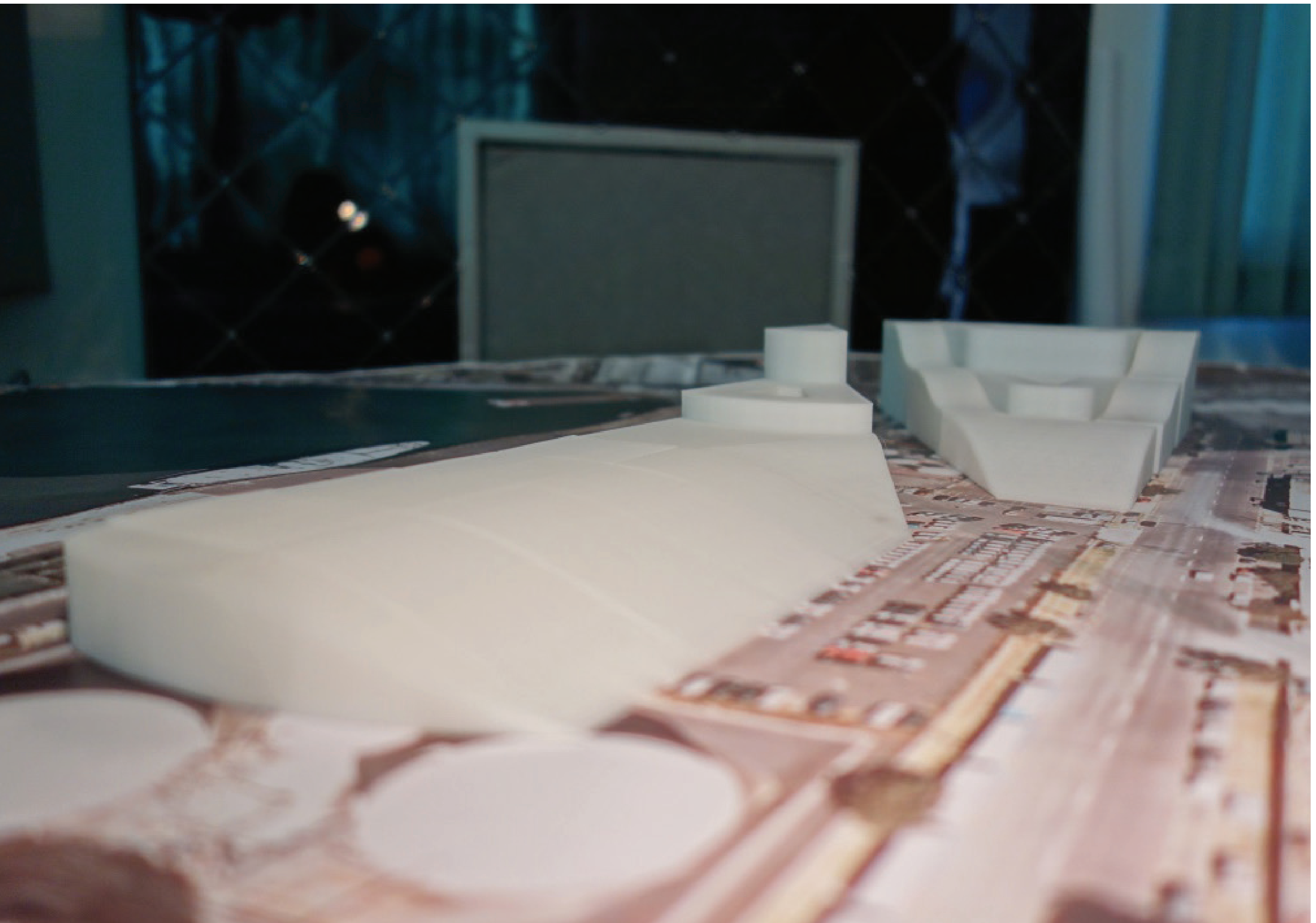


Ramps alongside buildings to allow light to fill buildings and connections to both the city and Harbour Bridge, allowing caterlievered viewing platforms

morphological approach .



