

# Architectural Ecology

*Cleansing & Regeneration of Polluted Place through Architecture*

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# Abstract

New Zealand was once considered one of the least environmentally damaged countries in the world. Heralded for its pristine landscape, and its 'Pure' moniker, New Zealand was promoted, perhaps unintentionally, as an environmentally conscious country. However, despite this image New Zealand, like other Westernised countries, suffers from the residual effects of agriculture and industry which have left a legacy of damaged and contaminated sites.

This thesis investigates how increased built development and regeneration of damaged environments can be achieved through architectural development, incorporating creatively and sensitively designed buildings. It seeks to adapt and translate technologies and resources to act not only as an environmental cleanser, but also provide for urban regeneration to go beyond the rhetoric of green and sustainable building principles.

The research finds that a change in focus is required; away from monetary focus and instead to environmental focus. This needs to occur immediately to avoid further environmental damage and to begin remediation of existing damage. This can be resolved by incorporating existing remediation techniques further into development.

The change also needs to incorporate the way in which we live. Urban responses and architecture play very important roles. The creation of mixed use sites with green space allow for localised consumption and recreation. Inhabitation patterns have been poorly addressed by New Zealand developers and a different rationale and process needs to be undertaken. It is time for New Zealand to stop appearing green and start taking significant steps to reducing environmental impact.

The project successfully investigates and addresses the issues of regeneration, both of site and urban conditions. It sits between the two streams of thought, technological and theoretical and extracts the positives of these two elements to create an informed solution that recognises past, present and future use.



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# Introduction



Figure 1: Advertisement from Tourism New Zealand's ongoing campaign.

From: Tourism New Zealand. (2010). 100% Pure New Zealand. Retrieved 25/05/2010  
<http://www.newzealand.com/International/>

New Zealand was once considered one of the least environmentally damaged countries in the world. Heralded for its pristine landscape, and its “100% Pure” (Tourism New Zealand, 2010) image New Zealand was promoted, perhaps unintentionally, as an environmentally conscious country. However in an increasingly environmentally conscious global climate, where man made climate change and pollution are loaded topics, New Zealand has been criticised as an underachiever.

New Zealand's clean green image is falsified due to the agricultural sector, industrial heritage and the social, economic and consumption patterns of the population. Recent reports in popular overseas newspapers, such as The Economist, state New Zealand's international image is a fantasy (The Economist, 2010), whilst the Guardian's environmental columnist Fred Pearce goes a step further, slamming New Zealand's response to climate change and reducing emissions as a “shameless two fingers to the global community” (Pearce, 2009). Added to this are reports of unclean rivers and harbours, farming intensification and an increasing number of polluted and damaged sites from industrial activity.

As a largely undeveloped country with a small population, New Zealand is likely, in the approaching decades, to experience an increase in migration and population growth. This, in turn, will create increased economic and urban growth. While this economic growth is required for the country's population to continue to prosper, it is vitally important for the health of the closed loop systems of the planet to follow through the 'Pure' image with new construction that strives for creative, forward thinking, long term, environmentally regenerative solutions for new development. Therefore any future urban growth must be carefully orchestrated to reduce environmental impact and attempt to create more sustainable ways of living.

This thesis investigates how increased built development and regeneration of damaged environments can be achieved through architectural development, incorporating creatively and sensitively designed buildings. It seeks to adapt and translate technologies and resources to act not only as an environmental cleanser, but also provide for urban regeneration to go beyond the rhetoric of green and sustainable building principles. The thesis aims will be tested with a design project which can be utilised as an opportunity not just to improve and repair New Zealand's image, but create a more mutually beneficial relationship between the built form and environment and influence future urban inhabitation.

## *Chapter Outline*

The thesis draws from a number of existing literary sources, communication with specific authorities and professionals and personal findings. It will be divided into two sections, consisting of two chapters each. The first section will develop a background of environmental and social issues and then elaborate on solutions - architectural and otherwise - to these issues. The second section will combine these solutions and issues through a case study of the Western reclamation in Auckland city as an exemplary site.

### *Section 1:*

Chapter one will focus on New Zealand's declining credibility as an environmentally conscious country. The focus of this chapter will be on agricultural and industrial impact on New Zealand, in particular on a number of environmental issues. These include soil contamination; water quality and air quality - issues of particular concern in Auckland and Christchurch. These issues stem from the residue of previous and current industrial and agricultural development in New Zealand. Further, the lifestyle of New Zealanders continues to apply increasing environmental pressure. Their Western consumption and settlement patterns that exist in New Zealand will also be discussed in this chapter and explored against the larger idea of global - and local - climate change.

Chapter Two of the report investigates the potential of sustainable and regenerative architecture with regards to site remediation and redevelopment. Although sustainable methods will be investigated, the focus will be on a regenerative approach, as sustainability focuses heavily on technological fixes and current social patterns and trends that are insufficient to facilitate the recovery of natural habitats and ecosystems. In particular the environ-

mental aspects affecting New Zealand addressed in the previous chapter will be questioned through case studies, architectural, technological and social interventions. Additional to an architectural focus, landscape methods, ideas and processes will be investigated through case studies.

## *Section 2*

Chapter Three provides a background to the chosen site, the Western Reclamation, as well as the larger scope of central Auckland. Auckland is a city built around a harbour. This was due to the positives a harbour offered to the fledgling colonial economy reliant on the import and export of resources and people. This seafaring culture has had a large impact on the harbour and surrounding land-mass, as has the western style of consumption that occurs in New Zealand. The research will discuss history of the site, highlighting previous development and impacts. Further to this, future plans for the reclamation, renamed The Wynyard Quarter, will be used as a case study. This will allow investigation and critique of planned future development with regards to regeneration of the urban area as well as the environmental conditions of the site.

The final chapter proposes a design solution for the site incorporating the aforementioned research. This case study will be expanded to the point of a developed design solution of a master plan, expressing findings within the report through an architectural outcome. This will be presented both through writing and through pictorial evidence of an architectural design. In addition to a master plan scenario, more detailed zones within the project will be developed to depict architectural solutions incorporating research into cleansing and regenerative principles.

Finally the research report will be concluded with a discussion of outcomes and the design undertaken. The outcomes of the case study will be analysed and future design and research paths and lines of development examined.





# Chapter One - The environment and New Zealand's declining credibility

New Zealand is in a highly enviable global position. It is a lowly populated, separated geography, which has had few man-made impacts. It has copious essential resources and a coastal climate which means it will be far less affected by the effects of climate change than its neighbours, such as Australia and the Pacific Islands. However this does not mean as a country New Zealand can become complacent in efforts to reduce emissions, environmental impacts and pollution.

As the state of the planet we inhabit has become a pressing issue New Zealand has been an active participant in key sustainability and environmental conferences, such as the United Nations Framework Convention on Climate Change (FCCC) 1992 - which resulted in the Kyoto Protocol - as well as the follow up conference in 2009 in Copenhagen. In addition to this pivotal forum, New Zealand has also attended smaller conferences like the World Summit on Sustainable Development Johannesburg 2002. Further to this, Tourism New Zealand actively markets '100% Pure New Zealand'<sup>1</sup> suggesting a pristine environmental paradise, a country concerned with preserving its environment. Despite pristine appearances New Zealand's environmental record is anything but 'clean' or 'green'. There are many ways in which New Zealand portrays itself as a country, intentional or not, that are not factual, and in some cases the complete opposite is true.

1. The name 100% Pure instils visions of a pristine country free from environmental issues. This is not the active image the marketing campaign aims for, rather a '100% Pure' experience. Despite this fact the website shows images of beautiful landscapes, such as Milford Sound and Mt Cook. (Tourism New Zealand, 2010)

This chapter initially discusses New Zealand's declining international credibility as an environmentally conscious nation. Following this the study focuses on the impact of built development and consumption upon New Zealand's natural resources, broadly broken up into six sections.

The first determines why New Zealand's credibility is declining at an international and local level. The second section focuses on soil and land use, investigating the impact industrialisation and production has upon the resource of ground. The third section, water, investigates both salt and fresh water stocks in New Zealand. The fourth section is focused on air quality, particularly with regard to increasing urbanisation in New Zealand. Examples of polluted sites will be shown through examination of the former Fruitgrowers Chemical Company site, in Mapua and the Tui Mine in the Coromandel. As well as environmental effects, the fifth section examines the impacts of lifestyle and settlement patterns of the inhabitants of New Zealand. These are discussed, at a local scale as is the impact on the larger closed planetary cycle that these sociological patterns have, through resource depletion and climate change in the sixth section.

## *Declining credibility*

There have been a number of recent reports, articles and incidents that have had significant impact on New Zealand's positive reputation overseas. The most damning of these appeared in the British newspaper *The Guardian*. The columnist, Fred Pearce, declares New Zealand's attitude towards solving environmental issues is a "shameless two fingers to the global community" (Pearce, 2009). This article and similar sentiments in *The Economist* newspaper have put focus on New Zealand's environmental performance.<sup>2</sup>

When ratifying the Kyoto Protocol, New Zealand agreed to not increase Greenhouse Gas emissions from 1990 levels to 2008-2012 (United Nations, 1998). However, over this period there has in fact been an increase of 22.5% (Ministry for the Environment (New Zealand), 2005, pg. 63). Of the 187 states that signed the protocol, only Ireland and Spain increased their emissions by larger amounts than New Zealand. Unfortunately, the failure to meet Kyoto Protocol targets is only the tip of the environmental iceberg.

In the past few years there have been an increasing number of reports which highlight significant decline in New Zealand's natural resources. One of the most recent examples of this is the 2010 report prepared by NIWA for the Ministry of the Environment (New Zealand). The report highlights a decline of water quality in almost a third of New Zealand's lakes in the past four years. This is largely caused by increased pastoral areas, a resultant of the dairying boom. This boom and the agricultural industry as a whole has also had serious impact on the quality and makeup of soils through the country (Parliamentary Commissioner for the Environment, 2004). In a broader

2. *The Economist's* response is much less emotive, highlighting both sides to the argument. However it still concedes that New Zealand could be making far more effort to reduce emissions and environmental impacts.

sense significant increases in transport, tourism and energy production and consumption all contribute further to the declining state of the local environment (OECD, 2007). All of the above impacts are heavily linked to continued economic prosperity and growth.

However, following current trends, this growth may be at the expense of New Zealand's image which would have significantly larger impact. In 2001, the Ministry for the Environment published a report estimating the value of the environment for three key New Zealand industries; dairy farming, tourism and organic foods.

The study has looked at whether we are as clean and green as we think we are, and surveyed key export customers to gauge how much our environmental image influences their purchasing decisions (Ministry for the Environment (New Zealand), 2001, pg. 3).

The impacts of perceived environmental degradation are huge. In the dairying sector perceived annual losses range between \$241-\$569 million dollars, with consumers indicating they would purchase 54% less New Zealand produce. The impact on tourism is even larger. The report estimates that a direct loss of \$530 million would occur annually, with a further \$408 million in indirect losses (tax and income) annually, resulting from 50-90% shorter stays from inbound tourists (Ministry for the Environment (New Zealand), 2001, pg. 5). This constitutes a massive concern for New Zealand with regards to both the tourism and agricultural sectors. For these industries, the two largest earners and employers for New Zealand, future built growth and development must be carefully considered to limit and reverse the impacts of previous development to have a positive impact on the country's environment.

Figure 2, 3 : Two images presented in Ministry for the Environment's inbound tourist survey.

From: Ministry for the Environment (New Zealand). (2001). Valuing New Zealand's Clean Green Image. Wellington: Ministry for the Environment (New Zealand), pg. D1.3



## *Impacts on soil / land*

There are two main environmentally degrading activities that currently occur in New Zealand. The first - and easiest to remediate - of these is pollution through leaching and contamination of land previously used for industrial purposes. The second is through increased intensification of agriculture, in particular dairy farming and the impacts it has upon land, water and atmosphere. These two factors are discussed below.

### *Polluted sites*

Economic growth has already had a negative impact on the environment. Although a young country, New Zealand has had countless industrialised processes undertaken within its boundaries since colonisation in the 19<sup>th</sup> century. The impact that these industrial processes - including, among others, chemical and hazardous material production and storage, mining, landfill and waste facilities and petrochemical processes - is very hard to gauge until the original process has ceased on the site and further development is to be undertaken. This can be seen from a continually increasing number of polluted sites in New Zealand. *OECD Environmental Performance Reviews: New Zealand* (2007) notes that:

In the 1990s, it was estimated that there were 7 000 to 8 000 contaminated sites in New Zealand; about 1500 of them were deemed to pose high risks to human health or the environment... More recent studies by regional councils suggest that these estimates are quite conservative. Most contaminated sites were previously used for pesticide manufacture, coal gas production, waste disposal, timber treatment or sheep dipping (pg. 59).

The two most documented of these sites, the Fruitgrowers Chemical Company, in Tasman and the Tui Mine near Te Aroha have been earmarked for remediation; these are briefly highlighted below to give an example of the soil impacts associated with pollution from industrial activities. These two sites are widely accepted as the largest and most polluted sites in New Zealand.

### *Fruitgrowers Chemical Company (FCC)*

The former Fruitgrowers Chemical Company site, in Mapua, near Nelson, was widely considered the most contaminated site in New Zealand (Tasman District Council, 2010).

It is the site of a pesticide factory that operated from the 1930s to 1988. Due to spills and some waste being buried on site, persistent pesticides made at this factory [sic] have remained at high concentrations in parts of the site.



Figure 4: Fruitgrowers Chemical Company, Mapua. Pre-remediation works. From:

Ministry for the Environment (New Zealand). (2010). Clean-up of the Mapua contaminated site. Retrieved 09/12/2010, <http://www.mfe.govt.nz/issues/hazardous/contaminated/mapua/index.html>

The site is about 3.4 hectares and contained 20,000m<sup>3</sup> (or 1,700 truck and trailer loads) (Tasman District Council, 2010) of contaminated soil that exceeds permitted levels for residential and commercial use. Of this soil:

- Half [the] soil is about 10 times too contaminated when compared to risk-based levels, and the other half is up to 1,000 times too contaminated.
- There are also 800m<sup>3</sup> of marine sediments adjacent to the site which exceeds internationally accepted criteria for marine life by up to 50 times.
- The risk-based criteria for soil are 5 parts per million of DDT and 3 parts per million of dieldrin. The marine sediment criteria are about 500 times more sensitive (Tasman District Council, 2010).

The successful soil remediation of the FCC site was undertaken through an ex-situ baffled roller remediation process, which will be explored in Chapter Two of this thesis.

### *Tui Mine*

The Tui Mine, near Te Aroha, operated from 1967 until 1973. Metal ores, including copper, lead and zinc were extracted. The mine prospered and the company found several thousand ounces of gold and silver among the ore. Then unacceptable levels of mercury were found in the ore and the company buying it pulled out in 1973 (Ministry for the Environment (New Zealand), 2008). Two years later the mine owner, Norpac, went into liquidation and the Tui Mine was abandoned. Despite the short period of its existence, when Tui Mine was abandoned it left behind a large pile of ore and sand-sized crushed ore (tailings), dammed to prevent it slipping down the mountainside. Over the years, this tailings dam fell into disrepair and became unstable (Ministry for the Environ-



ment (New Zealand), 2008).

This has lead to water and soil contamination through leaching and, in the event of a moderate seismic or extreme weather event it is predicted the tailings dam will collapse (Department of Conservation, 2008). Such an event could result in over 90,000m<sup>3</sup> of mine waste liquefying and flowing down the Tui Stream past the edge of Te Aroha (Department of Conservation, 2008). To prevent disaster remediation work has been undertaken to cap and repair the tailings dam to stop leaching. Further to this, the old mine shafts will be flooded and sealed (Ministry for the Environment (New Zealand), 2008).

The sites described above highlight two types of industrial activity that has lead to environmental damage: storage and processing of dangerous and damaging chemicals and the by-products of industrial activity that leach and impact on the environment.

There are many other polluted industrial sites within New Zealand. To help standardise and improve the cleanup process, the Ministry for the Environment has published a set of guidelines for managing contaminated sites and a fund to help with cleanup. Of this fund over half was spent cleansing the FCC site in Mapua. This small amount of funding shows that clean-up of contaminated sites is still not a major priority for national government. Part of the reluctance in funding is the debate as to how much remediation must be undertaken, and whether it is the responsibility of the former inhabitant. This is largely due to the fact that clean-up of the sites is a slow, costly process where liability is a large legal issue.



Figure 5: Tui Mine tailings - industrial waste is still prominent on the site.

From: envirohistoryNZ. (2010). A tale of mining in New Zealand – and the tragic tailings of Tui Mine. Retrieved 08/12/2010, <http://envirohistorynz.wordpress.com/2010/05/02/a-tale-of-mining-in-new-zealand-and-the-tragic-tailings-of-tui-mine/>

## Agriculture

Industrial sites are of a nature where cleanup, although expensive and time-consuming, can be achieved. New Zealand's remaining environmental problems are largely due to the increase in, and predominance of agriculture which is harder to cleanup and control. The other problem with agriculture is that it is also the country's largest exporter and employer. For example the estimated spend of all inbound tourists for 2009 represented a mere 45% of Fonterra's revenue for that year (Fonterra, 2010) and when all agriculture industries are included they account for 64% of New Zealand's exports.



Figure 6: Mackenzie Country Dairy Farming.

From: Forest & Bird. (2010). Save our Mackenzie Country. Retrieved 09/12/2010, <http://www.forestandbird.org.nz/what-we-do/campaigns/save-the-mackenzie> - photographer Peter Scott.

In the past decade New Zealand's agricultural sector has undergone massive changes. With the high payouts from dairy farms and the increase in irrigation capabilities there has been a change from lower impact sheep and mixed sheep and beef, to purely dairy farms. One of the most marked changes has been in the MacKenzie Country, in the South Island. Here vast areas of previous tussock land and high country farms have been scarred with massive centre-pivot irrigators, extracting abundant water from nearby hydro-schemes.

The MacKenzie Country is the most obvious example of how dairying is changing the perception and physical nature of New Zealand's environments. Further development on surrounding land has lead Conservation Minister Nick Smith to compare 'the number of cows being proposed... is the equivalent of putting a city of 250,000 [people] in a pretty fragile environment' (Wilkinson-Baker, 2010). This intensive farming leads to the prospect of over 1.7million litres of effluent being produced in the area every day. Effluent, erosion, leaching and irrigation run-off are the largest impacts on the physical environment of New Zealand and the Ministry for the Environment notes that:

By far and away, the main source of pressure on water quality is pastoral agriculture. Agriculture is a contributing factor to the degradation of many surface waters and some groundwater. Pollutants include sediment, animal waste and nutrients. Pastoral agriculture also contributes to increased flooding and erosion in many areas by removing deep-rooted vegetation from hillsides and riverbanks (Ministry for the Environment (New Zealand), 2001, pg. 3).

Despite this, very few concrete measures exist for the protection of waterways and surrounding areas. The most prominent measure, the 2003 Clean Streams Accord was introduced to ensure that dairying limited or reduced pollution to 'have water that is suitable, where appropriate, for:

- Fish;
- Drinking by stock;
- Swimming (in areas defined by regional councils)(New Zealand Government, 2003, pg. 3)

However, since the introduction of this largely voluntary measure, the dairy sector failed to improve its impact on waterways and has, in fact made very little progress; particularly with regard to effluent consents, wetland protection and clean waterways. This is largely due to the fact that the accord was not "focused on measurable improvements in water quality" (Deans & Hackwell, 2008, pg. 4). These actions, or lack thereof, show the complacency New Zealand has with regards to its water sources and, unless serious changes are implemented these impacts will increase in severity.

## *Impacts on water*

New Zealand has two specific areas of concern with regards to its water supplies and sources. These are divided into two sections, Fresh Water and Salt Water; and the issues and impacts of each are explained below.