Configurations were explored whilst maintaining permeability for sightlines, people, cyclists and vehicles

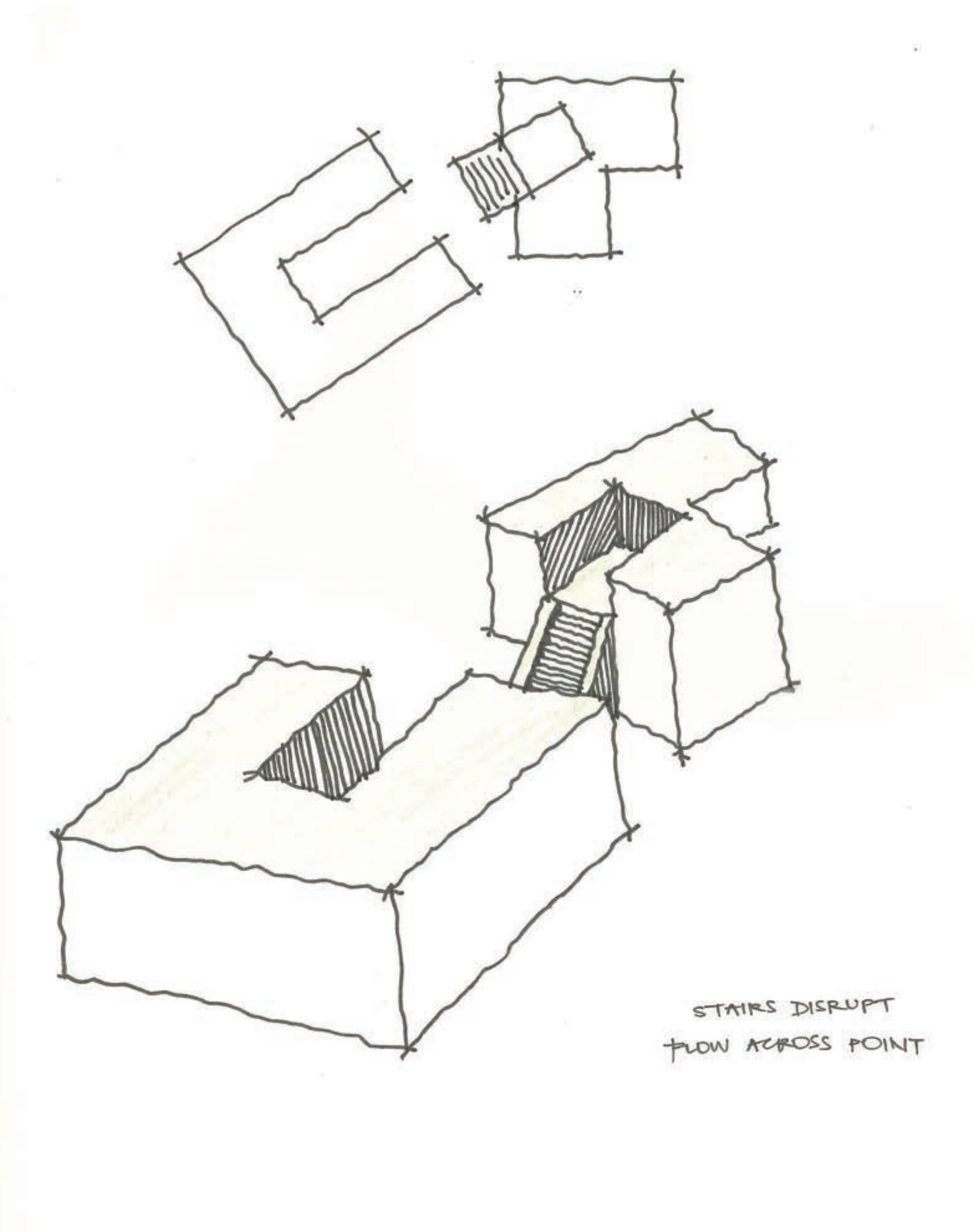


The morphological approach of connecting the buildings to the ground plane and the ground plane to the roof plane resulting in public realm being created within and on top of buildings.

urban grain and porosity . appropriation . cohabitation . connectivity . diversity .

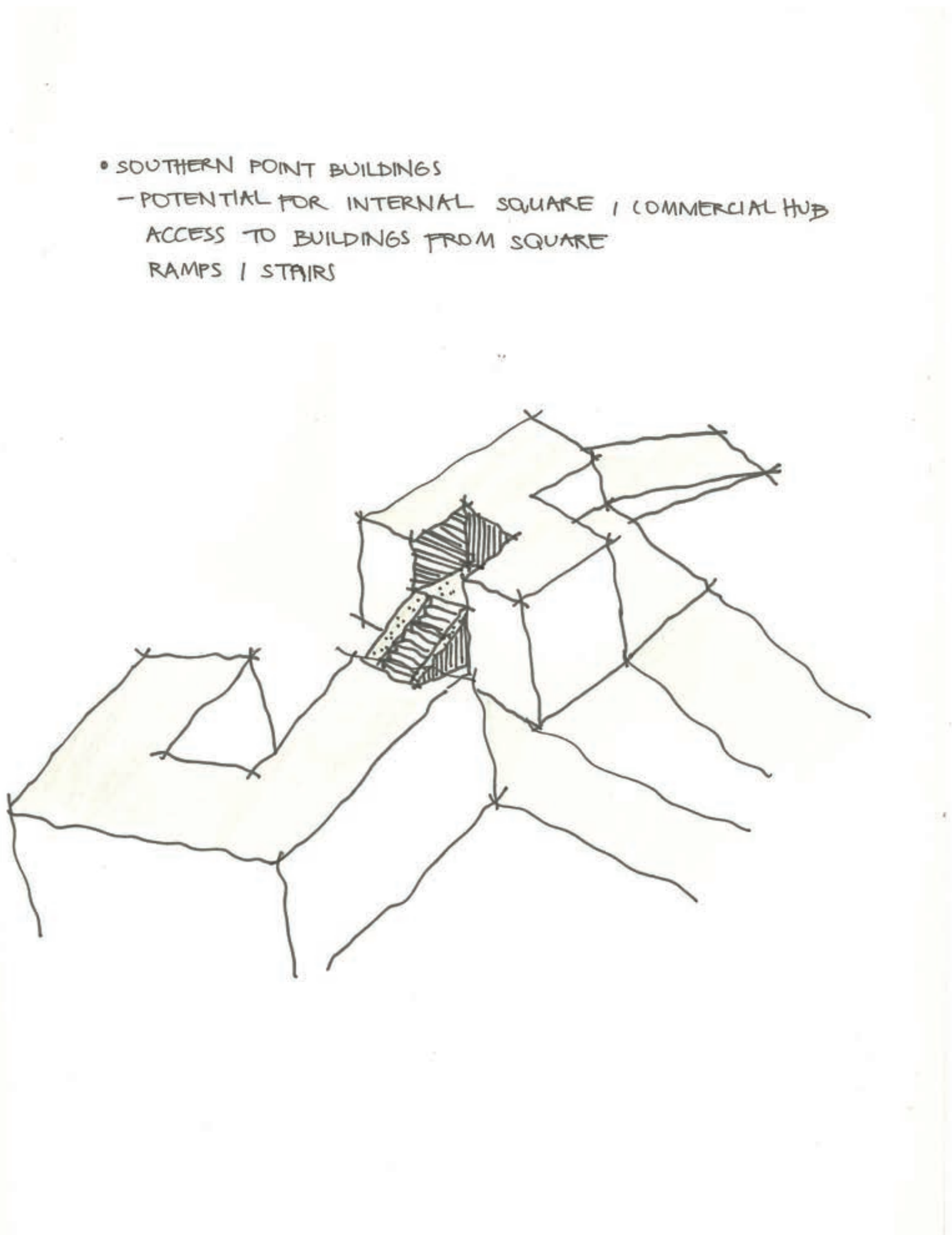
Taking pedestrian and vegetated space from the living roofs and access routes to the ground plane - allowing pedestrians and nature to have priority of the ground plane - creating shared green streets.

access investigations . stairs .