### *Fresh water*

The environmental damage from agriculture has had severe impact on New Zealand's lakes, streams, rivers and waterways. The Ministry for the Environment in the report *Valuing New Zealand's Clean Green Image* notes that "the more remote parts of New Zealand have some of the finest water quality in the world" (Ministry for the Environment (New Zealand), 2001, pg. 3.5) However, the report also alarmingly states that:

water quality declines measurably in lowland streams and rivers, particularly in pasture-dominated



Figure 7: Water pollution sources

From: Ministry for the Environment (New Zealand). (2007). *Environment New Zealand 2007*. Wellington: Ministry for the Environment (New Zealand), pg. 265.



catchments; some lowland rivers are unsuitable for swimming because of faecal contamination from farm animals, poor water clarity, and nuisance algae growths. Furthermore, the stream water in some intensive dairy farming areas is in such poor condition that it may be unsafe for livestock to drink. The lower reaches of some rivers are also polluted by discharges of industrial wastes, urban sewage and stormwater run-off.

In addition between 10% and 40% of New Zealand's 700 smaller shallow lakes are nutrient enriched (eutrophic). Most of these are located in the North Island and in pasture-dominated catchments. A number are subject to fish kills or are no longer capable of supporting fish life. (Ministry for the Environment (New Zealand), 2001, pg. 3.5).



Figure 8: Algal bloom in a low-land lake

From: Ministry for the Environment (New Zealand). (2007). *Environment New Zealand 2007*. Wellington: Ministry for the Environment (New Zealand), pg. 275.

This contamination, largely in pasture catchments, has led the Cawthorn Institute to note that some of our rivers are “very unhealthy,” (Cawthorn Institute, 2008, pg. 2) with unsafe levels of faecal content, nutrient concentration and poor water clarity. Five of the six most polluted rivers in New Zealand have catchments and outflows along the West Coast of the North Island of New Zealand. Some of these rivers provide drinking water to residents and animals alike. This has led to a number of sites to be considered unsafe. So much so that the aforementioned Ministry for the Environment report states that at least 18% of the population have an ‘unsatisfactorily high risk of contamination’ to their water supply.

### *Salt water*

Oceans, harbours and coastlines of New Zealand are also affected by pollution in a range of forms. In 1988 Fishing News International reported that there was now three times as much rubbish dumped into the world's oceans as the amount of fish removed (Department of Conservation, 1989). Originally most of this rubbish was thought to originate from “shipping, commercial fishing fleets, offshore energy explorations and recreational ‘boaties’,” (Island Care New Zealand Trust (ICNZT), 1996) however, over the past two decades research has shown that up to 80% of the pollution dumped into oceans is from land-based sources. The sources of this pollution are from oil and diesel spills, sediment and nutrient run-off from agriculture and from chemical leaching from industrial sites into the oceans. These pollutants can promote algal blooms, clog fish gills and cause diseases (Island Care New Zealand Trust (ICNZT), 1996, pg. 8). However, the largest land-based source is from rubbish caused by stormwater drain overflows.

In the 1990's, the Island Care New Zealand Trust (ICNZT) undertook a series of trapping studies for debris in the Auckland region. In two one-month long trapping periods on the Manukau Harbour over 90,000 waste items were collected from only 3 drains (Island Care New Zealand Trust (ICNZT), 1996). More recent findings from the Waitemata Harbour Clean-Up Trust estimates it has collected 1,806,614 litres of litter in its eight year history from 2002 (Auckland Council, 2010). From other research by the ICNZT, an estimate of 10 million items a year are washed out to sea from stormwater drains into the Waitemata harbour alone. Further to this:

Data from the stormwater report were compared to the information collected from island clean-ups to identify any possible correlation. The data reveals a striking similarity between the types of debris discharged from Auckland's stormwater system and that collected from the islands in our harbour (Island Care New Zealand Trust (ICNZT), 1994, pg. 15).

This provides a close correlation to the 2001 report *Valuing New Zealand's Clean Green Image* from the Ministry for the Environment. It states that:

The areas most under threat tend to be the harbours and estuaries close to major population centres. The State of New Zealand's Environment report notes the results of a qualitative survey carried out in the mid-70s in which the perceived quality of estuaries was assessed. Of the 162 estuaries for which responses were required, 38% were considered to be "clean", 41% rated as "slightly polluted", 16% "moderately polluted" and 4% "grossly polluted".

The problem estuaries included Waitemata Harbour, Manukau Harbour, Kaipara Harbour, Tauranga Harbour, Porirua Harbour, Wanganui River mouth, Ahuriri Estuary, Pauatahanui Inlet, Wellington Harbour, Waimea Inlet (Nelson), Brooklands Lagoon and the Waimakiriri River mouth, Avon-Heathcote estuary, Lyttelton Harbour and the New River Estuary (Invercargill) (pg. 3.7).

As well as the mounting problems of physical and chemical pollution from land, the world's oceans have the added impact of increased Carbon Dioxide (CO<sub>2</sub>) levels in the atmosphere. CO<sub>2</sub> is entering the oceans "at a rate of nearly 1 million tons (sic) per hour - 10 times the natural rate" (Gerdes, 2008, pg. 23). This increased level of CO<sub>2</sub> is making them more acidic. The increased acidity reduces the ability of coral to grow. This, in turn, reduces the environments and breeding grounds for other species and could lead to a collapse of the current forms of marine life (Gerdes, 2008, pg. 65).

Along with many other environments, New Zealand's coastal interaction between fresh water, coastline pollu-



Figure 9: Resultant of marine pollution and contamination. If clean-up crews don't get the rubbish it ends up here and is fatal.

From: Sustainable Coastlines (2010). Media. Retrieved 07/12/2010, [http://www.sustainablecoastlines.org/Kia\\_Ora/Sustainable\\_Coastlines\\_\\_\\_Media.html](http://www.sustainablecoastlines.org/Kia_Ora/Sustainable_Coastlines___Media.html)

tion and elemental leaching are all of serious concern to the nation's status as a 'Pure' tourist destination and a healthy living environment.

In the past the most important aspect in the capitalist system was wealth and economic gain, often at the expense of the environment. It is ironic that Adam Smith, the 'father of modern economics,' notes in his essay *An Inquiry into the Nature and Cause of the Wealth of Nations*:

The things which have the greatest value in use have frequently little or no value in exchange; and on the contrary, those which have the greatest value in exchange have frequently little or no value in use. Nothing is more useful than water, but it will purchase scarce anything; scarce anything can be exchanged for it. A diamond, on the contrary, has scarce any value in use, but a very great quantity of other goods may frequently be had in exchange for it (pg.13).

New Zealand on the whole, has been guilty of valuing the diamond instead of water. However, with the increasingly dire state of national waterways and harbours, coupled with increased global attention the attitude towards this vital resource is slowly beginning to change.

### *Impacts on air quality*



Figure 10: Christchurch air pollution

From: University of Otago. (2010). Dirty air - inside and out. Retrieved 09/12/2010, <http://www.otago.ac.nz/research/hekitenga2008/dirtyair.html>

Large tracts of New Zealand remain undeveloped. This is due to over 85% of the population residing in urban settlements (Ministry of Economic Development, 2010), mainly concentrated in six major cities: Auckland, Christchurch, Wellington, Hamilton, Tauranga and Dunedin. Of these six, Auckland and Christchurch suffer from poor air quality, caused largely from vehicular emissions and from domestic fires (Auckland Regional Council (ARC), 2006, pg. 2).

The most common air pollutants are carbon monoxide (CO), hydrocarbons (HC) and nitrogen dioxide (NO<sub>2</sub>), as well as a number of others. The majority of this pollution is caused by vehicles (83% of carbon monoxide and nitrogen dioxide emitted from vehicles). In Auckland the combined emissions from all polluters produces 35,000 tonnes of nitrogen dioxides, 64,000 tonnes of hydrocarbons and 171,000 tonnes of carbon monoxide annually

(Auckland Regional Council (ARC), 2006, pg. 2). These pollutants have significant health implications and are directly linked to the premature deaths of 400 Aucklanders every year from respiratory diseases and increase the severity of Asthma, which 1 in 6 New Zealanders suffer from.

To reduce emissions more efficient, cleaner cars are proposed as a solution. However, the largest change needs to be in the usage of vehicles. New Zealand has one of the highest rates of car ownership in the world and not only does this impact on air quality it has wider ranging social and environmental effects, including carbon dioxide emissions which lead to an increase in global temperatures.

## *New Zealand's consumption patterns*

As a developed, Westernised nation, New Zealand produces significant amounts of waste. The 2007 OECD Environmental Review of New Zealand notes that waste creation is increasing and continues to do so despite increases in recycling. This is directly linked with New Zealand's consumption and inhabitation patterns. Due to the low population and large land area New Zealand has been settled in an uncontrolled sprawl; high densities only occur in the central areas of cities.

A prime example of this is Auckland city. The Auckland region has a total area of 531km<sup>2</sup>, and a population density of 2200per km<sup>2</sup>. Of this population, only 1% lives in the central city. The rest live in surrounding suburbs and territorial areas, such as Manukau and the North Shore. However, a large number of these people commute daily into Auckland city, most often individually in private transport. This highlights one of New Zealand's negative consumption patterns. Due partly to the vastness and emptiness of the country, private car ownership is considered an essential tool and there are 481 cars per 100 people, the 8th highest rate in the world (United Nations (UN), 2010).

Car ownership is just a small facet of consumption patterns. New Zealanders have an unsustainable lifestyle, consuming more resources than are globally available. The *Living Planet Report 2008*, states that the ecological footprint, per New Zealander is well over 7 global hectares, the sixth highest rate of any country and almost three times the biocapacity of the earth (World Wide Fund For Nature (WWF), 2008, pg. 14).



Figure 11: The resultant of sprawl and lack of public transport - Auckland motorway.

From: Lee, M. (2010). *Sins of the Fathers: the fall and rise of rail transit in Auckland*. Auckland: Auckland Regional Council, pg. 4

It is clear that current consumption and lifestyle patterns cannot be sustainably maintained. As humanity's impact on the earth continues to increase through population growth - projected to reach almost 9 billion by 2050 - the footprint of individuals must reduce significantly.

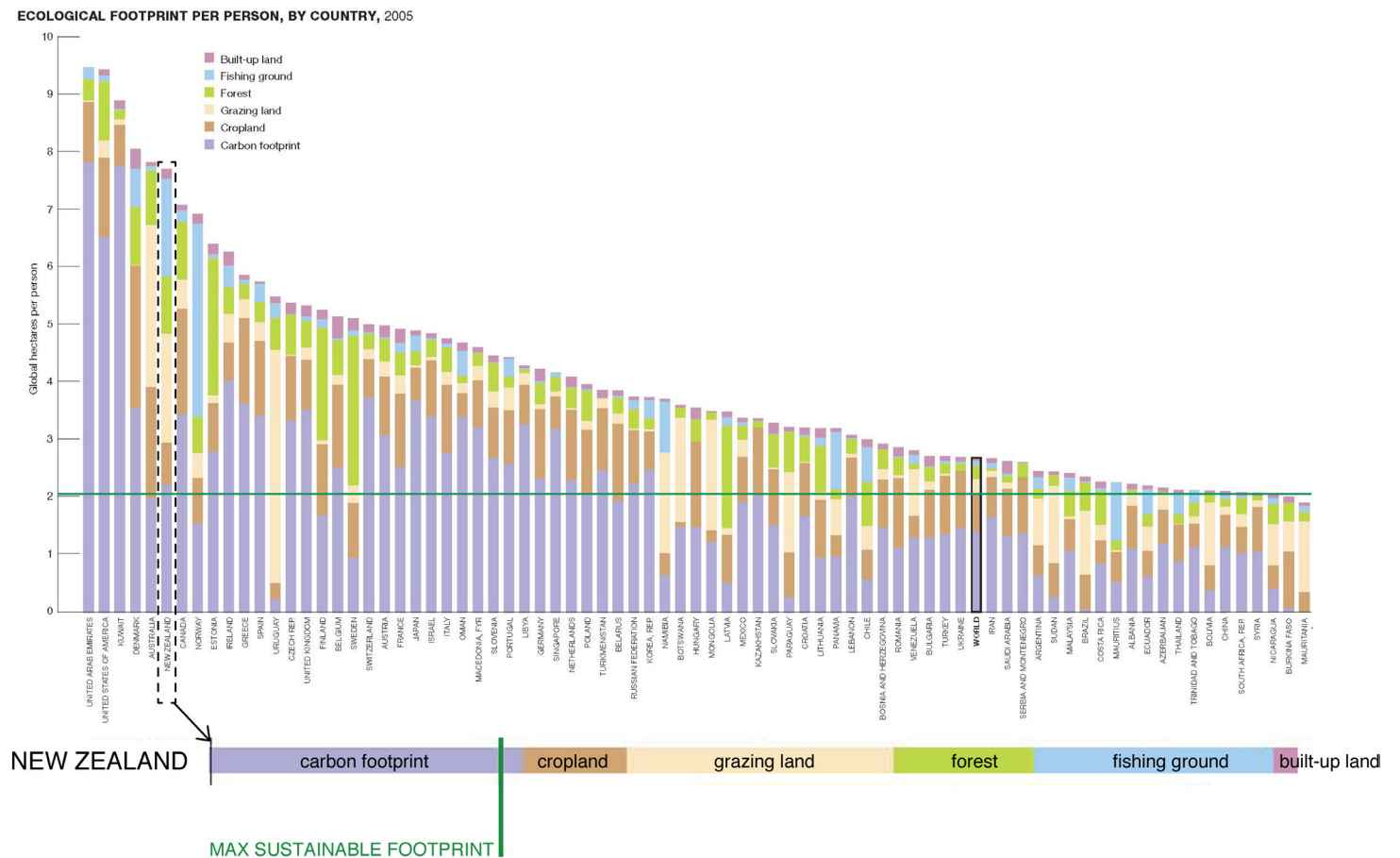


Figure 12: New Zealand has the sixth highest per-capita footprint in the world.

From: World Wide Fund For Nature (WWF). (2008). Living Planet Report. Gland, Switzerland, pg. 14-15.



## *Climate change*

Excluding small dissenting factions, it is almost universally recognised that the earth's climate is increasing in temperature. There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities (Intergovernmental Panel on Climate Change (IPCC), 2003). These activities tie into both industrial and agricultural attitudes, as well as consumption patterns and vehicular emissions mentioned previously that impact on individual aspects of the earth.

These actions have resulted in climatic changes which occur at global and local levels. The increased temperature of the earth results in:

Changes in sea level, snow cover, ice extent, and precipitation are consistent with a warming climate near the Earth's surface. Examples of these include a more active hydrological cycle with more heavy precipitation events and shifts in precipitation, widespread retreat of non-polar glaciers, increases in sea level and ocean-heat content, and decreases in snow cover and sea-ice extent and thickness (Intergovernmental Panel on Climate Change (IPCC), 2003).

In addition to these consequences an increase in both intensity and likelihood of drought in other regions places diminishes productive and inhabitable land capable of supporting the global human population, or that of other species. As a result there will be increased pressure on already endangered species, increases in catastrophic natural disasters and an increased requirement for availability of fertile land.

## *Discussion*

New Zealand's environmental integrity has been damaged. It is losing face internationally due to its failure to attend to its local environmental issues and the wider issue of climate change. The country is beginning to appear less attractive, both as a destination and as a place to live. Regarding soil, water and air quality there are issues of contamination due to industrial and agricultural activity. Contamination is wide spread and constantly increasing

in New Zealand. This has a direct impact upon the conditions of cities and rural areas.

In spite of this, there has been little intervention undertaken to reverse or negate these effects. These changes could occur at a policy level or in the form of exemplary action to influence behavioural change. There have been policy interventions but as can be seen from previous greenhouse gas targets, there has been little done to ensure their success.

The place for us to begin is to stop acting as if there exists a separation between the natural and the artificial, between use and nature. *We are* nature, and those who exploit or harm it exploit and harm all of us (Fisher, 2008, pg. 13).

To minimise climate change and prevent further damage to the country there needs to be a change. This change needs be undertaken on a large scale and at a rapid pace, with less focus on cost, profit and convenience as the major development initiatives and instead, greater focus on environmental impacts and the repercussions on flora, fauna. There needs to be a large shift in attitude, behaviour and the relationship between humanity and nature.

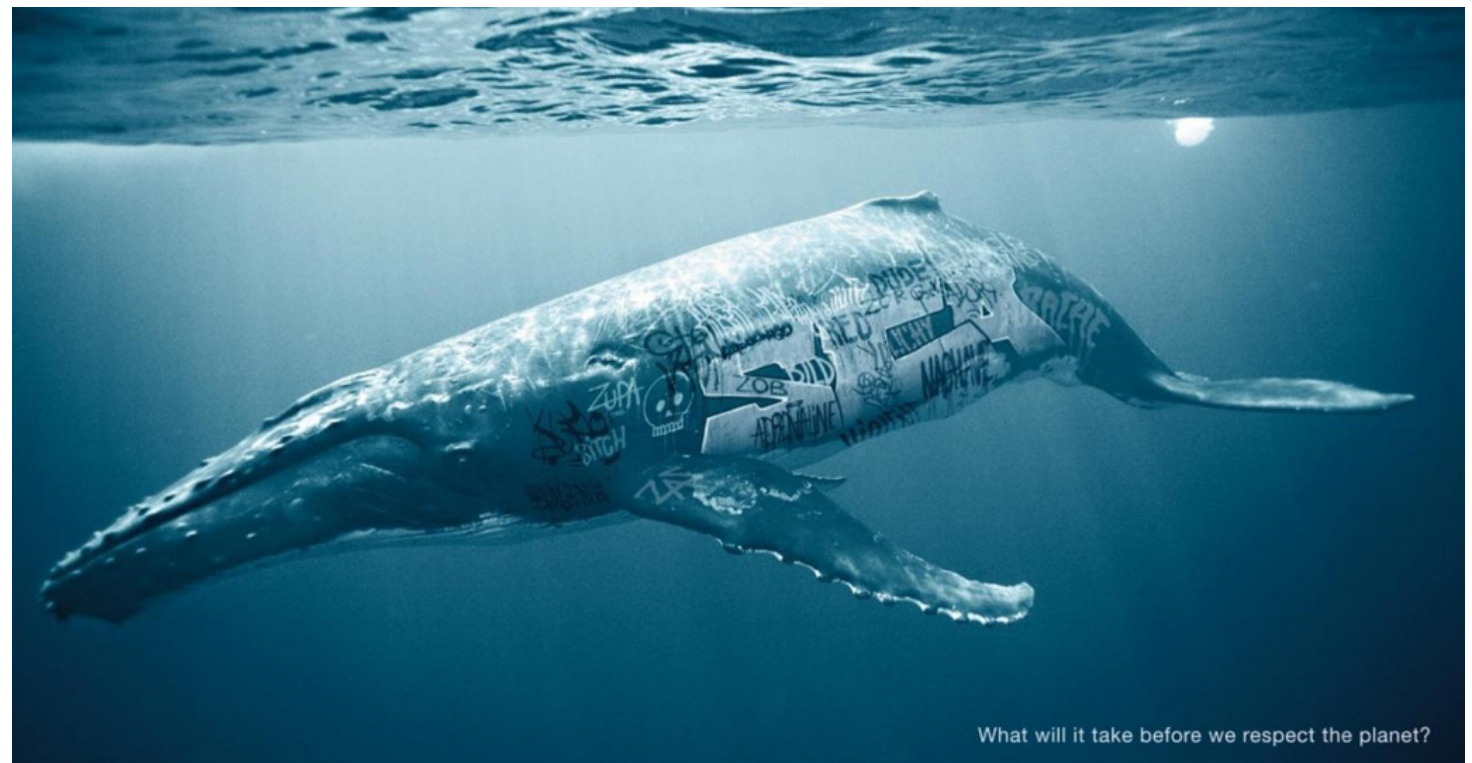


Figure 13: WWF's provocative advertising campaign highlighting the negative impact that mankind has on other species and ecosystems.