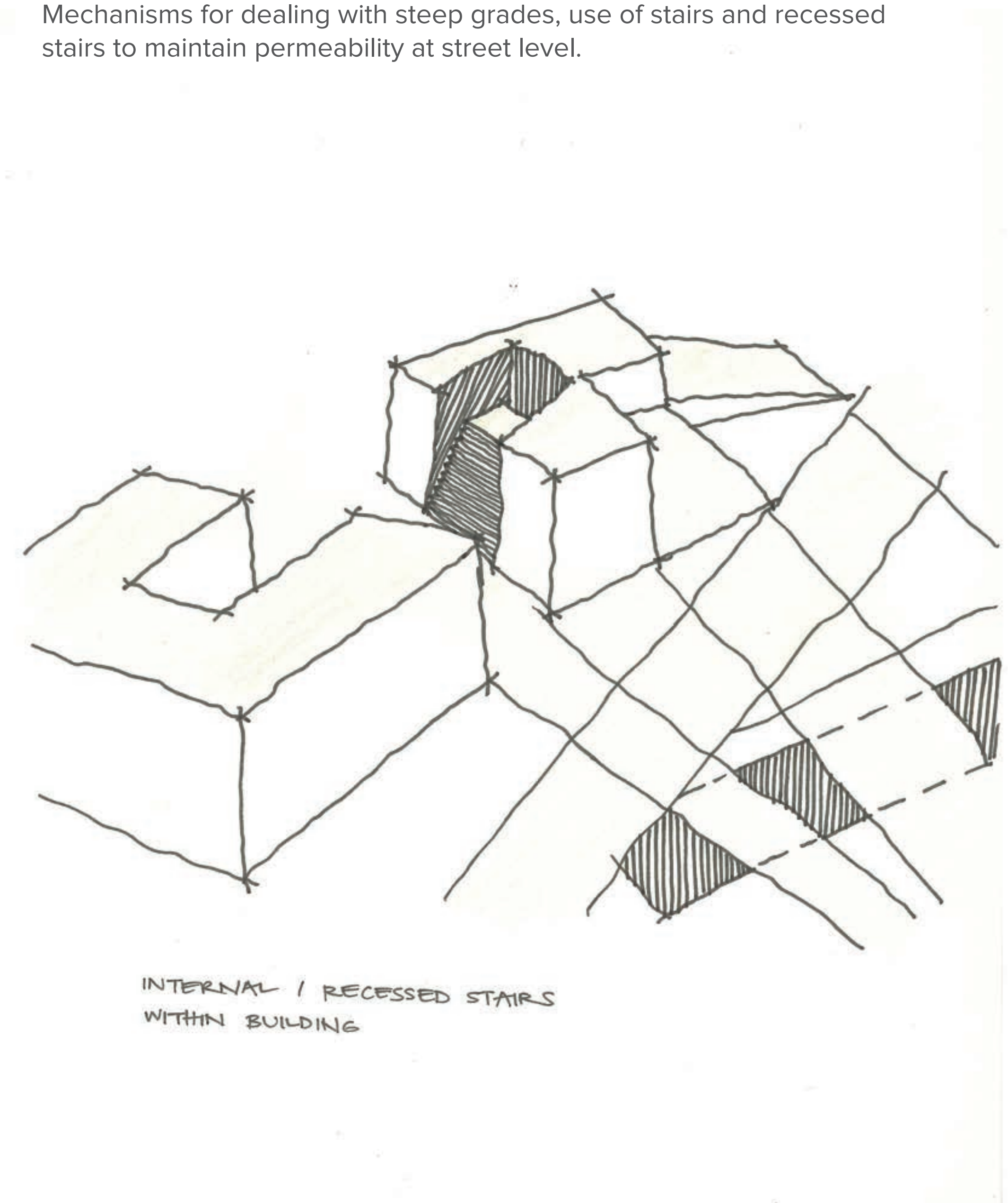
STAIRS DISRUPT FLOW ACROSS POINT

public realm access to building . ramps .

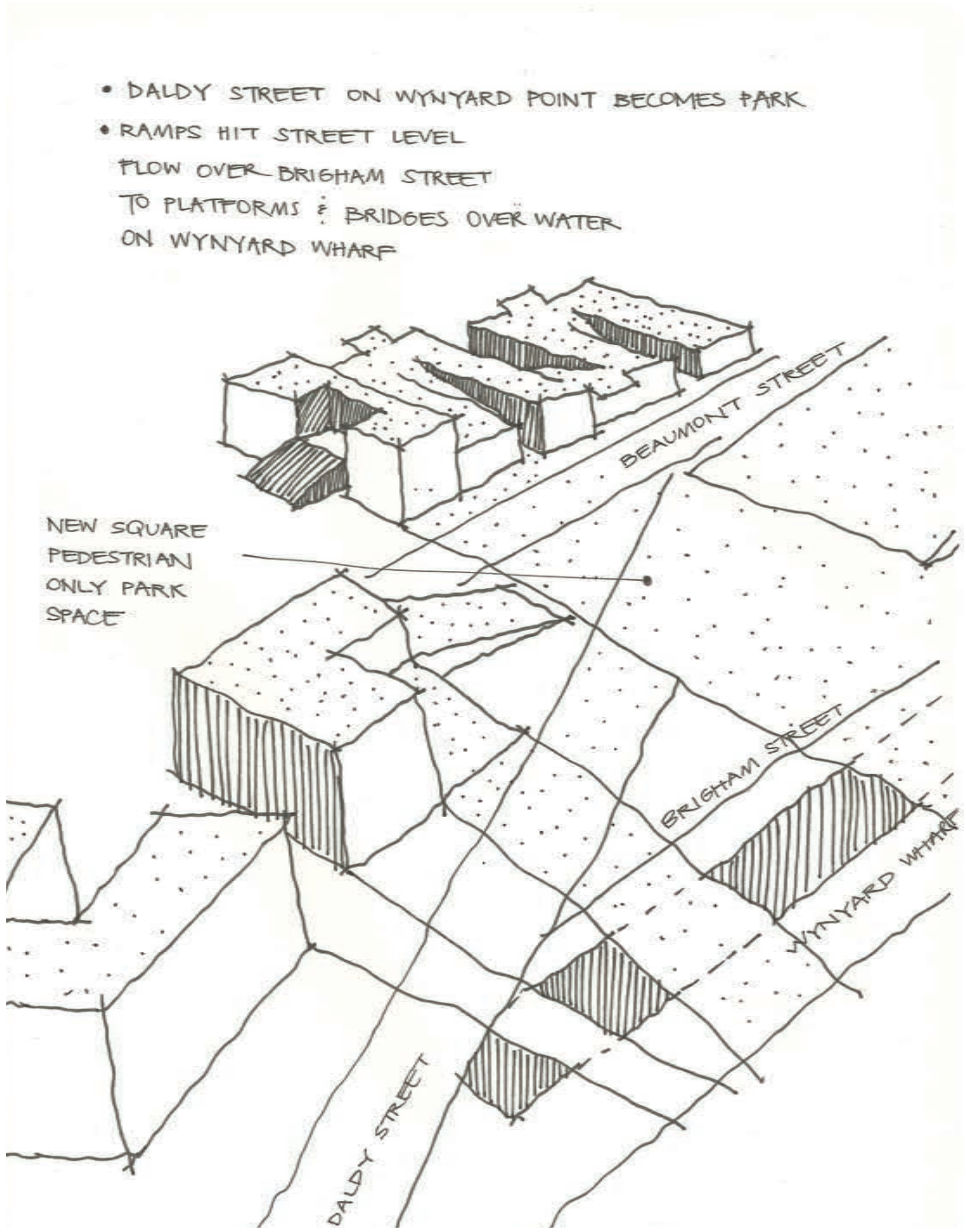


- SOUTHERN POINT BUILDINGS
  - POTENTIAL FOR INTERNAL SQUARE / COMMERCIAL HUB ACCESS TO BUILDINGS FROM SQUARE RAMPS / STAIRS

Mechanisms for dealing with steep grades, use of stairs and recessed stairs to maintain permeability at street level.