From: Ogilvy (2010). What will it take before we respect the planet? for World Wide Fund For Nature (WWF). Paris, France: World Wide Fund For Nature (WWF)





# Chapter Two – Architectural Implications

Whilst the architecture industry and architects themselves cannot solely be blamed for the state of environmental systems and global pollution, it is naive to believe that there is no link between the two. With increasing global populations comes an increase in building. This is a mixture of residential, commercial, industrial and infrastructural development to facilitate population growth. This construction of the built environment has a huge impact upon the planet. The energy used in the built environment accounts for 50% of the total energy used in the United States, (Buchanan, 2005, pg. 6) while, in terms of waste and by-products, it is estimated that waste from construction and demolition represents up to 50% of all waste deposited in landfills in New Zealand, equating to 1.7 million tonnes annually (Burns, 2008, pg. 107). Although architects do not have input into all of these buildings and sites, the impact that architecture and architects can have upon the attitude of the building environment is large. This can be seen through the development in recent years of the ideas and rhetoric associated with the terminology of 'sustainability,' 'green building' and 'regenerative' architecture.

Rather than investigating all of these aspects, this chapter first defines and then questions the idea of architectural sustainability and whether it is significant enough action considering the man-made impacts on the environment. It then presents the idea of regeneration, applied through architecture, landscape and urban design, to reduce and reverse human impact on the environment and climate that are described in the previous chapter.

Within the chapter, the idea of sustainability is compared to that of regenerative and positive actions. The relevant regenerative technology, methods and theories currently employed in the construction will be investigated and compared with the previously mentioned environmental impacts. Throughout the chapter these methods and

technologies will be discussed with regards to the architectural opportunities present.

## Sustainability

The term sustainable is defined by *Oxford English Dictionary* (2010) as being “able to be maintained at a certain rate or level” and “conserving an ecological balance by avoiding depletion of natural resources.”<sup>3</sup> The idea of sustainability or ‘green building’ has become an integral and very public part of architectural language. However, current architectural sustainability struggles to align with the base definition and has minimal positive environmental impact. Sustaining current lifestyles will not allow for the closed loop systems of the earth to survive.

Sustainable architecture is often presented as a solution to the impending climatic issues facing the earth. There has been a widespread ‘greening’ of the way we do things. The basic principles, such as limiting energy use, maximising natural light and ventilation and low energy materials are all positive steps towards lowering the impact upon the planet. However, the rise of sustainability as a concept has also led to criticisms of its effectiveness. Rosalie Geneviro, in *Ten Shades of Green* notes that:

American environmentalism in architecture, to date, has been largely focused on technical fixes, on figuring out how to build essentially the same buildings that have always been built, but to make them consume less energy... it has not taken on, nor has it asked its clients to take on, the bigger questions of what is to be built, and why (pg. 5).

Geneviro highlights the failure of sustainability to alter social patterns, instead taking the option of technological fixes. In a far more scathing commentary highlighting the flaw in how society functions, Dushko Bogunovich comments upon the existing systems of urban inhabitation, noting that there are two ways that current urban trends can be viewed. The first states that:

‘urban sustainability’ is an oxymoron. Cities cannot, and will never be sustainable: being nature-friendly was never their brief. On the contrary, a city’s purpose has always been to elevate humans ‘above nature’ and lighten the battle for biological survival (Bogunovich, 2008, pg. 20).

This is apparent through the continuing degradation of built environments as well as increased pollution. Despite this there are positive actions taken through the sustainability ideal. However, even though a significant number

3. Further, the *Our Common Future* report (1987) describes sustainable developments as:

...development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of ‘needs’, in particular the essential needs of the world’s poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future need. (pg. 65)

From: United Nations World Commission on Environment and Development (WCED). (1987). *Our Common Future*. Oxford.

Although perhaps a more focused definition, the thesis focuses on more than just development and therefore a broader definition is needed.



Figure 14: Greenway selfpark, HOK is a prominent example of “greenwashing,” integrating technologies that in reality have no positive impact.

From: Kamin, B. (2010, 21/11/2010). For parking garage, it's not easy being green. Chicago Tribune, accessed online 08/12/2010, photographer Antonio Perez

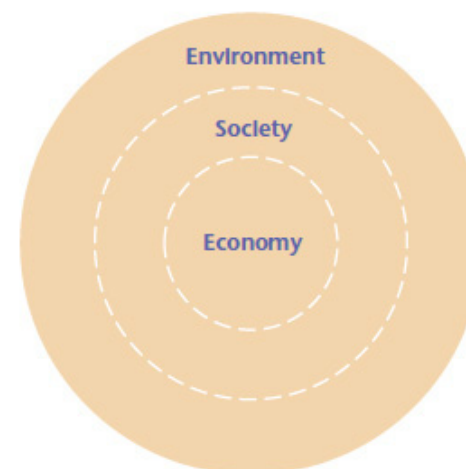
Figure 15: Sustainable model

From: Parliamentary Commissioner for the Environment. (2004). Growing for good: Intensive farming, sustainability and New Zealand's environment. Wellington: Parliamentary Commissioner for the Environment, pg. 7

of project have a (sometimes small) positive impact, as a concept with non-defined targets, sustainability allows itself to be abused and exploited by companies to help in selling a product which may have very little, or no positive environmental impact.

Often called “greenwashing”(The Economist, 2010) this practice is often associated with architecture in creating a marketing tool for a company or firm. There are numerous examples of this, such as the new Greenway Self-park in Chicago, Illinois, touted as “Chicago’s first earth friendly parking garage” (Greenway selfpark, 2010). Designed by HOK architects, the building - currently awaiting LEED certification - boasts wind turbines, naturally ventilated exterior walls, a cistern rain water collection system, a green roof, and electric car plug-in stations. However the irony is that the building leads to increased space for single person transport in the central city resulting in decreased motivation to use public transport, especially considering it is located very close to the public rail network of the city.

New Zealand is equally guilty of greenwashing. As a young country, it has not had a large population on much of the land. This, as well as the early establishment of many National Parks, has left large areas of land remaining as successful natural landscapes. The success of these landscapes can be - and has been - used an example of New Zealand’s ‘green’ image when they are in no way a product of New Zealand consumer ideals. This continues to be underlined by the 2002 *Creating our future* report, prepared by Parliamentary Commissioner for the Environment. The report presents the sustainable model, placing the environment as the most important element (pg. 7).



Further, the report notes:

New Zealand's urban areas, where the vast majority of New Zealanders live and where some of the major effects on other ecosystems are generated, have not received the attention they need to promote sustainable urban environments and infrastructures (pg. 8).

However, there has been little policy intervention, in terms of architecture, or development that has helped to fully highlight this issue. New Zealand has had small assertions of sustainability but lacks projects that have a larger societal impact.

The above criticisms of the idea of sustainability weigh heavily on societal patterns and action, particularly capitalist economic requirements. These patterns associate a sustainable future as one where humanity can continue thrive whilst keeping the planet at the current levels of emissions, pollution, depletion and population, creating a separation between mankind and natural systems, despite models that state otherwise. The model of sustainability does not go far enough to prevent the destruction that is occurring in ecosystems around the world. It aims to slightly alter the status quo, continuing the ideas of capitalism, which have resulted in consumer products with shortened life-spans.

To begin to alter the cultural view of sustainability a new terminology, employing a more radical outlook for development needs to be employed. In the reading of the urban environment Bogunovich describes the other way that cities can function:

The other view of the idea of urban sustainability could be described as optimistic. It accepts that current cities are indeed parasites, but then argues that they should still be viewed as an ecosystem. Once this view is adopted, the focus is on how they might be redesigned so that, like the natural ecosystems, they also perform in a bio-productive manner (Bogunovich, 2008, pg. 20).

This thesis argues that Bogunovich's alternate view is, in fact, not sustainability but is rather a call for a regenerative future.

## *Regenerative*

Regenerative architecture as a model has many similarities to sustainability. However the largest difference is that a regenerative model aims to leave a positive environmental impact on a site, instead of creating a project that has as little impact as possible, as sustainability does. It recognises the damage that is occurring at an environmental level and notes that to continue to prosper as a species, humanity need to stop treating the natural and built environments as separate entities and instead create a mutually beneficial relationship between the two where the built environment acts to improve the natural environment.

Architectural regeneration can be achieved through similar means to sustainability. The most effective ways to create regenerative architecture is to highlight the areas of current systems and building trends that have the most negative impact on the environment. Buildings currently have a detrimental effect on the natural environment, largely through energy use, air pollution, water and stormwater pollution and ground based pollution, particularly on industrial sites. The current patterns of building and living in New Zealand, with increasing residential home sizes and a continuing abundance of single, detached suburban dwellings furthers the impact of construction upon previous greenfields, as opposed to brownfield development where existing developed or contaminated land is cleansed and reused for a differing purpose. Further to this the shortening lifespan of buildings often means they are demolished well before their full lifespan (with regards to materials used) has been achieved.

In the following sections of the chapter, architectural regeneration will be investigated with regards to:

- Site regeneration - incorporating air, water and ground cleansing
- Urban regeneration; discussing settlement patterns, density, uses, lifespan and fit-for-purpose trends within developments.

Architectural opportunities will be compared against current sustainable ideas, as well as development in similar disciplines, such as landscape architecture processes; as well as historical and theoretical trends and propositions.

## *Site regeneration*

As previously stated, humanity's actions, particularly industrial developments have had significant detrimental impact on an ever-increasing number of sites worldwide and in New Zealand. These sites are often classed as brownfield sites - former industrial sites that have been abandoned by the previous tenants which "have tended to leave behind tracts of contamination, often arising from a mix of historic uses and resulting from decades, if not centuries, of mishandling and spillage of materials" (Urban Task Force, 1999, pg. 37)

In the past two decades there has been a marked increase in efforts to cleanse these contaminated sites to allow for re-use. These efforts focus typically on the two ground-borne elements of the site: soil and water degradation; however they sometimes encompass further concerns, such as air pollution. These three elements in particular will be discussed below.

### *Soil remediation*

Soil is often the largest concern with brownfield sites. For developments to proceed the soil that the building is cited upon must be safe to inhabit. There are two main ways of undertaking the cleansing process: passive solutions and energy intensive solutions. Both have positive and negative elements and are suitable for different types of sites. Dickinson (2000) briefly highlights the main remediation options in the table on the facing page. The relevant of these methods will be examined in more detail in the following sections.

Figure 16: Remediation techniques

From: Dickinson, N. M. (2000). Strategies for sustainable woodland on contaminated soils. Chemosphere, 41. pg. 260

| Method              | Comments   | Passive / Energy Intensive |
|---------------------|--|----------------------------|
| Removal             | Most common technique: excavate (average 1.5±2 m), cart and dump to landfill | Energy Intensive           |
| Encapsulation       | Containment of hot spots on site using barriers and capping                  | Energy Intensive           |
| Physical treatment  | Heat treatment, soil washing   | Energy Intensive + Passive |
| Chemical treatment  | Liming (to raise pH), soil additives (e.g. zeolites, phosphates)             | Passive                    |
| Natural attenuation | Dispersion, dilution, adsorption, volatilisation, biodegradation             | Passive                    |
| Bioremediation      | Biodegradation by microorganisms   | Passive                    |
| Phytoremediation    | Phytoextraction, phytostabilisation  | Passive                    |

### *Energy intensive remediation*

Energy intensive remediation processes are the most frequently used remediation techniques. As Dickinson states, the most common process is removal of the toxic material to landfill. This process is most common because it is quick and easy. The draw-backs to this method are that the soil is not cleansed; rather it is moved to landfill where it adds to the contaminated soil there. This is currently common practice in New Zealand due to the low cost of landfill dumping of the soil.<sup>4</sup> Encapsulation does just as its name states, sealing the contaminated soil on site to be dealt with at a later date and considerable expense. Energy use is also high, from excavation and concrete pours.

The remaining treatment is Physical treatment. Although it is also energy intensive, either for washing the soil, heat treatments or baffled roller systems (as undertaken at the FCC in Mapua) the benefit of physical treatment is that the contaminants are removed from the soil. All three methods require significant energy to undertake and require a long time frame and microbes and chemicals are used to speed up the process. Baffled roller systems have been proven to be highly effective in decontamination (Tasman District Council, 2010), however, the long process and the refinement of soil create air pollution and soil losses.

4. This was also the case in Australia until the government implemented environmental tariffs. These increased the cost from around \$60 per tonne (similar to current New Zealand prices) to around \$400 per tonne. This has resulted in less removal of contaminated soil to landfill and more on-site remediation.







ronment in which the organisms must carry out the detoxification reactions (Water Science and Technology Board, et al., 1993, pg. 2).

In-situ decontamination is of significant benefit to decontamination of groundwater and will be further elaborated upon in that section. With regards to soil decontamination, Water Science and Technology Board et al. (1993), note that “the most elemental criterion for success of an in-situ bioremediation effort is that the microorganisms are mainly responsible for the cleanup” (pg.3). However, these processes are much harder to trace and control in-situ.

Ex-situ actions require significantly more energy use, as the contaminated soil must be removed from its original location. An ex-situ bioremediation process then occurs in a secondary location, such as soil columns. Soil columns are a pressurised column in which the contaminated soil is placed to undergo the cleansing process. The following excerpt from Liu et al. describes the make-up of a soil column:

The column provided an inlet and outlet for the nutrient solution, which was aerated and sterilized before entering the column. Four sampling pores were set vertically for the purpose of taking samples. The four columns were kept upright to allow vertical flow of the influent nutrient solutions in a bottom-top direction (Liu, et al., 2008).

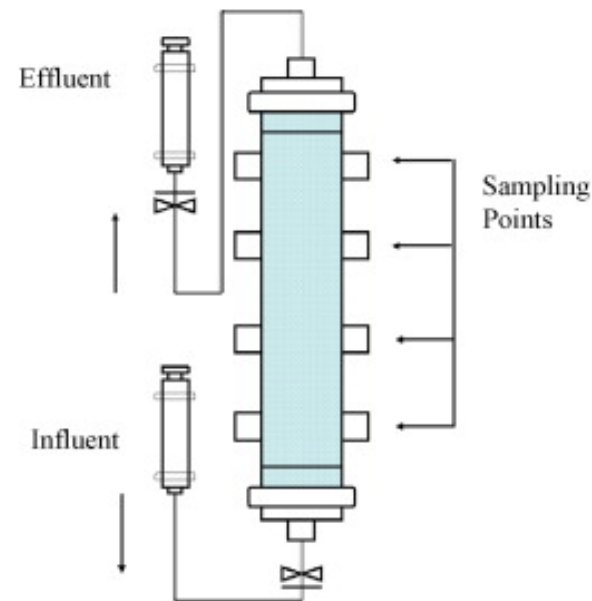


Figure 18: Soil column schematic.

From: Liu, G., et al. (2008). Biodegradation of diesel-contaminated soil: A soil column study. Tainan, Taiwan: National Cheng Kung University, pg. 3

Previous investigative articles have provided proof that soil columns offer effective decontamination but, as a passive process take significant time to undertake the process (Baker & Herson, 1994 ; Banat, 1995).

This offers a sizeable architectural opportunity. As a long-term decontamination strategy there is potential to incorporate soil columns into architecture. The structures used to house the soil could be incorporated into the built form either as reinforced columns to support the building itself or as structural or non-structural walls. Soil acts as a very successful thermal insulator and dependant on the exterior of the column, can be a very visually engaging aspect of a building or structure.

Re-using existing structures or buildings is also an architectural possibility. As many contaminated sites are former industrial locations, existing facilities often includes bulk storage. Examples of this include former gas works, liquid and petroleum storage tanks and concrete production plants all offer existing structures that have both the volume and engineered strength required for soil decontamination to occur with very minimal alterations to the existing structures. This offers a short-medium term alternative to demolition or relocation of these structures further reducing the required energy to regenerate the site and keeping a visual history of previous uses.

The final process, phytoremediation, is very similar to in-situ bioremediation. It focuses on green plants - both small and large - to assist in attracting and absorbing contaminants present in the soil. There are a number of different focuses of phytoremediation, including phytoextraction, phytovolatilization, phytodegradation - which occur in the leaves and stem structure - and rhizodegradation, rhizofiltration and phytostabilization, which occur in the root structure of the plants (Van Epps, 2006, pg. 2). There are a number of different studies which highlight the success of these methods; however, the success of phytoremediation at a given site cannot always be attributed to just one of these mechanisms because a combination of mechanisms may be at work. The process of phytoremediation is successful for site rehabilitation; however, the benefits are most easily achieved through landscape architecture.



Figure 19: Gas Works Park, Seattle, Wa. An example of phytoremediation on a former industrial site.

From: Mabel, J. (2006). Gas Works Park, Seattle. Retrieved 14/11/2010, from <http://www.flickr.com/photos/paulmagnus/167328804>, photographer Joe Mabel

Therefore appropriate planting in any architectural development is highly important to aid in regeneration of soil. This is of particular importance in schemes where an urban framework is to be considered, balancing the need for areas of phytoremediation with usable public open and green space. Phytoremediation also serves a purpose as a demonstrational tool in landscape architecture, yet, with regards to constructed interventions, the phytoremediation process offers limited opportunity. To achieve soil remediation and incorporate the process within architecture, the remediation process with the most promise is that of bioremediation, achieved through ex-situ action.

### *Water remediation*

There are two aspects to contamination of water on sites. Both are caused largely by leaching, either due to contaminated soils, or from industrial processes wherein water is used to clean sites. These two aspects lead to contamination of water in groundwater and stormwater, both of which have a significant environmental impact. Processes to remediate both aspects will be described in this section, as well as methods of utilising them within architectural, landscape and urban development.

#### *Groundwater*

There are a number of ways of treating contaminated groundwater. Most of the techniques are similar to those to treat soil, as leaching from the soil into the water-table of the site naturally occurs. For example, bioremediation and phytoremediation can also be highly beneficial processes for cleansing contaminated groundwater, although phytoremediation is limited by the depth of the plants roots in its ability to affect groundwater, which is normally less than one metre in the productive life of suitable trees, such as willows. Depth, however, is not an issue for the bioremediation process:

In-situ groundwater bioremediation is a technology that encourages growth and reproduction of indigenous microorganisms to enhance biodegradation of organic constituents in the saturated zone. In-situ groundwater bioremediation can effectively degrade organic constituents which are dissolved in groundwater and adsorbed onto the aquifer matrix (Adventus Americas, 2010).

Within the process of bioremediation, there are a number of factors that need to be considered. An electron acceptor (oxygen, nitrate); nutrients (nitrogen, phosphorus); and an energy source (carbon) all need to be present. If

bioremediation of the soil is also being undertaken then groundwater will eventually be cleansed as a by-product. As most biological groundwater cleansing processes occur in-situ there are very limited architectural opportunities associated with it.

### *Stormwater*

Stormwater, on the other hand, is a much more visual process, one which is often explored through landscape architecture, as well as in architecture itself. Excluding large water treatment plants there are many smaller scale methods of dealing with site stormwater and run-off. In recent times the impact that hard paving surfaces have on increasing the flow of stormwater has been realised and other solutions have begun to be implemented.

The most common treatment procedure undertaken in landscape architecture involves treatment through on site filtering processes. Martin Bryant (2010) is quick to point out that these processes are hardly new, and have in fact been employed by a variety of cultures, particularly in Asia and India, for thousands of years. These days systems employed by landscape architects are made up of three phases.

The first, swales, filter the initial stormwater surge through plant-life, such as grasses and allow water to begin to seep into the soil. They are ephemeral in nature and can replace kerbs and gutters. These begin to purify and filter the water. The second phase is wetland areas. These are shallow bodies of water with reeds. These allow for the treatment of larger volumes of water and begin to purify and filter the water through reeds:

Particulate Pollutants are removed from the water as it passes through the densely planted native sedges and reeds. Concurrently, water permeates into the gravelly subgrade where bio-organisms remove suspended pollutants. Plants help maintain the porosity of the filtering medium (Wraight and Associates Ltd., 2008, pg. 4).

The final phase involves larger, deeper storage ponds. These ponds may also incorporate planting to attract pollutants; however, the stiller water of ponds allows remaining sediment in the water to settle to the base of the pond where it collects. It then accumulates and can be removed through mechanical means.

The use of filtering processes creates significant points of interest and breaks up the landscaped elements of a development. The final benefit that on-site stormwater treatment is that it offers benefits with regards to irrigation for green areas within a landscape or urban development. One of the best examples of this is Waitangi Park, Wellington, developed by Wraight Associates and Athfield Architects. The park integrates wetlands and a pond

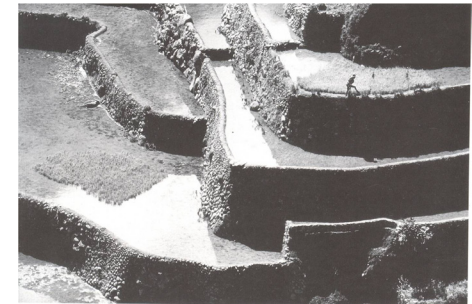


Figure 20: Rice paddies are an ancient form of water purification across a site.

From: Bryant, M. (2010). Infrastructure - Utility services, Water sensitive urban design, Wellington, pg. 7



system into a waterfront park and creates a successful, highly usable space that also functions as a stormwater cleanser. Although highly successful as a single intervention, the main criticism that exists of the scheme at Waitangi Park is that it is not more comprehensively integrated into the fabric of the city to minimise stormwater run-off and pollution, which would result in a shift in social perceptions of waste water, but also significant cost.

Figure 21, 22, 23 (L-R): Three phases of water treatment: swales - CentrePoint, Wellington, Waitangi Park wetland section - Wellington, storage pond - unknown location

From (L-R): Bryant, M. (2010). Infrastructure - Utility services, Water sensitive urban design, Wellington, pg. 36

Ibid, pg. 44

Computation Hydraulics International (CHI). (2010). Detention pond design. Retrieved 10/12/2010, <http://www.chiwater.com/Solutions/Software/DetentionPond-Design.asp>

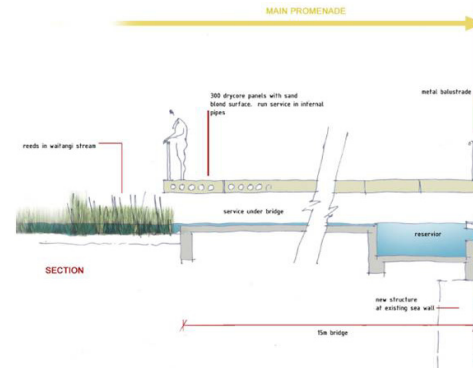
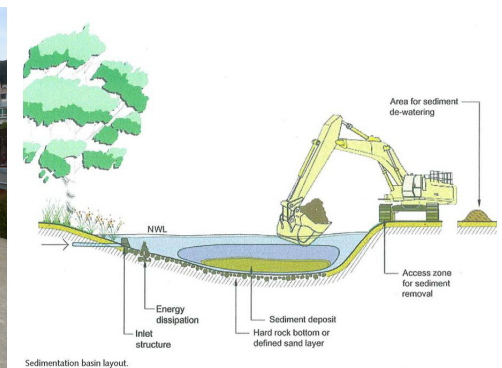


Figure 24, 25, 26 (L-R): Three phases of water treatment: swales - Victoria Park, Sydney, Waitangi Park wetlands - Wellington, storage pond - schematic

From (L-R): Bryant, M. (2010). Infrastructure - Utility services, Water sensitive urban design, Wellington, pg. 25

Author's own image

Bryant, M. (2010). Infrastructure - Utility services, Water sensitive urban design, Wellington, pg. 20



These landscape processes can also be undertaken in a vertical sense through “hanging swamps,” as illustrated by the collaborative project undertaken by Innovarchi and LEUD, Government Architects Office NSW, *bilpin visitor centre*. Filtration of rain and greywater occurs through swamps that act as facade and roof systems for the building. The horizontal and then vertical procession of the water leaves pollutants in the planting, leaving the water safe for re-use.

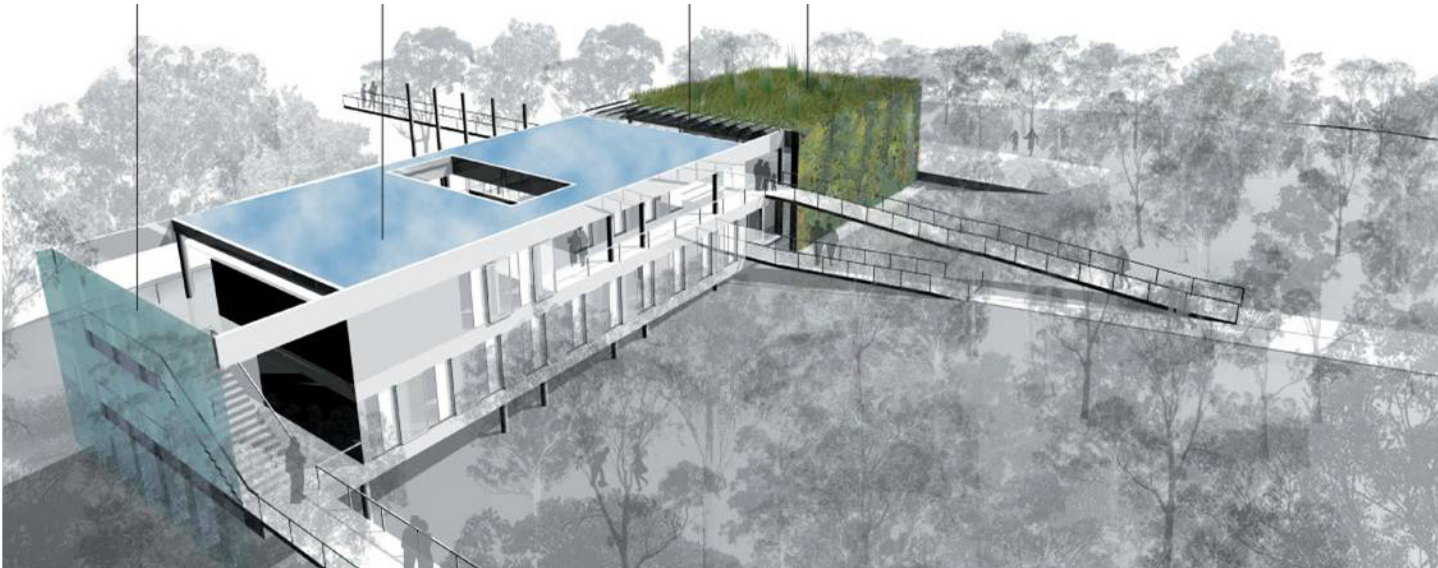


Figure 27: Water cleansing swamp in a vertical facade system - visitor centre, Bilpin NSW - Innovarchi and LEUD

From: Innovarchi. (2010). Bilpin visitor centre. Retrieved 25/11/2010, <http://www.innovarchi.com.au/innovarchi.html>

Also translating cleansing processes into an architectural system is *Aqua Alta 2.0* by the firm R&Sie(n). Their unbuilt proposition for a water-bar on the canals of Venice integrates a cleansing process through an unspecified system. R&Sie note:

The lagoon stinks. It stinks of shit and humanity, of algae and hydrocarbons, between the salty sweat of summer fragrances and spongy lichens lodged in the smallest interstices of oozing bricks... Instead of a global vision, the macropolitics of International Architecture... seeking to wipe the whole planet squeaky clean, we need to infiltrate ourselves into the innermost folds of a situation, to let ourselves be dominated by the physical and *chemical* nature of a context (Ruby & Durandin, 2004, pg. 118).

This infiltration occurs through the work, albeit in an unspecified manor but provides discourse to an earlier project *Aqua Alta 1.0*, which aimed not to cleanse the water, but purely to create a spectacle of the filthy existing site





Figure 28: Aqua Alta 1.0, R&Sie(n), Venice

From: R&Sie(n). (2010a). *Aspiration*. Retrieved 08/09/2010, <http://www.new-territories.com/apiration.htm>

condition through expression as a facade. Although this does not create a cleansing process through architecture and, in fact, suggests the antithesis of such an idea, the visual impact and resultant discussion created questions why architecture cannot act in the opposite to this.

### *Air remediation*

Air pollution is a growing concern in most major cities worldwide. A striking example of this was during the 2008 Summer Olympics in Beijing, China, a city that suffers from serious air pollution. To reduce the impact on athletes authorities in the city shut down factories around the city and removed around half of the estimated 3.3 million vehicles on the cities roads (Daily Mail, 2008). These two elements are the leading causes of air pollution that is dangerous for humans. Cities in New Zealand are not immune either, with Auckland and Christchurch suffering from bad air caused by automobiles and fires. There are two ways of reducing air pollutants; social and policy-based fixes, and technological fixes. Both of these will be described below.

The first option, as highlighted by the Beijing is to reduce emissions. The steps taken to reduce pollution in Beijing were extreme, but can be undertaken in a New Zealand through social and policy actions. Recently New Zealand has brought in more stringent air emissions levels for motor vehicles and local body actions in areas such as Christchurch has seen a banning on open and old-style wood-burning fires.

There is significant architectural opportunity associated with social action, particularly in an urban sense. As previously stated New Zealand is a country with very high private transport ownership and very low public transport use. New urban schemes and development need to consider the impact of transportation. A continuation of suburbia demands private car ownership. To combat this, urban development needs to focus on in-fill and increased density of existing areas. New Zealand needs to shift its focus from the idea of the “quarter acre dream” (Heyworth, 2008, pg. 36).

To create successful new urban developments that reduce air pollution public transport needs to be an integral part. Douglas Farr describes in *Sustainable urbanism: urban design with nature* (2008) the idea of sustainable urbanism as effectively integrating walkable space with high-performance building and effective public transport within high quality green space (pg.42). To achieve this, significant density needs to be achieved to ensure a

transport system is utilised. As Farr notes “increasing neighbourhood population also supports improved public transit service.” This, combined with walkable paths significantly reduces the requirements for private car transport, thus reducing air pollution.

The other point mentioned by Farr is that of high-performance building. By reducing the need for energy in a building for heating, cooling and lighting, emissions from these systems, as well as electricity production is minimised. To achieve this passive heating, cooling and ventilation are key issues. This is achieved through material selection, natural lighting and insulation. It is also achieved by smaller, more efficient spaces. As Robert and Brenda Vale remark in *Time to Eat the Dog* (2009):

The bigger the house, the more energy it uses, even if it is a low-energy house. This suggests that, rather than undertaking extensive research into making embodied energy figures more and more accurate, we should concentrate on showing how small houses can be beautiful and wonderful spaces for families to live in (pg. 138).

These issues are all social and cannot be changed by architecture. But, architecture and urban planning can have significant effect in reducing air pollution through well thought out design.

The other way that architecture and construction can have a positive influence on air quality is through technological development. Pollution removing technologies are beginning to appear to reduce air pollution whilst being practical and interesting elements of architecture. Two examples, Prosolve 370e and the work of architects R&Sie(n) will be elaborated on to discuss technological fixes.

#### *Prosolve 370e*

Prosolve 370e is a facade panel developed by the company Elegant Embellishments. The seemingly randomly generated patterns created are made from a combination of just two modules creating a maximised facade area to reduce air pollution:

Employing a unique configuration of this technology, the tiles neutralize air pollutants when sited near traffic or densely polluted conditions.

The tiles are coated with a superfine titanium dioxide (TiO<sub>2</sub>), a pollution-fighting technology that is activated by ambient daylight. This is the nanophotocatalytic version of conventional TiO<sub>2</sub> commonly used as pigment and already known for its self-cleaning and germicidal qualities. It requires only small amounts of



naturally occurring UV light and humidity to effectively reduce air pollutants into harmless amounts of carbon dioxide and water (Elegant Embellishments Ltd., 2010).

Prosolve 370e effectively neutralizes nitrous oxides (NOx), a harmful by-product of combustion engines in vehicles. As a facade material it offers an interesting and changeable option for construction that allows for a positive environmental impact. Further to this, the tiles themselves are made from plastics sourced from recycling car bumpers (Elegant Embellishments Ltd., 2010). The product offers significant architectural opportunity in designing and redeveloping spaces.

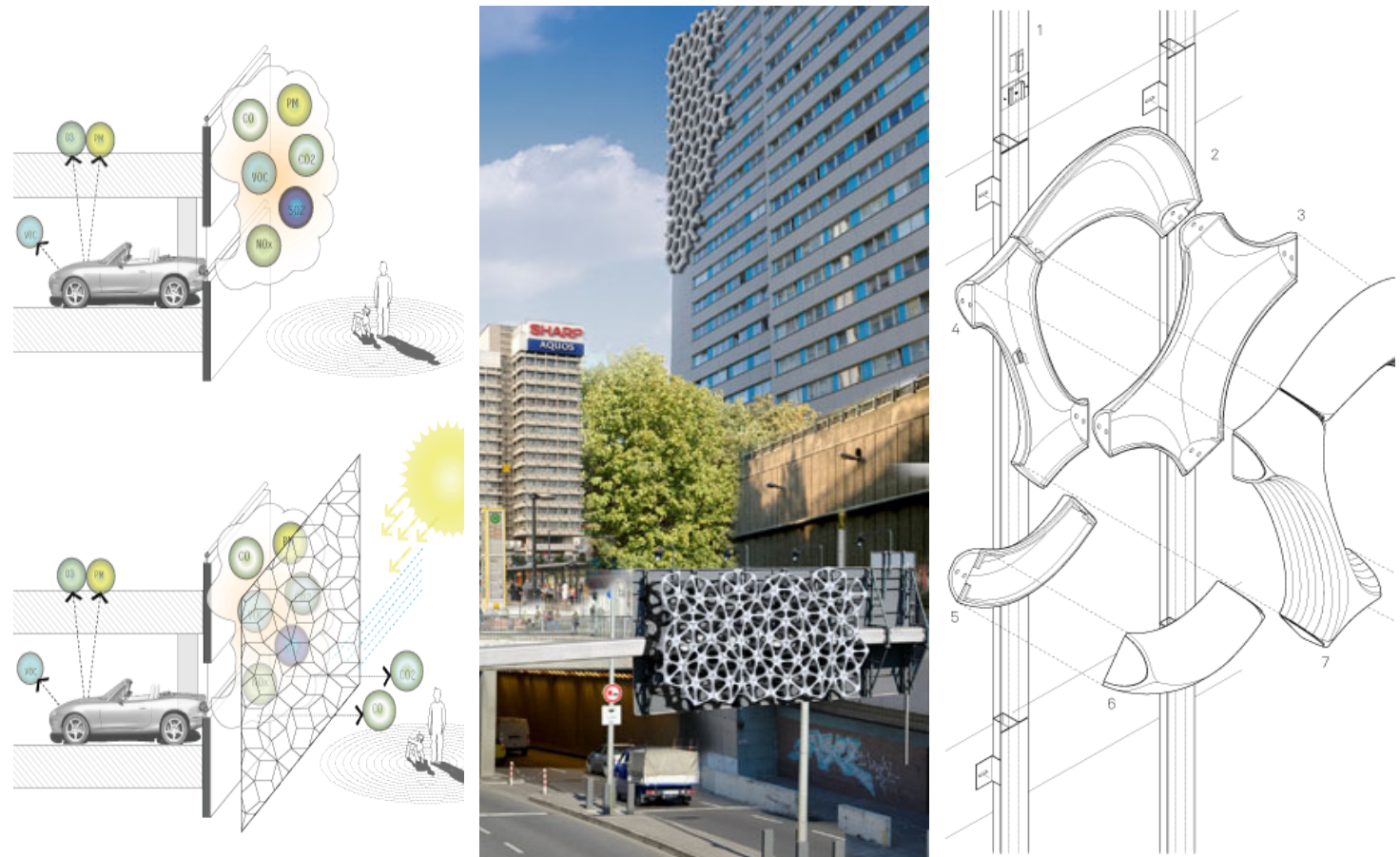


Figure 29, 30, 31: Prosolve 370e, technologies involved and physical applications of the two panel system. The plastic coating absorbs NOx and with the aid of sunlight breaks it into CO<sub>2</sub> and CO

From: Elegant Embellishments Ltd. (2010). prosolve 370e. Retrieved 08/08/10, <http://prosolve.elegantembellishments.net/home.htm>

In contrast to the previously mentioned technological fix, the work of French firm R&Sie(n) presents environmental solutions that are fully integrated into the structure and function of buildings, as mentioned in the water remediation section of this research. The work of this firm is largely unbuilt but offers a different attitude towards environment than normally seen in architecture where, when built offers a:

bucolic disinhibition [that] is the radical antithesis of Paris' manicured urban condition, but architects R&Sie(n) (punningly pronounced 'heresy') actively relish all manner of tensions, whether between nature and architecture, purity and corruption, attraction and repulsion (Slessor, 2009, pg. 70)

For R&Sie(n) the external and built environments are not separate entities and this becomes apparent through their design solutions. The project *Dusty Relief / B-mu* is sited in Bangkok, a city with considerable air pollution issues. *Dusty Relief / B-mu* proposes a facade system that collects the dust particles "on the surface of aluminium latticework using an electrostatic system" (Ruby & Durandin, 2004, pg. 137) . The project, incorporating a functional museum that "feeds off of the climatic opposition between the urban environment's protuberant energy and the interior subdued and subject to the museum's conditioning procedure" (Ruby & Durandin, 2004, pg. 138). This presents an incorporated way of dealing with environmental issues while addressing the fundamental issue of creating a better environment.

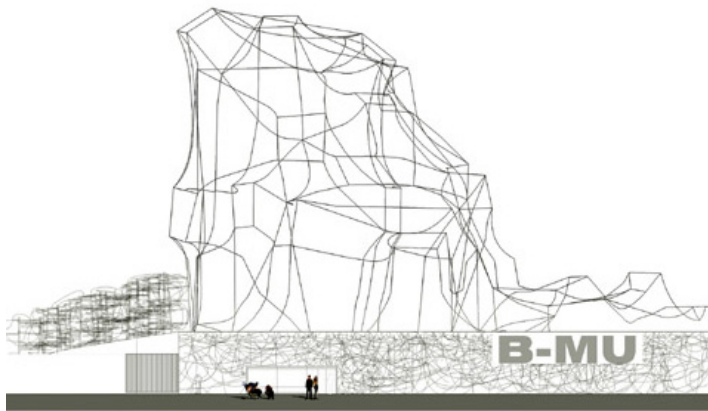
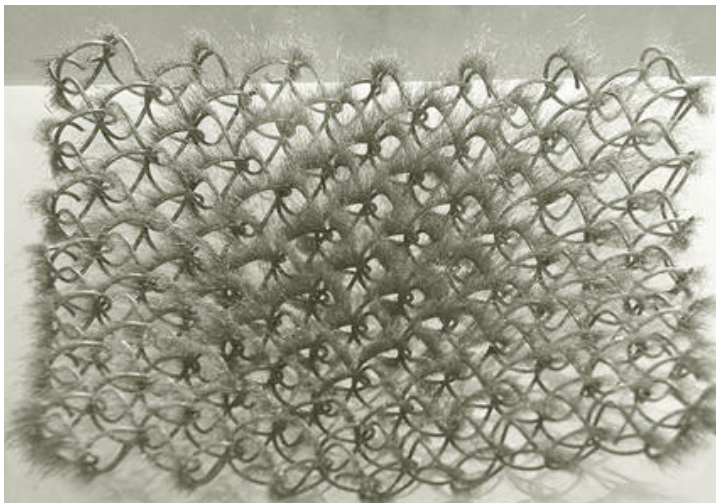


Figure 32: R&Sie(n) address on-site electricity generation in un-plug, Paris

From: Ruby, A., & Durandin, B. (2004). *Spoiled climate* :R&Sie, architects. Boston, Mass.: Birkhauser-Publishers for Architecture, pg. 139

Figure 33, 34: Using static electricity, R&Sie(n) attract pollutants to the buildings facade system - Bangkok.