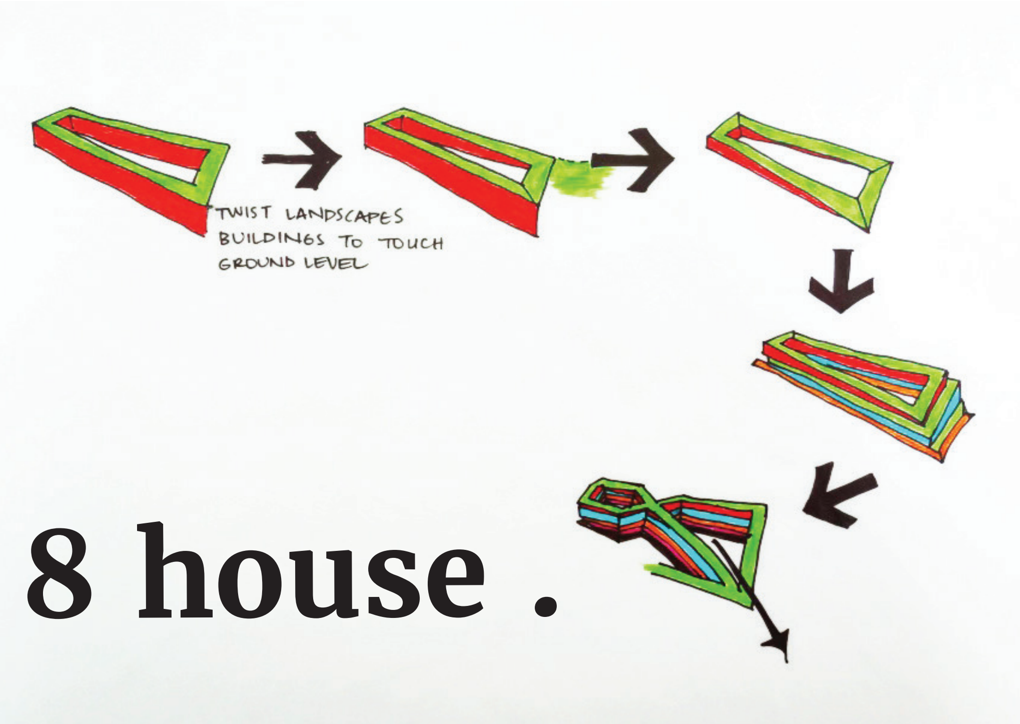


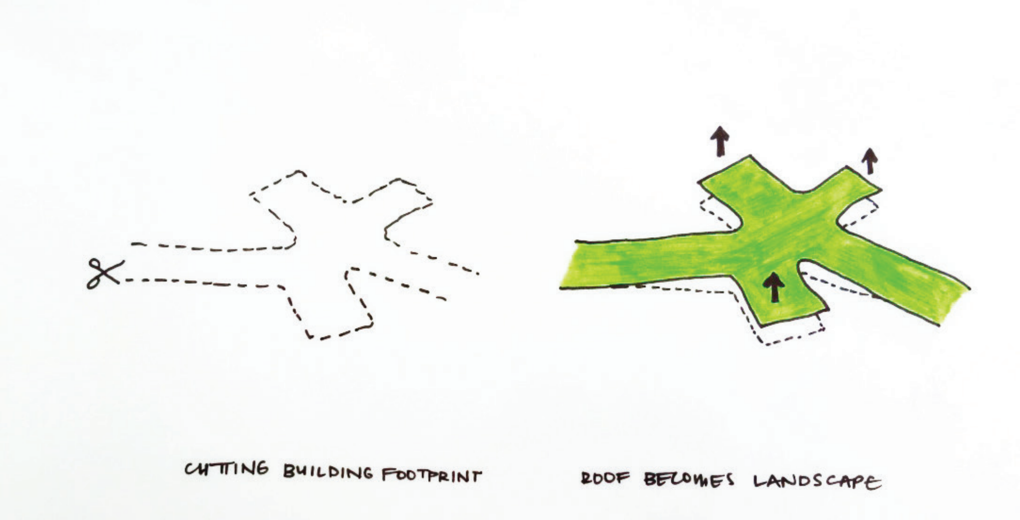
recessed stairs .
axis links .