From: R&Sie(n). (2010b). *Dusty Relief*. Retrieved 08/09/2010, <http://www.new-territories.com/roche2002bis.htm9>





Figure 35, 36, 37 (T-B): Three stages in the history of Melbourne Docklands: past, present, future. Docklands is a former industrial site that has been redeveloped.

From: Lovell, P. (2009). Melbourne Docklands: workaday yet relentlessly romantic. *Historic Environment*, 22(2), pg. 34.

Sauer-Thompson, G. (2009). Public Opinion. Retrieved 07/12/2010, <http://www.sauer-thompson.com/archives/opinion/2009/09/melbournes-dock.php>

Docklands Sailing School. (2005). The Melbourne Docklands. Retrieved 09/12/2010, [http://www.docklandsailingschool.com.au/the\\_docklands.html](http://www.docklandsailingschool.com.au/the_docklands.html)

From research, it can be seen that there are a number of solutions to the issue of air pollution that can be addressed architecturally. Although there are two streams of thought, it is in the area that they overlap, combining social patterns of change and new technology to allow for this change that appears to be the most successful way to integrate air cleansing procedures into architectural and urban design.

### *Urban regeneration*

New urban development can be strongly linked to the regeneration of previously contaminated sites. The reuse of brownfield sites significantly reduces the strain on productive, greenfield sites, which helps offset the up-front costs of remediation. Additionally, if these sites are urban or near-urban sites they can aid in changing patterns of inhabitation and consumption if the facilities and programmes of the development are well considered. As Douglas Farr succinctly proposes:

Reduced to its most basic tenets, sustainable urbanism is *walkable and transit-served urbanism integrated with high-performance buildings and high-performance infrastructure*. Compactness (density) and biophilia (human access to nature) are core values of sustainable urbanism (pg. 42).

Using sustainable urbanism as a platform to go beyond, these aspects, coupled with careful consideration of lifespan of building and development can lead to new urban development having an extremely positive impact with regards to regeneration of neighbourhoods and community, as well as reducing the impact on greenfield sites and the environment as a whole. These elements will be further outlined below taking into account current theory, as well as examining historical precedents, such as Constant's New Babylon, Superstudio and the Japanese Metabolist movement.

### *Urban infill*

It is only in the last century that there have been significant changes in how humanity inhabited the land. Until then, populations existed largely in smaller, localised groupings. As Fischer notes in *Architectural Design and Ethics*, it was only "after the [second world] war, many people began to move into mostly suburban developments characterised by nearly identical houses and nearly identical neighbours, ghettoizing themselves." Suburban development lead to massive increases in private automobile transport and created settlement patterns that have continued to strongly privilege this form of transport to the point where "we spend more time travelling, typically by car, to the next building than we do enjoying outdoor spaces between them."

In recent decades the movement of populations away from rural to metropolitan areas has created massive and continually increasing sprawl and lead to a reduction in productive land.<sup>5</sup> In association with constantly increasing populations due to growth the result is that:

Even with the shrinkage in our environmental footprint as a species, the exponential growth in our numbers means that we will continue to tax the resources of the earth in ways that affect every other species and every corner of the world (Fisher, 2008, pg. 12).

New Zealand is in the fortunate position that it has plentiful land resources and a small population. Unfortunately this has lead to suburban sprawl. In contrast to this, in Japan, the urban metropolis had already run out of in-fillable space by middle of last century. This need for further land in part gave birth to the Metabolist movement, envisioning “sea and sky as future sites for human habitats, and they suggested the city would grow and transform in a manner like the evolution and metamorphosis of an organism” (Lin, 2010, pg. 1).

Therefore a shift to urban infill, increasing density and rezoning former industrial and commercial sites where the tenants have moved to more appropriate areas provides an opportunity to reduce environmental impact. This densification and infill has numerous benefits. Increasing neighbourhood population supports improved public transit service (Farr, 2008, pg. 44) and the relative centrality of infill development further diminishes the use of private transport. This is a key element to reduction in environmental impact, as 40% of New Zealand’s energy-related greenhouse gas emissions are from motorised transport (Lietz, 2008, pg. 29). Densification also results in smaller plot sizes and therefore significantly smaller dwellings than in suburban areas. This, in turn results in a decrease in resources consumed bringing about changes in behaviour. As Robert and Brenda Vale (2009) note to reduce environmental impact and footprint size “we need to have less, which means living in and using smaller buildings” (pg. 189).

The Vales also comment “that behaviour change, rather than a change in technology, can make a significant difference - and incidentally costs nothing” (pg. 154). Therefore combining the idea of more compact housing into more dense settlements has a substantial impact on reducing resource consumption, as well as allowing for the physical regeneration of site and neighbourhood due to the developments. In this way the “availability of contaminated or ex-contaminated sites is a development opportunity which can help stitch back together the urban fabric and create value” (Urban Task Force, 1999, pg. 244).

*Mixed use development / Relationship between built and open space- Landscape urbanism*

5. Despite its small population, New Zealand’s cities, particularly Auckland and Christchurch have a very large built area and a low population density.

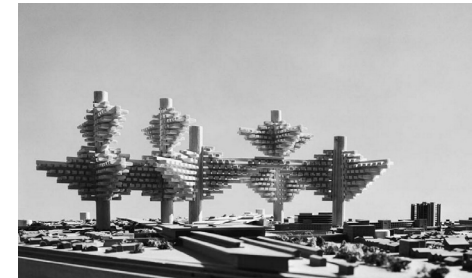


Figure 38: City in the Sky, Arata Isozaki, integrating many of the Metabolist principles expanding into the sky

From: Lin, Z. (2010). Kenzo Tange and the Metabolist movement :urban utopias of modern Japan. New York: Routledge, pg. 70

If the clean-up and infill development of a contaminated is to occur it is vitally important to consider the inherent functions, programs and uses that will take place within it. Megan Howell notes in *A Deeper Shade of Green*:

There are important planning roles in creating the best possible conditions for sites and buildings, including aspects such as proximity of services, retail and public transport, how key services (water, energy, waste) are provided for, and – in the case of new subdivisions – achieving the best site orientation for solar gain and community interaction (pg. 28).

Therefore, the number of different functions to occur in a development needs to be strongly considered against the size of proposals and the needs of surrounding areas. In the case of a large parcel of brownfield land there is significant potential to incorporate a number of mixed uses and choices, particularly as “choices, for example allowing residents to shop, work and recreate locally, is critical to sustainability and resilience of communities(Howell, 2008, pg. 28). If these facilities are successfully supplied it significantly reduces the need of residents to travel and therefore further reduces the need to travel.

Figure 39: Potsdamer Platz, Richard Rogers. The development integrate a wide variety of uses into the plan

From: Richard Rogers. (2010). Potsdamer Platz. Retrieved 02/12/2010, [http://www.richardrogers.co.uk/work/all\\_projects/potsdamer\\_platz](http://www.richardrogers.co.uk/work/all_projects/potsdamer_platz)





The idea of mixed use implies that with different requirements for different functions there will be different architectural response. A commercial building will have different requirements to an apartment or house and therefore should exist on differing scales. This is an essential element in creating a development that will regenerate and allow for continued prosperity of community and neighbourhood functions – if a development is too bland it will not be accepted by residents and they will outsource their requirements for retail and essential services to more attractive areas if possible. Schropfer et al. (2010) note this in their study on Valdespartera<sup>6</sup> saying that because there are very few typologies for building in the development the same “superblock” is repeated throughout, making it monotonous and drab (pg. 14).

Another aspect of mixed-use development to avoid monotony and to create a positive sense of place is the relationship between the built environment and open green spaces. In traditional models of inhabitation there was significant separation between green space and built areas, suggesting that the city and nature were separate elements that could not coexist.

In this view, cities are seen to be busy with technology of high-density building, transportation infrastructure, and revenue-producing development, the undesirable effects of which include congestion, pollution, and various forms of social stress; whereas landscape, in the form of parks, green-ways, street trees, esplanades and gardens, is generally seen to provide both salve and respite from the deleterious effects of urbanization (Corner, 2006, pg. 24).

To avoid this Corner suggests the idea of *terra fluxus* that integration of green space and built areas offers. In this sense the rigidity of existing urban development gives way. The combination of architecture with landscape and greenscape creates far more successful urban infrastructure. He notes:

The term *terra firma* (firm, not changing; fixed and definite) gives way in favour of the shifting processes coursing through and across the urban field: *terra fluxus* (Corner, 2006, pg. 25).

Corner’s assessment of architecture as something that “consumes the potential of a site in order to project”(Corner, 2006, pg. 25) , is, however, not necessarily true. Although poorly considered architecture can have this sort of impact, in reality a building can have a minimised impact upon a site. A number of architect Steven Holl’s new projects promote this relationship, heavily privileging inter-connectivity, not just of architectural programmes, but at urban and landscape scales whilst minimising ground cover.

Two quite different examples of this are Linked Hybrid and Horizontal Skyscraper, both in China. *Linked Hybrid*,

6. A purpose built ecologically friendly development for up to 24,000 residents in Zaragoza, Spain. The development is on a former brownfield site, converted from military use.

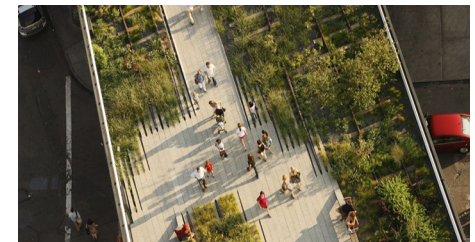


Figure 40: Highline, New York - an example of Corner’s “landscapes of chage” idea

From: Field Operations. (2010). The Highline, New York. Retrieved 06/12/2010, <http://www.fieldoperations.net/>



Figure 41: Continuous Monument, Superstudio

From: Lang, P., & Menking, W. (Eds.). (2003). *Superstudio - Life Without Objects*. Milan : Skira ; London: Thames & Hudson.

Figure 42 (L): From Steven Holl Architects. (2010b). Linked Hybrid. Retrieved 22/11/2010, <http://www.stevenholl.com/project-detail.php?id=58&type=&page=0>

Figure 43 (R): From Steven Holl Architects. (2010a). Horizontal Skyscraper. Retrieved 22/11/2010, <http://www.stevenholl.com/project-detail.php?type=&id=60>



Figure 44: New Babylon model, Constant

From: Wigley, M. (1998). *Constant's New Babylon : the hyper-architecture of desire*. Rotterdam: Witte de With Center for Contemporary Art : 010 Publishers, pg. 110

in Beijing, consists of linked buildings with “porous urban space, inviting and open to the public from every side” (Steven Holl Architects, 2010b), offering large public spaces at ground as well as shared facilities as roof gardens and raised public facilities occurring at a 12-18<sup>th</sup> “floor public sky-loop” (see below left, Figure 42)(Steven Holl Architects, 2010b). The second project entitled *Horizontal Skyscraper* aims to utilise even less of the ground plane for building area. Instead the project aims to “generate the largest possible green space open to the public on the ground level” (Steven Holl Architects, 2010a) by raising all of the building off the ground on eight legs (see below right, Figure 43). Propositions such as this question the need for built inhabitation at ground level. However, although there are few built examples, in reality this idea is not a new train of thought.



The idea of raising the ground plane to create a second level of inhabitation gained favour in the 1960's and 70's through the utopian projects of the likes of Constant Nieuwenhuys (*New Babylon*), Superstudio and the Japanese Metabolist movement. *New Babylon* proposed an urban interaction without the boundaries that currently exist in society and, although provocative as a sociological theory, the images and models are by far the strongest point of Constant's decade long experiments in architecture. His montages and models suggest a world inhabited above ground with layouts of interchangeable spaces. A similar theme is exhibited in Superstudio's works. *The Continuous Monument* is made up of a “sequence of ‘sectors’, gigantic structures built on high supports that tower over a landscape used for fully mechanised agricultural production and covered with lanes of fast-moving traffic” (Heynen, 2004, pg. 62).

It is this agricultural production that is of most interest in the current climate. With continuing reductions in productive land the visions of Superstudio suggest an avenue that has been largely overlooked. By raising built inhabited environments the amount of productive land available is significantly increased. Furthermore by localising production costs, both monetary and environmental, can be reduced through reduction in food miles. Added to this are the economic and poetic opportunities of urban farming - particularly in New Zealand.<sup>7</sup> The opportunity to keep productive land at ground level drastically reduces the cost of urban farming compared to the idea of vertical farming, which although an interesting proposition is prohibitively expensive when weighed up against the cost of urban land and construction costs (Ehrenberg, 2008).

7. As a major exporter of dairy, meat and agriculture New Zealand is often referred to as a 'Bread Basket' economy and promotes its farming industries as innovative.

### *Lifespan*

The final aspect to consider in urban development is that of the lifespan of developments. Historically buildings stood for hundreds of years but nowadays a building may not even see out its physical lifespan, demolished years before it needs to be, particularly in rapidly developing nations such as China. For example, in Shanghai officials predict that any housing built prior to 1999 will have to be demolished well before their designed lifespan. As Yu Hongsheng, director of the Urbanization Research Center in Shanghai comments in The China Daily:

Today, there is an impulse from both the government and developers to build newer and higher buildings to gain greater profits, which has accelerated the pace of the demolition of old buildings. But it is actually not in line with the concept of sustainability (Yanfeng, 2010).

This phenomenon highlights the speed at which needs and uses change in the modern world, even more so in developing nations such as China. Therefore new building needs to be one of two things: either highly flexible to accommodate change; or built with a short lifespan acknowledging the limited lifespan it may achieve. Both of these are valid responses and to an extent can both be achieved within developments.

The first approach, flexibility, is an idea that is applied currently in development. However, this normally applies only in office buildings at an interior level - as floor plates are designed to be adjustable to different functions of tenants. This is due to a large, exterior shell which allows for flexible interior changes. The Metabolist movement addressed this concept at a city-wide level:

To accommodate a city's growth and regeneration, Metabolists advanced transformable technologies based on prefabricated components and the replacement of obsolete parts according to varying life cycles. This notion of growth and change at the scale of the city ultimately overthrew traditional theories of city



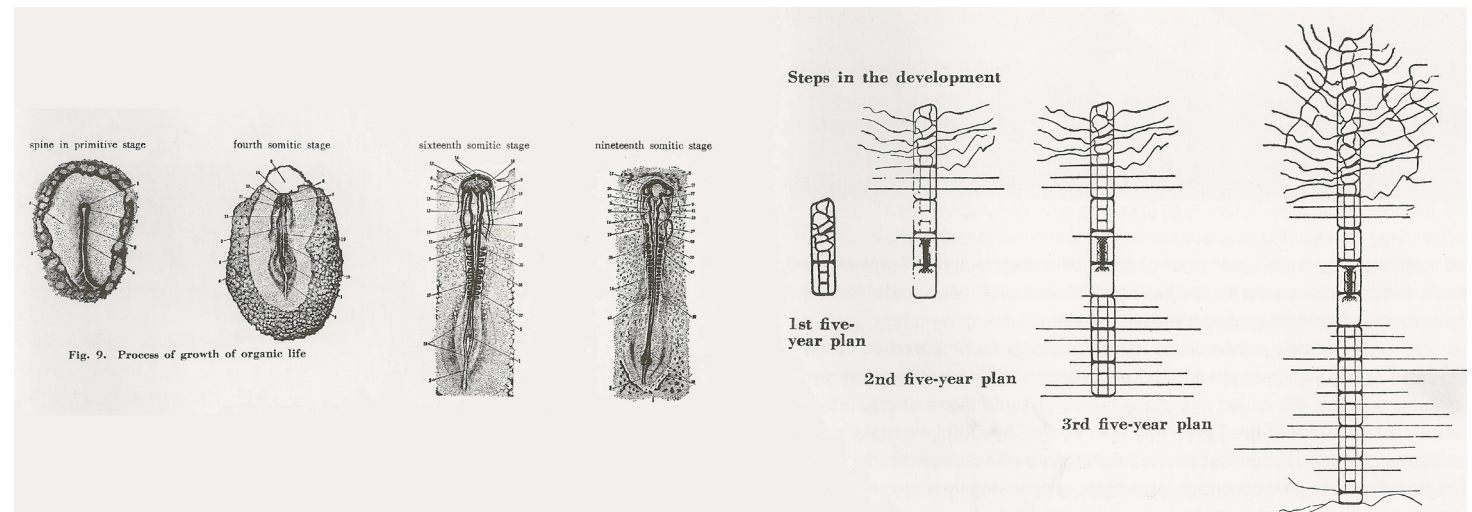
planning and demanded a redefinition of several critical relationships on design: order/chaos, permanence/transience, collective/individual, and planning/ spontaneity (Lin, 2010, pg. 2) .

These relationships are built on throughout Metabolist works and are best expressed with proposals such as Tokyo Bay by Kenzo Tange and Arata Isozaki's Clusters in the Air scheme from 1962. Isozaki's scheme focuses on a central spine with cantilevering units hanging off it, effectively creating two aspects to the project, a skeleton and infill units. Fumihiko Maki builds on this theory and in his 1964 investigations notes:

The element in mega-form does not exist without a skeleton. The skeleton guides growth and the element depends on it. The element of group-form is often the essence of collectivity, a unifying force, functionally, socially, and spatially (as cited in: Lin, 2010, pg. 19).

Figure 45: Tange compares the growth of an organism to the growth of his Tokyo Bay proposal suggesting the linear extension and outwards growth as a natural solution

From: Tange Associates, cited in Lin, Z. (2010). Kenzo Tange and the Metabolist movement :urban utopias of modern Japan. New York: Routledge, pg. 160

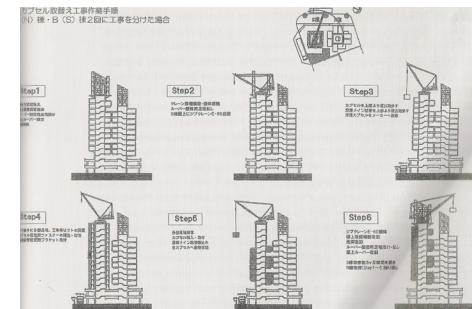


This skeleton and infill relationship allows for two systems to develop - shorter term changeable units that are supported by a longer term structural skeleton. As Tange declares “ the two tendencies - towards shorter cycles and towards longer cycles - are both necessary to modern life and to humanity itself” (as cited in: Abley, 2009, pg. 12). The relationship created by these Metabolist works creates an interaction that facilitates the relationship between these two facets.

The Metabolists also investigate the life of building units and elements throughout their dissertations. Kawazoe takes the idea of the larger skeleton but focuses on the infill units made up of ‘parts.’ The focus of these factory produced parts is that they:

...will be capable of endless combination and change by means of standardized systems and joints. People will be able to select suitable shapes, colours and quantities according to their liking, and put them together in entirely free sizes on the necessary scales (as cited in: Lin, 2010, pg. 107).

The best example of these ‘parts’ existing in a temporary nature is Kisho Kurokawa’s Nakagin Capsule Tower in Ginza, Tokyo. One of the few built projects that appear to fully encapsulate the Metabolist ideals, the tower comprises of a concrete frame with 140 modular units bolted to it. The aim of these units was that they would be removed and replaced when their short lifespan was complete. The irony of this fact was that the units were never replaced and the building is now caught in a battle to either be demolished or preserved as an architectural relic.<sup>8</sup>



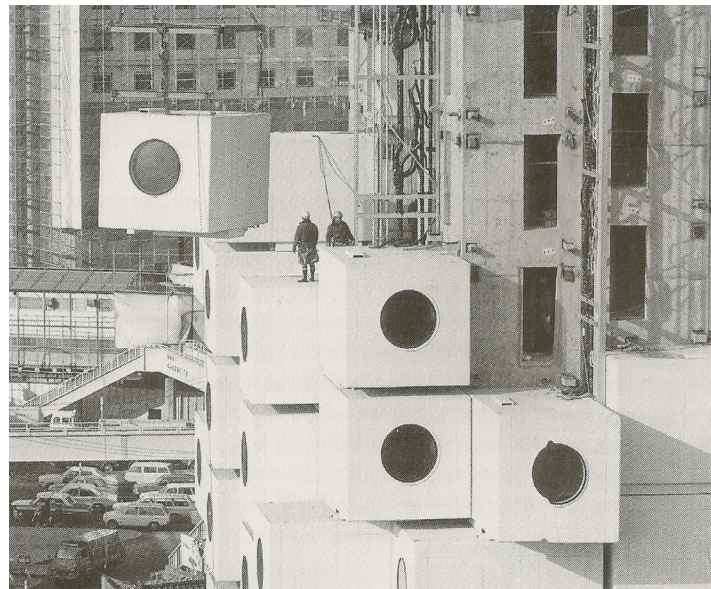
8. Both proposals were rejected by the late Kurokawa who instead suggested ‘unplugging’ the existing modules and replacing them to achieve the original aim of the development (above) in Figure 46.

From: Kisho Kurokawa, cited in Kenzo Tange and the Metabolist movement :urban utopias of modern Japan. New York: Routledge, pg. 241

Figure 47, 48: Nakagin Capsule Tower, Kisho Kurokawa - construction

From: Kisho Kurokawa, cited in Kenzo Tange and the Metabolist movement :urban utopias of modern Japan. New York: Routledge, pg. 234

From: Ibid, pg. 239



For the lifespan of a development to have a regenerative impact it is important to consider both the element of flexibility and lifespan. By achieving the right combination of the two, waste products can be reduced and elements can be reused and recycled to future developments. As the building industry currently has such high waste these elements are vitally important to reduce site impact.

## *Discussion*

There are a number of solutions to aid in the regeneration of contaminated and damaged sites, both technological and social. With regard to soil and water these are normally based around the introduction of plants or microbes to undertake bioremediation. Air quality issues can be resolved through technology and architectural integration, such as Prosolve 370e, or through behavioural changes; such as reductions in personal car use.

As urban responses, architecture and urban planning can play very important roles. The creation of mixed use sites with large amounts of green space, incorporating Metabolist principles of two cycles of development can lead to developments having very little contact and impact upon the ground of sites. This results in the productive re-use of land once remediation has been undertaken.

These remediation techniques are all possible; however, changes are required to be made in behaviour and the development approach to make them successful. Environmental impact needs to be the strongest driver in a project, rather than just cost and profit and then changes need to happen immediately to begin replenishing environments and reducing impacts on the climate and finite resources of the planet.



# Chapter Three - Site Analysis

From a synthesis of the research undertaken, to achieve an architecture that not only cleanses site conditions, but also offers a positive change to established New Zealand settlement patterns, an urban site of a contaminated nature is required. To achieve this, a number of sites were considered from around the country. The chosen site is the Western Reclamation, on the western edge of the Viaduct Harbour in central Auckland. There are numerous benefits and reasons for choosing this site.

The first of these is that the site is already widely accepted as a contaminated site, due to its historical and current uses. The second reason for selection is that there is an existing development plan to transform large areas of brownfield land into a mixed use area, known as the 'Wynyard Quarter.' This allows for a discussion and comparison of existing methods and proposals against regenerative and cleansing ideas. The final reason for the site selection is the nature of the site. As it is situated on the edge of Central Auckland, it offers an opportunity to highlight inner city inhabitation and urban densification; instead of the ingrained suburban nature of much of the city. In addition, the site "headland is prominent from many places along the harbour shores (meaning any major structure built on it would be visible from many corners of greater Auckland)" (Bogunovich, 2007, pg. 3). This means the location provides a very visible platform which can influence future developments and provoke discussion.

This chapter will firstly outline the history of the site, as well as giving brief insight into the history of wider Auckland. Secondly, the existing master plan of Sea + City, for the Wynyard Quarter will be assessed. Finally, recommendations will be made as to how the contamination research undertaken can help to guide future development on the site beyond the Sea + City masterplan.



## History of the Western Reclamation

Auckland, as a city, has always had a close association with the sea. As Michael King notes in *The Penguin History of New Zealand*, Auckland's "prosperity was ensured by its location on an isthmus between two navigable harbours," (pg. 173) which resulted in Auckland being the only city in New Zealand to grow from unorganised migration.

From the outset the port was a focal point for development, with the city expanding out and away from it. The waterfront was quickly populated and, as the need for flat land increased, so too did reclamation out into the harbour. Reclamations were made by the Auckland Harbour Board from whatever was nearby. In the case of the Western Reclamation in Auckland, the most abundant material was the waste from the shore front industries of Freeman's Bay, namely a pit sawing area, a brick kiln and a gasworks (Harbour Edge Advisory Team (AKC), 1990, pg. 3). This meant that from the outset, the Western reclamation was not clean soil but a mix of old rubbish, chemicals and dirt.

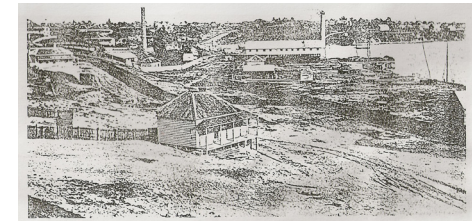


Figure 49: Early development in Freeman's Bay, Auckland, 1877. The smokestack on the left is now part of Victoria Market

From: Harbour Edge Advisory Team (AKC). (1990). Waitemata Waterfront - Harbour Edge Development Group - Vision for the Auckland Harbour Edge. Auckland: Auckland City Council (ACC), pg. 3

The area was initially utilised by the timber trade, and then in the 1930's it started to be used for bulk petrochemical storage. This activity now dominates the northern end of the reclamation, which has often been referred to as the 'Tank Farm' (Sea + City, 2009e).



Figure 50: Existing Tank Farm on Western Reclamation with Auckland CBD in the background

From: Sea + City. (2009c). Photography. Retrieved 02/07/2010, <http://www.seacity.co.nz/images.htm>

9. see Appendix Two

Through its life as a petro-chemical store, the site has had a number of tenants. Shell and Mobil were both major tenants until the 1990's. There have been numerous uses for the tanks throughout their operational lifespan. This is shown by documents obtained from the Auckland Archives. They show "petrol, Avgas 100, Jet A-1, hexane, kerosene ... ammonia... ethanol [and]... turpentine," (Auckland City Council (ACC), unknown) among others, have all been stored on the site.<sup>9</sup> Currently Marstel Terminals operates the only remaining storage facilities on the site.

10. see Appendix One

The history of uses of the site has left, in its wake, some serious contamination issues. There is a verbal history reporting that the contents of one of the bulkstore gasoline tanks emptying entirely into the soil in the late 1980's. Reporting undertaken for the Auckland City Council has found "there is significant soil and groundwater contamination within the study area... there is potential for further contamination to be found" (Harbour Edge Advisory Team (AKC), 1990, pg. 7.0).<sup>10</sup> The Sea + City development agency has also had contamination studies undertaken. These highlight the presence of heavy metals and separate phase hydrocarbons (SPH) in the soil of the site (Matthews & Carruthers, 2010, pg. 33).

Changes in bulk liquid transportation and the advent of the pipeline from Marsden Point (Harbour Edge Advisory Team (AKC), 1990) has meant that the majority of the land on the Western Reclamation has become superfluous to the needs of the original industries. In the 1990's much of this land was bought by Auckland Regional Holdings (a subsidiary of the then Auckland Regional Council) for development.

Large scale urban redevelopment of the adjacent Princess Wharf and Viaduct Basin, occasioned by the winning of the America's Cup by Team New Zealand in 1995, have provided a model for the possible urban redevelopment of the Western Reclamation (Bradbury & Hinton, 2009).

This resulted in the current plans to turn the area into the Wynyard Quarter, a mixed-use development of apartments, commercial, industrial, public and green space.

Figure 51: Trueview simulation across to Wynyard Quarter from Pt Erin

From: Sea + City. (2007). Illustrations and Graphics - Trueviews. Retrieved 02/07/2010, [http://www.seacity.co.nz/images\\_trueviews.htm](http://www.seacity.co.nz/images_trueviews.htm)



## Sea + City – Wynyard Precinct

*The redevelopment of the Western Reclamation, also known as The Tank Farm or Wynyard Quarter, in Auckland is envisioned to be New Zealand's leading example of sustainable development. Design and development will incorporate world class and best-practice sustainability strategies and design components* (Sea + City, 2009d, pg. 2).

There has been an ongoing process to develop the Western Reclamation for some time. This section will examine the schemes and evaluate the most current version (by Sea + City) against previous versions and against the research set out in the previous chapters.

Since the 1990's there have been various projects undertaken to change the Western Reclamation into a more constructive precinct within the city of Auckland. The first of these was "Project '90," undertaken by Fletcher Construction. This led onto the *Harbour Edge Report* (Ports of Auckland, 2005, pg. 5), that has been previously quoted in this chapter. The report identified issues of contamination with the site and noted significant soil and groundwater contamination. These early findings have in some ways shaped future development projects, as it identified the site as a contaminated brownfield site that would need remediation. Throughout the late 1990's and early 2000's there were a number of plan changes that allowed for the site to be potentially developed into a more mixed use area (Ports of Auckland, 2005, pg. 5).

The first design iteration was commissioned by Ports of Auckland<sup>11</sup> in 2005 and involved Peter Walker and Partners (U.S.A.), Architectus, Beca and Innovus to create initial design plans for the quarter. The plan developed a number of key principles for the new precinct which was to originally be called *Kahurangi*:

- Re-establishment of the Waterfront - linking with the CBD through the introduction of a bridge to Te Wero Island. This connection, "the spine"... [is used] to extend the activity and vibrancy of the Viaduct Harbour into the reclamation... The concept also suggests the potential establishment of a 'cultural anchor' such as a gallery or museum on the Westhaven end of the spine" (Ports of Auckland, 2005, pg. 6).
- Re-Introduction of Water – proposed along the northern face of North Wharf, forming the northern edge of the spine. This strategy reinforces the spine's waterfront context and orders the site north and south of this axis (Ports of Auckland, 2005, pg. 6). This pond also allows for the on-site treatment of stormwater.

11. The successor to the Auckland Harbour Board



- Connectivity - the design suggests three important connections: a green connection between Victoria Park and the Point Park; a water connection, aligned with the axis of the Wynyard Wharf and a CBD connection, to the Viaduct and the central city.
- Layering of Uses and Activities
- Buildings as Topography
- Phased Implementation
- Two Grids - on different angles following the natural shape of topography.
- Open Space - the most successful element of the proposal, allocating 21% of the overall site area to public open space. "The open space system is structured around two major parks and a linking element along the western edge" (Ports of Auckland, 2005, pg. 7). One of these parks is at the termination of the CBD axis, while the other, at the point of the reclamation introduces a reference to Auckland's volcanic history with a man-made mound that spirals up.

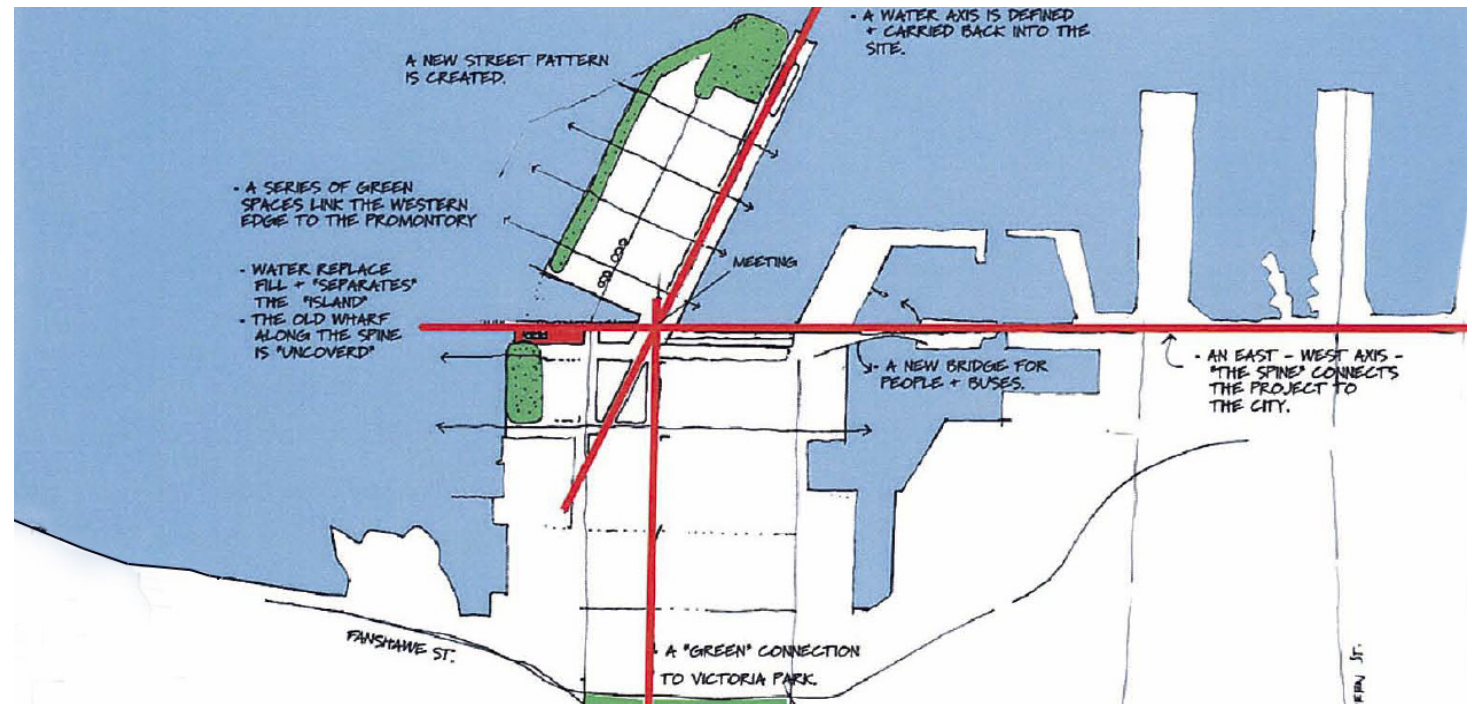


Figure 52: Key features of the original Ka-hurangi proposal by Peter Walker et. al.

From: Ports of Auckland. (2005). Western Reclamation Design Concepts. Auckland: Ports of Auckland, pg. 7

The initial investigation presents a thorough plan which offers many positives, including linking the city, the layering of activities and uses, and the significant amounts of open space. There are, however, a number of criticisms that can be made about the *Kahurangi* development. The first of these is that the development significantly reduced land available for the marine industry (Orsman, 2006), the largest earner and employer in the area. The other criticisms were of the use of the end of the site for a “volcano” (Rudman, 2005) and that the proposal was not creative enough for such an important site.

The next phase in development was the current masterplan, by the renamed Sea + City for the renamed area, the *Wynyard Quarter*. The plan retains the general layout of the earlier Walker version but expands public space, removes the volcano and increases land availability for the marine industry (Sea + City, 2009a). Sea + City also set out a *Sustainable Development Framework*, discussing benchmarks for important issues. Some of the more important benchmarks include:

- a 40% reduction in energy use
- a 30% on-site renewable energy use
- a minimum standard of 4 star NZGBC (or equivalent) building across the site
- a ratio of 1.4ha / 1000 people of open space

Although the framework sets out these goals, there is very little concrete planning, or evidence on how to achieve these goals. Nor does the current version appear to incorporate the idea of renewable energy into publically available sketches of the masterplan (Sea + City, 2009c).

One area that is considered in depth (although not necessarily successfully) in the proposal of Sea + City is that of site remediation. Due to the nature of the site this is a particularly important issue, as highlighted by the risk assessment undertaken by the Harbour Edge Advisory Team (1990 report). Therefore, the developer proposes to remove soil as required. There has been ongoing discussion with previous tenants (such as Shell and Mobil) as to the timeframe that is required to undertake this process. Currently, monetary provisions have been made to remediate the site when required (Matthews & Carruthers, 2010). The positive of this is that the whole site will not be excavated and fully replaced with clean soil. Instead, soil will only be removed and replaced as required, as foundations and underground building will decrease the need for clean soil. The negative aspect of this proposal is that the contaminated soil is merely moved to landfill, the cheapest and least positive remediation technique.<sup>12</sup>

12. See Chapter Two - Soil remediation.

**Figure 53:** Refined Sea + City proposal - point park has been flattened and public spaces increased.

From: Sea + City. (2009a). Concept Framework. Retrieved 02/07/2010, [http://www.seacity.co.nz/design\\_concept\\_framework.htm](http://www.seacity.co.nz/design_concept_framework.htm)



Since the original plans of Sea + City have become available, there has been discussion that public open space will also be reduced to cut costs and increase revenue (Orsman, 2009). Combined with increased building heights and the lack of creativity in addressing issues, the new scheme has drawn public and industry criticism (Bogunovich, 2009). This led Bradbury and Hinton (2009) to note that the master plan effectively reinvents the site as real estate, but it “fails to [fully] address the serious environmental issues that are present on the site... major stormwater pollution... and serious terrestrial pollution, from petroleum products” (Bradbury & Hinton, 2009, pg. 152). Bradbury and Hinton attempt to address stormwater concerns on the site by creating a large wetland instead of the proposed Wynyard Point Park. By addressing contamination through staged phytoremediation and creation of storage ponds the scheme largely removes publically accessible greenspace and instead proposes “a gently sloping plaza... beach... boardwalks... [and] shipping containers for local vendors... [through] the wetlands” (Bradbury & Hinton, 2009, pg. 155).



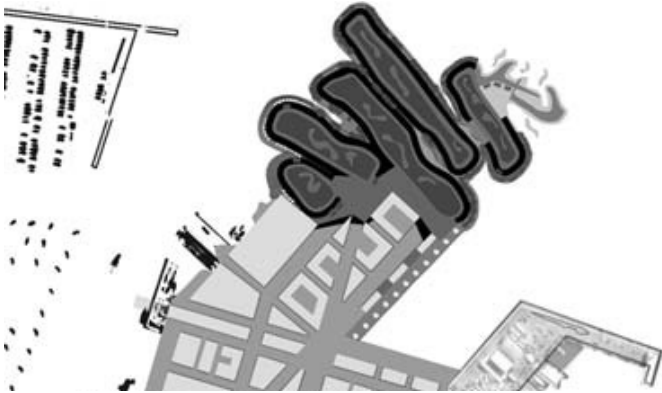


Figure 54, 55: Wynyard Park, Bradbury and Hinton. Public spaces are set amongst a functional wetland.

From: Bradbury, M. A., & Hinton, B. (2009). *Pelagic city: The Wynyard Point Park*. In Feyen, S. & Feyen, N. (Eds.), *Water and Urban Development Paradigms*. London: Taylor & Francis Group, pg. 155

From: Ibid, pg. 155

Dushko Bogunovich's comments and papers also points out problems with the Sea + City proposal. Bogunovich notes that there is little information on environmental impacts, nor "how the projects could or should be made environmentally sustainable, or what exactly was the economic development agenda of this project, that is beyond sheer property development" (Bogunovich, 2007, pg. 4) His proposal for the space suggests a "waterfront entirely self-sufficient in energy, water and waste disposal" (Bogunovich, 2006). He suggests:

Let's build a beautifully designed wind, sun and sea-powered and/or hydrogen plant on the Tank Farm and show the world that having a city that generates locally clean and safe energy is the ultimate cultural statement. It could be part of a museum of the future or an art and technology gallery.