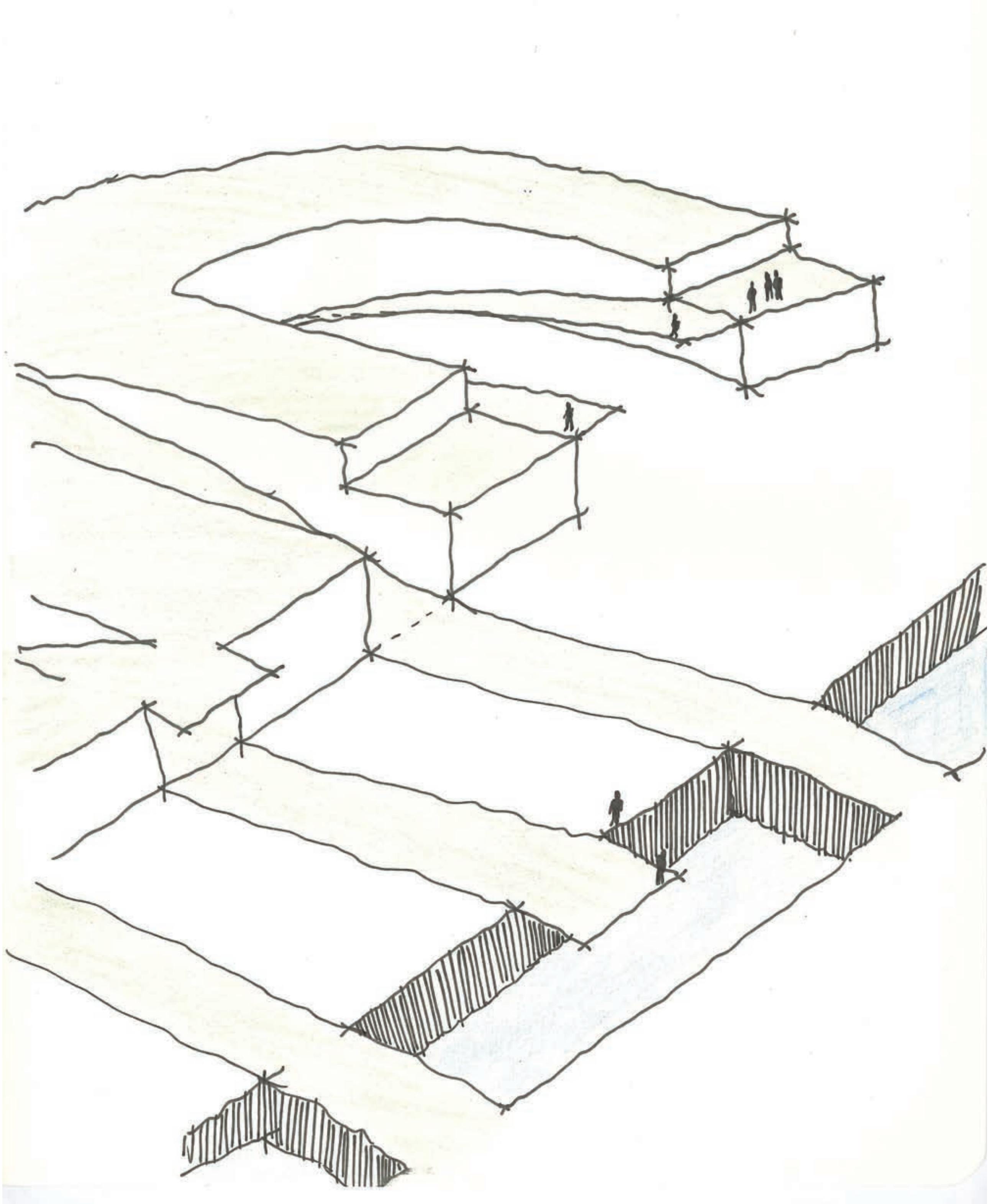
ramps blends public : private
space . links to water .

morphological approach .





extending axis for viewing platforms of city and bridge .



Considering the landscape and built form together, rather than separate where the landscape is merely the land left over, or the ‘in between’ spaces, highlighted the possibilities for park space being created not just at the ground level, but on top of buildings and on the access points to the building. Where the ramps could be park spaces, engaging the senses to the immediate landscape of the artificial headland and natural landscape, volcanoes and headland beyond.

As part of this design exploration, plazas and squares appeared, simple block lines with ramps, enclosed buildings creating city squares, where sunlight and views are not obstructed and the roof plane connects to the ground plane blurring the public vs private landscape realms.

Potential for the same density on the Point but configured differently alongside the introduction of living roofs, more green space, higher permeability which maintains views and connections. Creating public squares that are sheltered and surrounded by active building frontages.

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Institute of Technology
TE WHARE WANANGA O WAIRAKA

Full name of author: ZOË JANE AVERY

ORCID number (Optional):

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Associate Supervisor: Matthew Bradbury.

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