In this context, the waterfront is first and foremost our facade, showcase and shop-window. Its potential to act as a display for the city, the region and the nation is priceless. This is the place to exhibit our best goods and our most important messages... to show in tangible terms what sustainable development is all about, particularly in urban circumstances... Before this can happen we must realise that more Viaduct Basin-type urbanism on the waterfront would be a wrong step. It would take us straight back to the 20th century, instead of putting us in a position to lead the world into the 21st (Bogunovich, 2009).

## *Discussion*

Currently the Sea + City proposal continues, with the North Wharf promenade as well as an interim link across the Viaduct Harbour and the Events Centre scheduled to be complete in time for the Rugby World Cup, in 2011. As the development is staged there is still time to alter ambitions and targets for the development. From the case study a number of serious shortcomings of the Sea City scheme have been identified. The main issues that are not adequately addressed are:

- the contamination of site and environmentally positive remediation techniques
- successful use of public places and green spaces in the Wynyard Point Park
- the mixed use that should occur across the site and whether the whole site should be inhabited or be used as a showcase
- creative and innovative thinking about issues that will affect future urban development and wider ecological systems.



# Chapter Four - Design

In this chapter the site issues identified in the previous chapter, combined with research into the ability of architecture to aid in cleansing and regenerating site is explored through design. This exploration is presented through an amalgamation of visual images and discussion and explanation of design elements.

The chapter begins with a brief site description, followed by discussion of precedents and the methods chosen to inform the design process. These lead onto design development, outlining a programme and site relationship. Subsequently, the design outcome will be presented, followed by discussion. It should be noted that the design is not necessarily a termination of the research; rather it is an applied case study to a particular situation with specific issues. In this way, the addressing of the site is undertaken as a specific solution. Further, the research findings, through architectural development, imply that a site specific solution will always be necessary; rather than a broad, generic framework.

As the purpose of this research is to outline an architectural solution to issues focusing on site remediation and urban regeneration there are limitations to the design. Research undertaken is purely theoretical and has not been personally site tested. Therefore the design assumes that research findings are correct and will result in successful remediation. Further, limitations are acknowledged with regards to engineering and landscape solutions. To reduce assumptions, discussion has been undertaken with relevant design professionals, including an engineer, landscape architects and urban designers. However, further development would be required to implement a fully successful solution.





## *Design outcome*

The design outcome investigates how remediation and cleansing of the site conditions can be integrated into an architectural development that incorporates the positive elements of the existing Sea + City development and also address its deficiencies. The design addresses the large scale master plan to regenerate and apply an urban framework for the development and then focuses in more depth on a specific area. The concepts applied are not purely architectural, but are also technological, psychological and explore the implications of architecture beyond the physical edifice.

Re-use of the existing tank structures is used as the initial design rationale. This limits new construction and helps to provide an interesting, productive, visual and historical trace of former uses as well as retaining some of the constraints of the existing site.

Note: All images in this section are the authors own work unless otherwise stated.



## *Site description*

The Western Reclamation is an area of reclaimed land of approximately 18 hectares, stretching from Pakenham Street in the south, to the point of the reclamation (Bradbury & Hinton, 2009, pg. 152). The site also consists of 1.8 hectares of coastal marine structure (wharves) (Ports of Auckland, 2005, pg. 3) The site is largely owned by Auckland Regional Holdings (ARH), although a large area is inhabited by Marstel Terminals, whose lease periodically expires between 2016 and 2025 (Sea + City, 2009a). The other remaining tenants are industrial, largely associated with the marine industry.

As stated there is an existing master plan for the area which seeks to house large numbers of new residents, commercial and industrial activities, public facilities and public open space. It proposes to remove almost all traces of the site, leaving only the large concrete silo and the “six pack” (Sea + City, 2009a).<sup>13</sup>

13. It is planned that the remaining tanks will be demolished or relocated.





## Precedents

From research into the existing Sea + City plan for the site, it becomes obvious that the developers believe that the existing tank structures offer no future benefit. The proposal keeps the large cement silo and six-pack at the western edge of the site but their uses are not only vaguely defined - the brochure *Discover Wynyard Quarter* suggests “a light house,” (Sea + City, 2009b) as a public installation, whilst the six-pack of silos is not addressed at all.

There are a number of precedents which successfully integrate existing industrial structures into a new development. In first dates from 1975 when architect Ricardo Bofill transformed an abandoned cement factory into his head office and personal house.

The factory, abandoned and partially in ruins, was a compendium of surrealist elements— stairs that climbed up to nowhere, mighty reinforced concrete structures that sustained nothing, pieces of iron hanging in the air; in short, huge empty spaces filled nonetheless with magic (Ricardo Bofill Taller de Arquitectura, 2010).

Figure 57, 58, 59 (clockwise from left): The abandoned concrete factory before renovations.

Exterior after renovations. Planting has been used to soften the appearance of the forms.

Boardroom after renovations. The concrete silo is an integral part of the design.

All images from: Ricardo Bofill Taller de Arquitectura. (2010). Ricardo Bofill Taller de Arquitectura in Barcelona. Retrieved 03/12/2010, <http://www.ricardobofill.com/en/7462/Architecture/Ricardo-Bofill-Taller-Arquitectura-in-Barcelona.htm>





Figure 60, 61 (L-R): View of The Silos from Raglan wharf.

Courtyard between the two silos.

All images from: The Silos. (2010). The Silos. Retrieved 10/12/2010, <http://www.the-silos.co.nz/pages/home.asp>

The second exemplar is the re-use of former silos as accommodation/ *The Silos*, a former Golden Bay cement silo on Raglan Wharf is a New Zealand example of positive reuse. The silo and a subsequent new building attached results in three apartments overlooking the harbour.

In an overseas context, *Oil Tank (Oljetanken)* is constructed from a surplus Mobil oil silo on a small Norwegian island. The tank is re-used to create a single family dwelling which is capable of withstanding the harsh coastal environment.

Figure 62, 63, 64 (L-R): During the renovation process.

Completed dwelling. The roof has been lifted 30cm to allow for three full height floors.

Access to roof garden.

All images from: Otterbeck, M. The history of thought (translated). Retrieved 10/12/2010, [http://www.oljetanken.no/index.php?cid=16342&pageNum\\_Recordset1=3](http://www.oljetanken.no/index.php?cid=16342&pageNum_Recordset1=3), photographer Nina Ruud



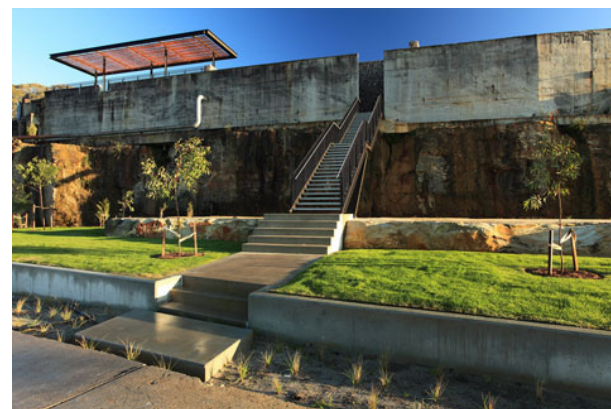
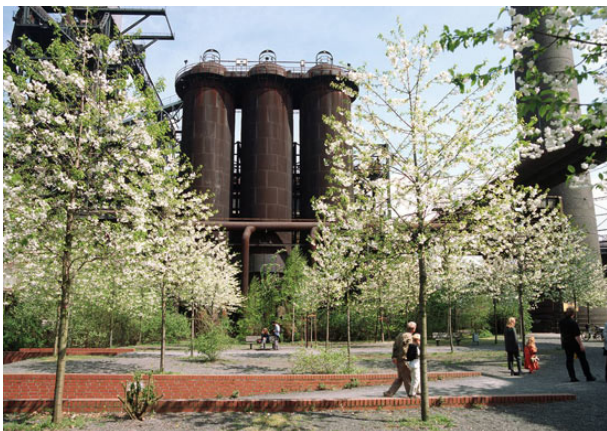


Figure 65, 66, 67 (L-R): Blast Furnace Park in Duisburg Nord

Open air gallery incorporating old structure and planting for phytoremediation, Duisburg Nord

Climbing walls re-use the old industrial structures in a new and interesting way, Duisburg Nord.

All images from: Latz + Partner. (2010). Landscape Park Duisburg Nord. Retrieved 07/12/2010, <http://www.latzundpartner.de/projects/detail/17>

Figure 68, 69, 70 (L-R): Aerial view of Ballast Point Park.

Former tank structure is re-used as a productive sculpture, invoking historical reference and utilises regenerative energy.

Old structures and excavations create different zones in the park.

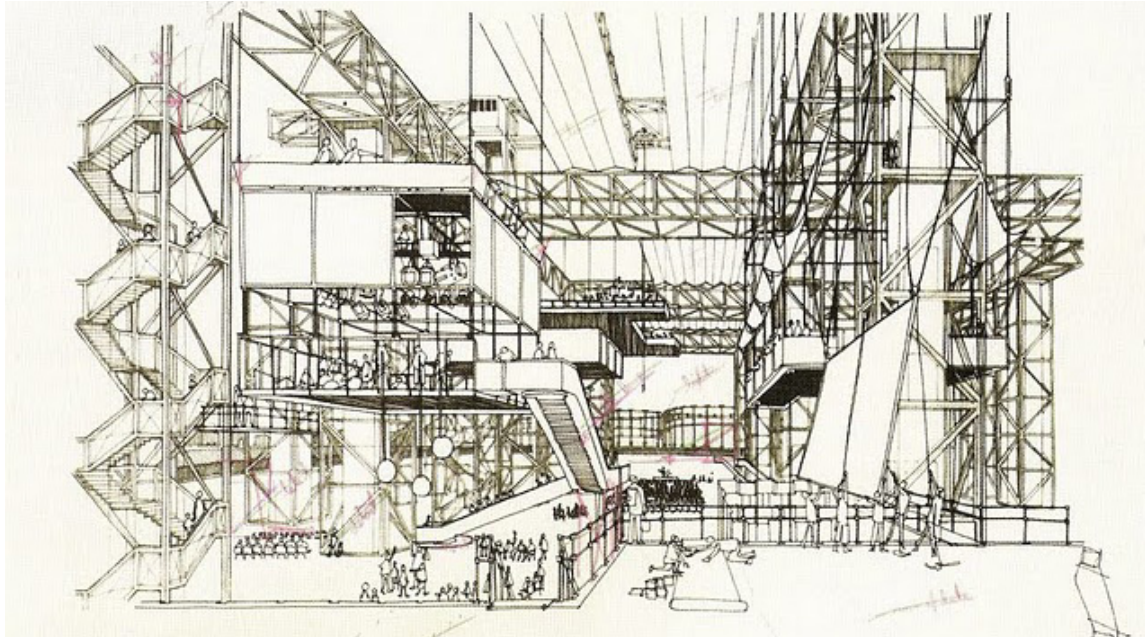
All images from: World Landscape Architect. (2010). McGregor Coxall Wins International Waterfront Design Honour Award for Ballast Point Park Sydney. Retrieved 19/10/2010, <http://worldlandscapearchitect.com/mcgregor-coxall-wins-international-waterfront-design-honour-award-for-ballast-point-park-sydney/>

The third precedent is a landscape park designed by Latz + Partner. The *Landscape Park Duisburg Nord* in Germany utilises a former coal and steel plant and addresses contamination through phytoremediation. Post remediation the park provides a number of unique environments for the public.

The final design precedent regarding the integration of existing structure and remediation of site is *Ballast Point Park* in Sydney. One tank has been sculpted into a productive sculpture and other historical traces of the former industry remain throughout the park.

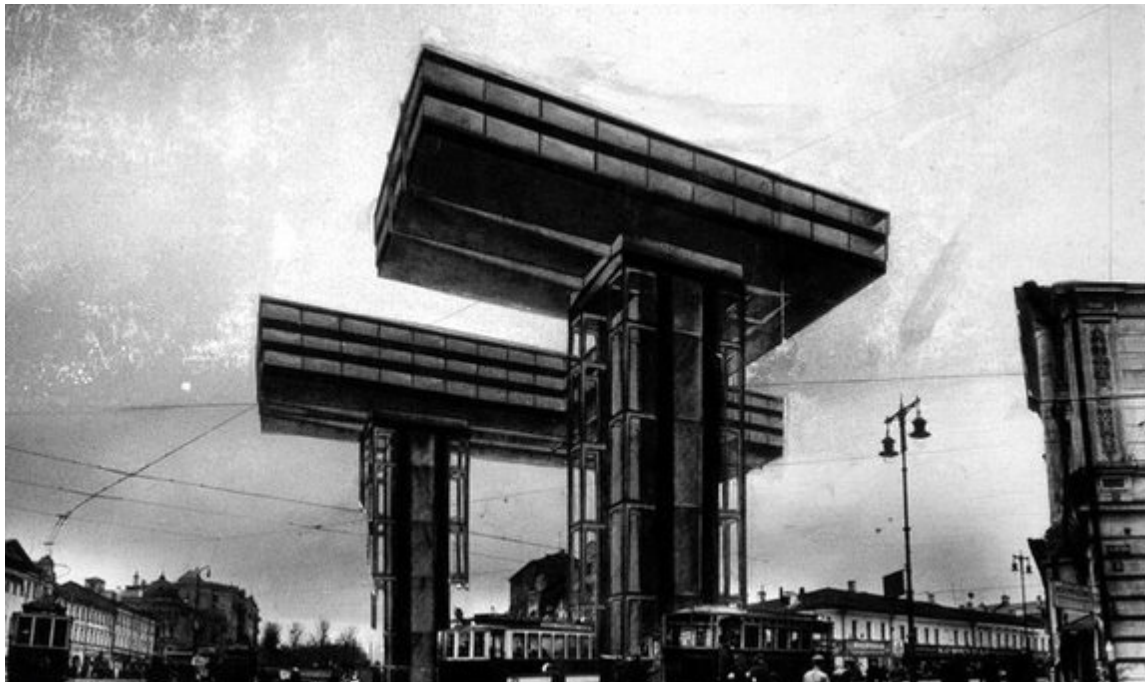
A number of other architectural projects also helped to gain focus for this project. Many of these (such as the Metabolists) have already been mentioned throughout the research. Those not yet mentioned will be incorporated over the following pages.





**Figure 71:** Fun Palace, Cedric Price. The structural frame supports interchangeable functions and can be altered to suit conditions and events.

From: Canadian Centre for Architecture (CCA). (2010). Cedric Price: Fun Palace. Retrieved 14/12/2010, <http://www.cca.qc.ca/en/collection/283-cedric-price-fun-palace>

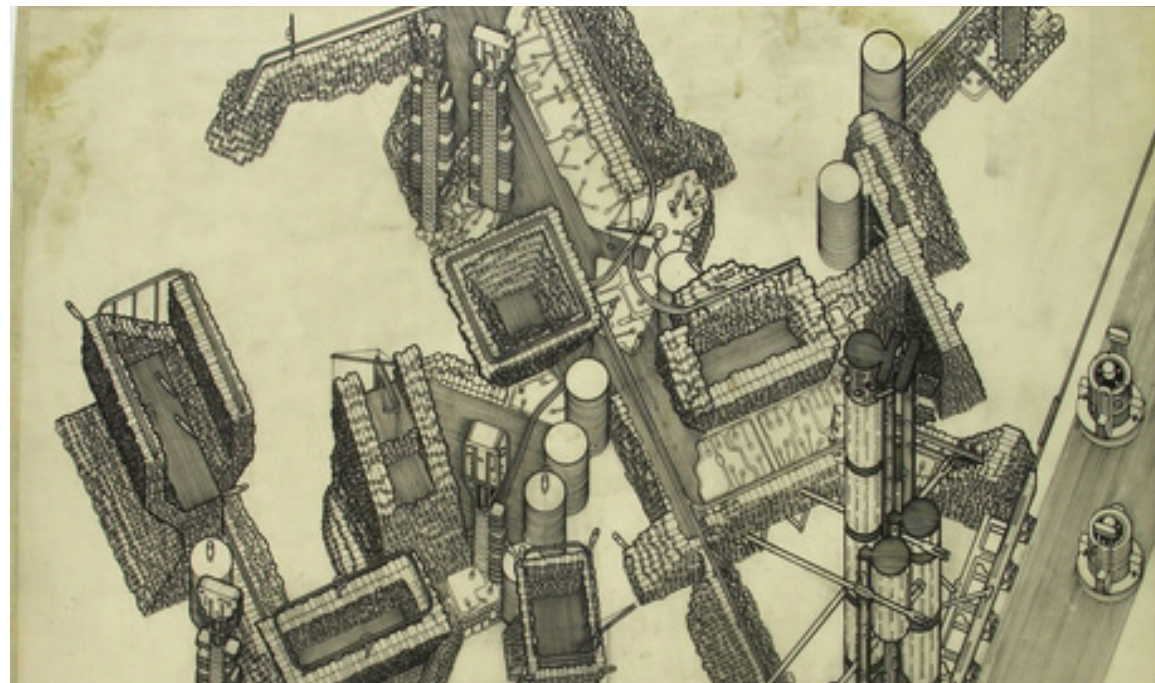


**Figure 72:** Cloud Hanger, el Lissitzky. The photomontage suggests raised inhabitation as early as 1925.

From: Bussagli, M. (2005). Understanding Architecture. London: I. B. Tauris, pg. 176

**Figure 73:** Reuse of former industrial structures to combat the effects of rising sea levels on the Thames. Floating City 2030, Anthony Lau.

From: Lau, A. (2010). Floating City 2030: Thames Estuary Aquatic Urbanism. Retrieved 26/07/2010, <http://www.flickr.com/photos/bldgblog/sets/72157624266798837/>



**Figure 74:** Plug-in city, Archigram (Peter Cook). The structure incorporates removable housing elements into a megastructure of concrete.

From: Cook, P. (Ed.). (1999). Archigram. New York: Princeton Architectural Press, pg. 37.

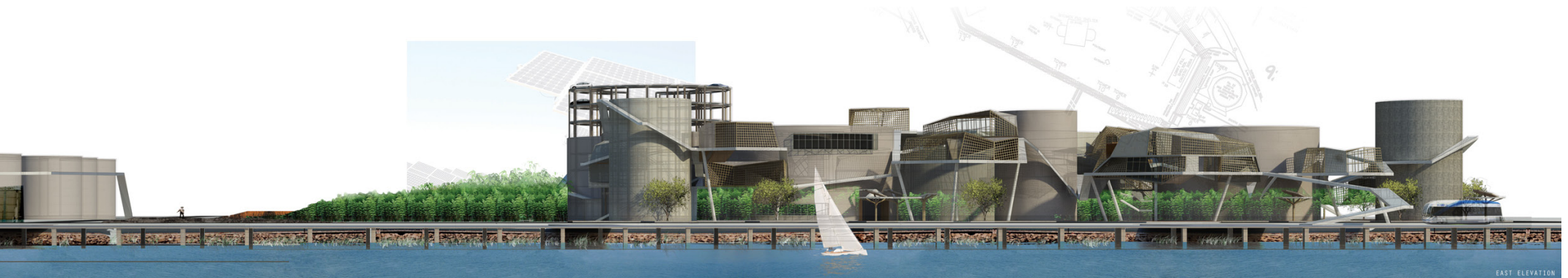


Figure 75: Time based elevation of the design showing three stages: before remediation (left), during bioremediation (centre) and full site inhabitation (right).



## *Design detail*

The design acknowledges that not all elements of regeneration and development can be undertaken simultaneously. Therefore the project is based upon three stages. The first focuses on site regeneration, the second, initial inhabitation and the third focuses on long term use and future proofing.





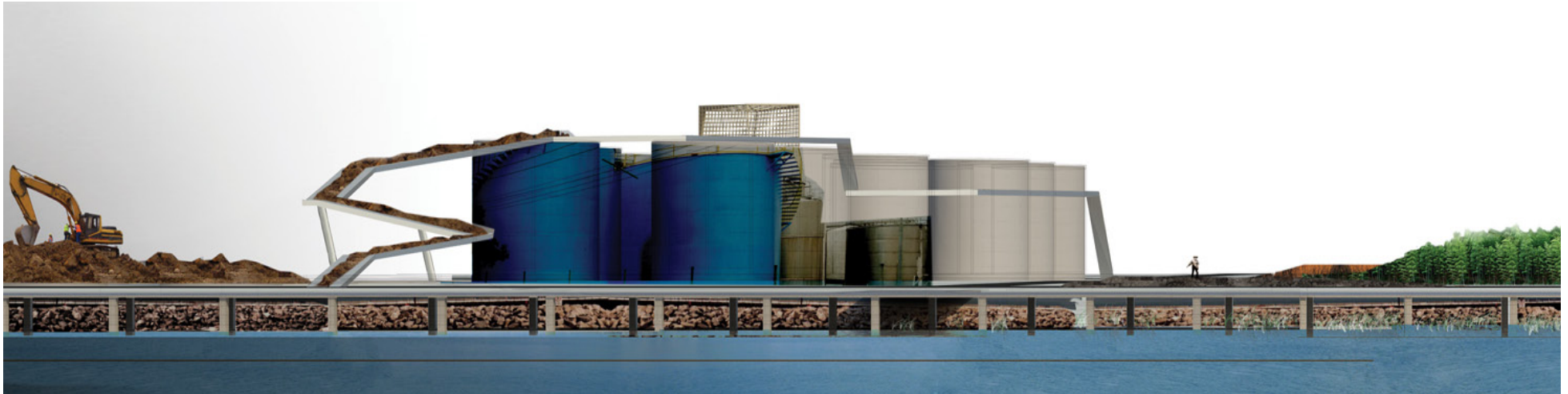


Figure 76: Stage one - phytoremediation and bioremediation processes of soil and water cleansing being undertaken. The first crop of bamboo may have too many absorbed pollutants to be used for construction.

## Stage one: Site regeneration

The design deals with the two different types of architectural implications set out in chapter three. It firstly deals with issues of remediation of site, before urban regeneration can occur. The most important aspect to consider on the Wynyard site is the contamination present in the soil. The two most effective ways of dealing with this contamination, considering that heavy metals and SPH's are present, are phytoremediation or bioremediation. The design project uses a combination of the two, taking into account the limited depth at which phytoremediation can occur.<sup>14</sup>

14. In Matthews & Carruthers, (2010) contamination appears present to a depth of approximately 4m (pg. 33).

The project re-uses the existing tanks to undertake bioremediation. The tanks act as soil columns and remove contaminants over the period of approximately a year. This requires three actions. The first is minor alterations to the tanks so that the influent and effluent solutions can be administered and the soil can be removed at the end of the cycle.<sup>15</sup> Strengthening of the tank foundations may also be required.

15. Based on the report of Liu et al., a cycle of 330 days created biodegradation of pollutants of up to 80% (pg. 13).

The second action is the excavation of the soil. Due to the number of tanks and the volume of soil, it is calculated that (assuming most of the tanks are kept) there will need to be between four and five rotations to treat all of the accessible soil of the site. The soil that cannot be excavated - for example, that which is in too close proximity to the tanks themselves - is addressed through phytoremediation. This is undertaken with bamboo. Bamboo was chosen as it is fast growing, has a large root rhizosphere (to attract pollutants) and is a highly versatile construction material. The site excavation that is undertaken is done with heavy machinery. It is sorted into soil and waste products (such as concrete) which will be reused and recycled where possible.

Figure 77, 78 (L-R): Bamboo root diagram

From: Nilsson, J. (1998). Parts of a Bamboo. Retrieved 14/12/2010, [http://www.bambooland.com.au/information\\_terms.htm](http://www.bambooland.com.au/information_terms.htm)

Material separation is currently occurring onsite to separate concrete, asphalt and soil.

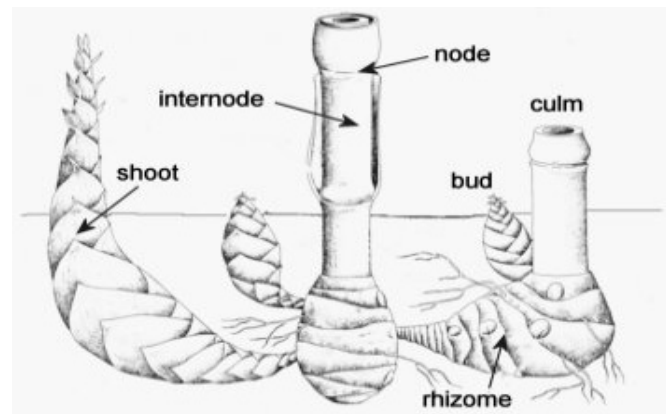
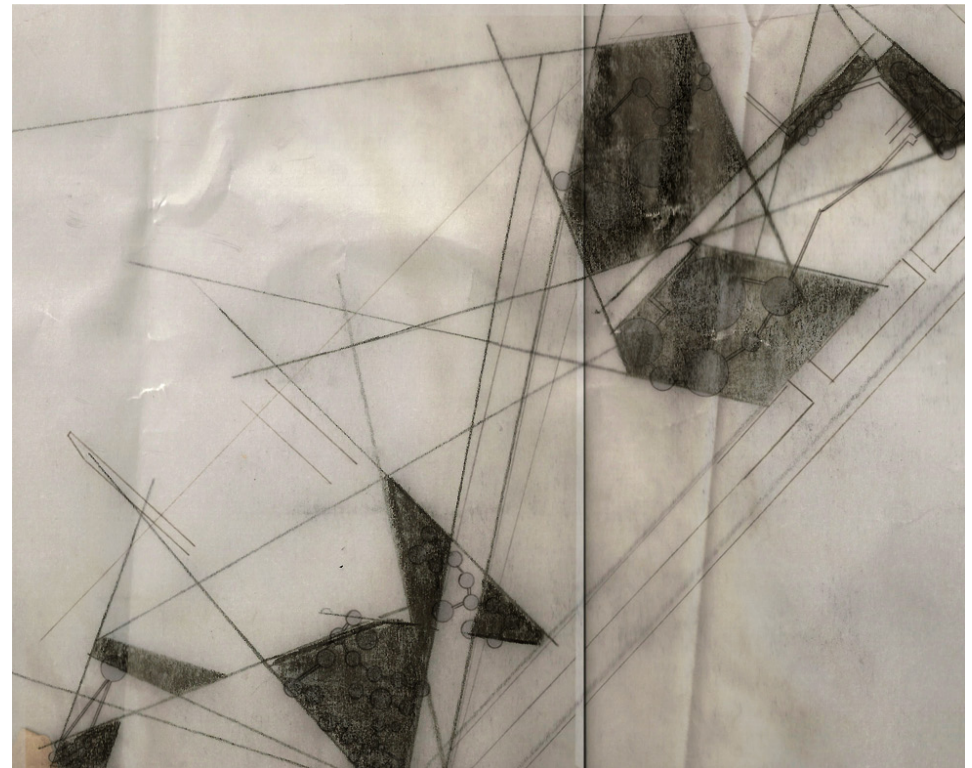
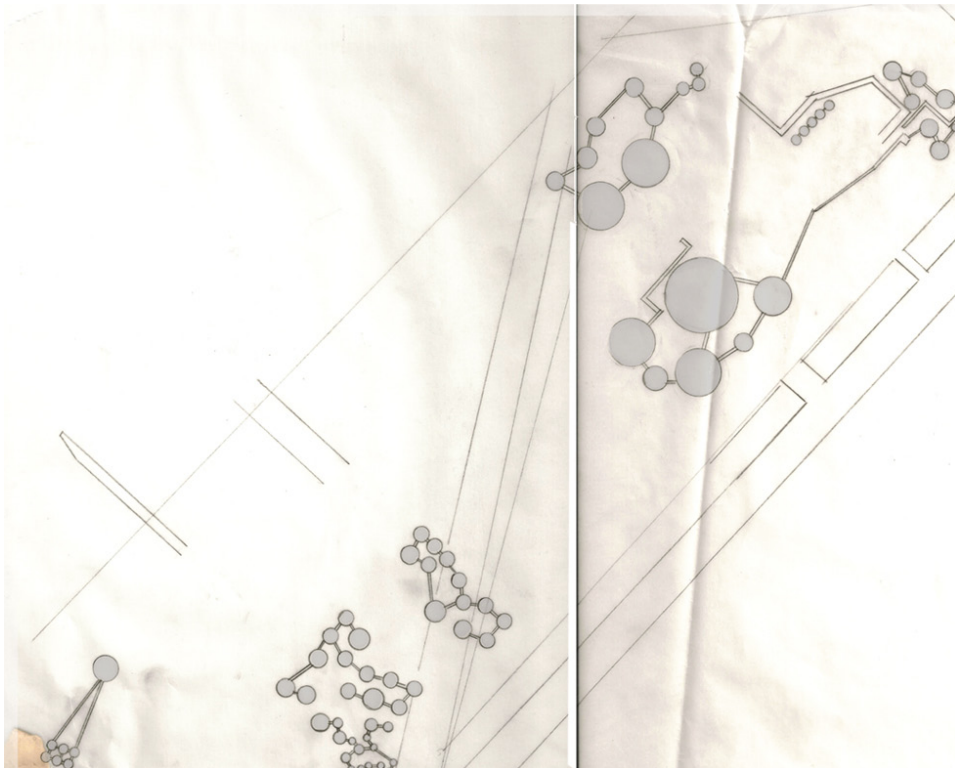


Figure 79: Development of hexagonal frame pattern. Derived from the tank shapes and the aims of reducing impact on the three axis of the existing plan and reducing impact on the ground plane.





The third site remediation intervention is the transport of the soil into the existing tanks. The transport of the soil occurs on conveyor systems, supported by a hexagonal structural framework that wraps around the tanks. This frame incorporates the ideas associated with Prosolve 370e. However, instead of using these panels as a facade element, the design incorporates the pollution absorbing technology into the cladding over the steel structure of the frame. The frame is created from a number of interweaved hexagons of different sizes and heights. It is largely elevated off the ground, supported from the tanks themselves and from steel columns. It provides an aesthetically effective frame that follows a definable pattern and provides contrast to the circular forms of the tanks themselves. The makeup of the frame offers a large amount of surface area. This allows the frame to remove air pollution whilst acting as a system within the larger development. Due to the number of rotations required to decontaminate the soil across the site this permanent frame is constructed instead of a temporary solutions, such as cranes or portable conveyor systems.

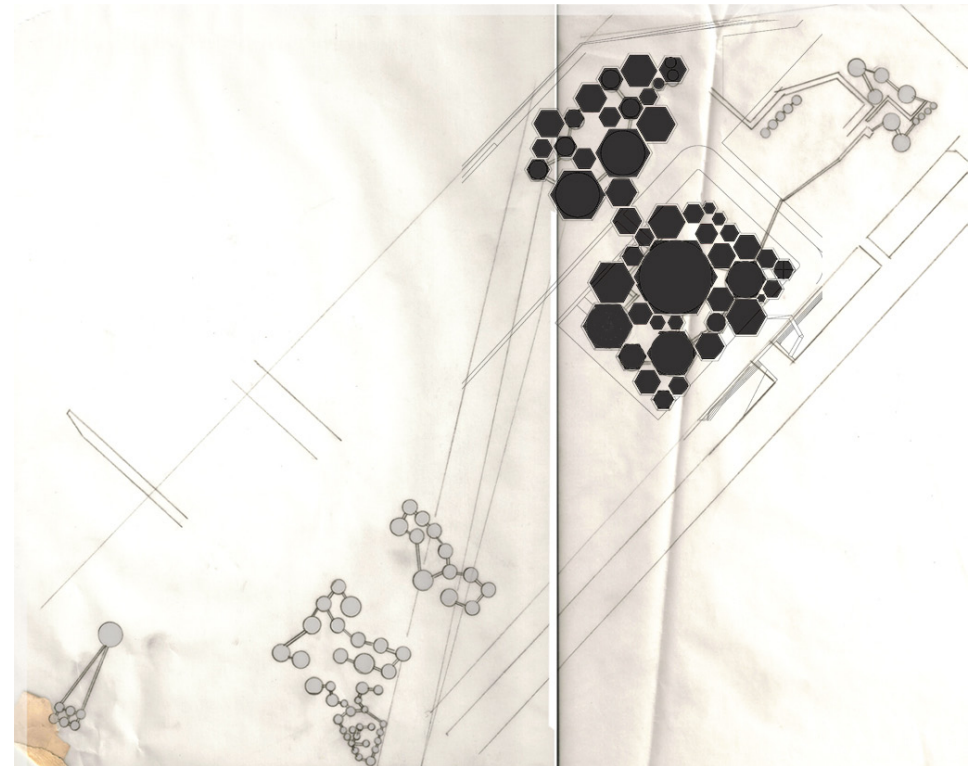
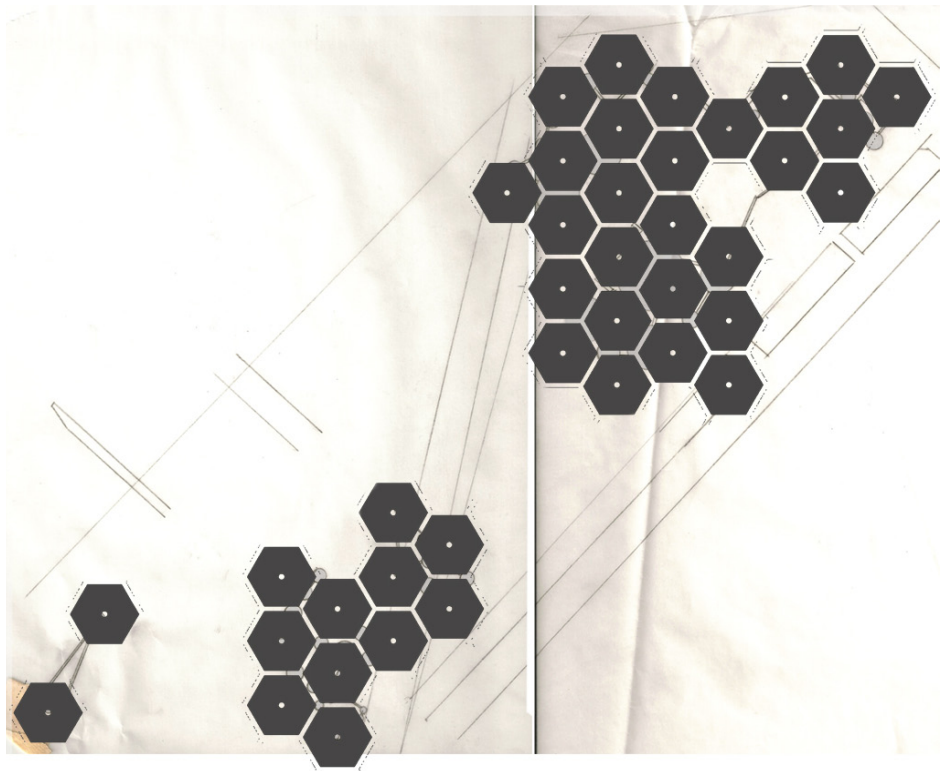


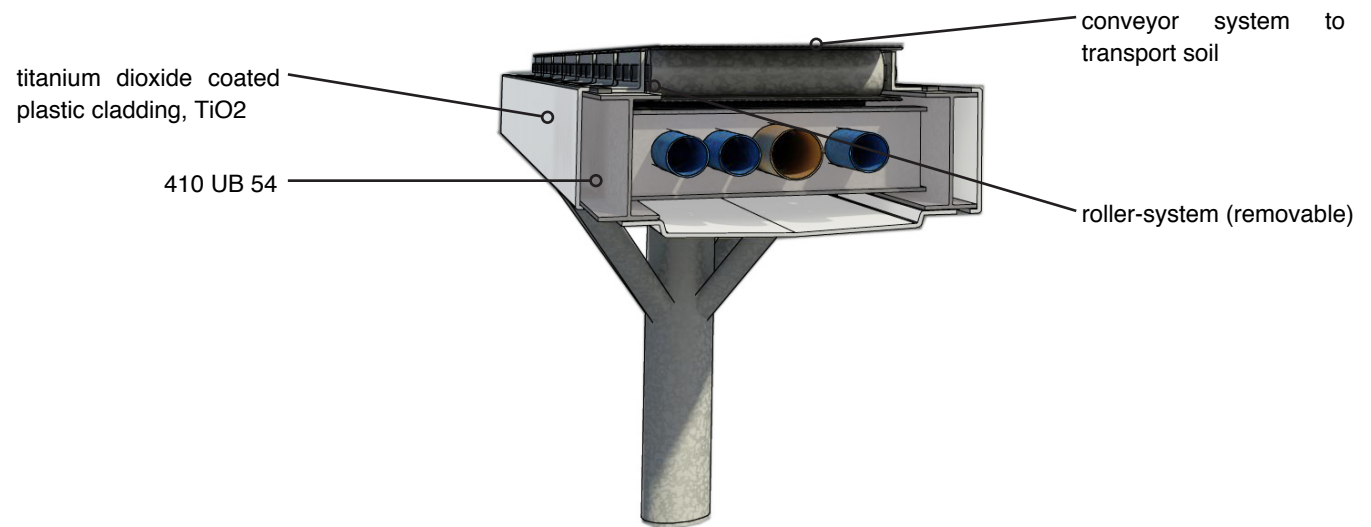


Figure 80: Section Z - Z through the site during excavation and remediation process (stage one). The buildings on the right are workers accommodation and laboratories.

The other positive the frame offers is that it provides access to the tanks and can be used to support smaller structures such as laboratories and accommodation for the workers. This is envisioned to be a number of light timber frame buildings that are supported by the hexagonal frame. The long term nature of the frame contrasts with the shorter lifespans of the infill buildings, allowing for the “skeleton” (as cited in: Lin, 2010, pg. 19) and infill that Maki describes.

By elevating much of the inhabited and functional programmes through the use of the hexagonal frame, the water table of the site is allowed to return to a more natural cycle, less inhibited by built forms; such as underground carparks, floor slabs and large scale foundations. The planting systems integrating bamboo and the reduction in ground plane contact also reduces run-off from rain and thus, reduces the load on future stormwater systems. This means that the site is regenerated into a more natural form once the cleansed soil has been returned.

At the end of first stage of development soil on the site will have been returned to safe levels, natural water tables and flows will be resumed and there will be measures in place to reduce air pollution levels.



**Figure 81:** Hexagonal structural framework detail (stage one). A conveyor system attaches to the steel allowing for the transport of dirt. The frame is clad in panels that use a TiO2 coating based on that of Pro-solve panels.





Figure 82: Stage two - re-inhabitation of site. The smaller buildings wrapped around the tanks are residential while the tanks are a range of uses, including carparking building (far left), office space (centre left) and church (far right).

## *Stage two - Urban regeneration*

Once the site has been remediated it will become safe for inhabitation. The project argues that to cleanse the earth, only to build over it and again create impermeable ground planes is a tremendous waste of productive land. Therefore the majority of building around the tanks will be raised up, supported by the frame structure and the tanks themselves.

Once the tanks have fulfilled their role in the remediation process they present two options: be removed, or integrated into the development. The design focuses on the latter, allocating public and commercial functions to the larger tanks, such as an art gallery, parking building, gym and church. Tanks are also used for greywater storage and treatment and for water storage, heating and energy production. These functions have been selected as they are very inwards focused, requiring few changes to the tanks, as openings compromise their strength as shell structures. Interior functions within the tanks are a mixture of self-supporting boxes, such as in the gym; or floors supported from the tank shell. The smaller tanks at the southern end of the reclamation are devoted to residential, although this has not been investigated beyond precedents such as *The Silo* and *Oil Tank (Oljetanken)*.

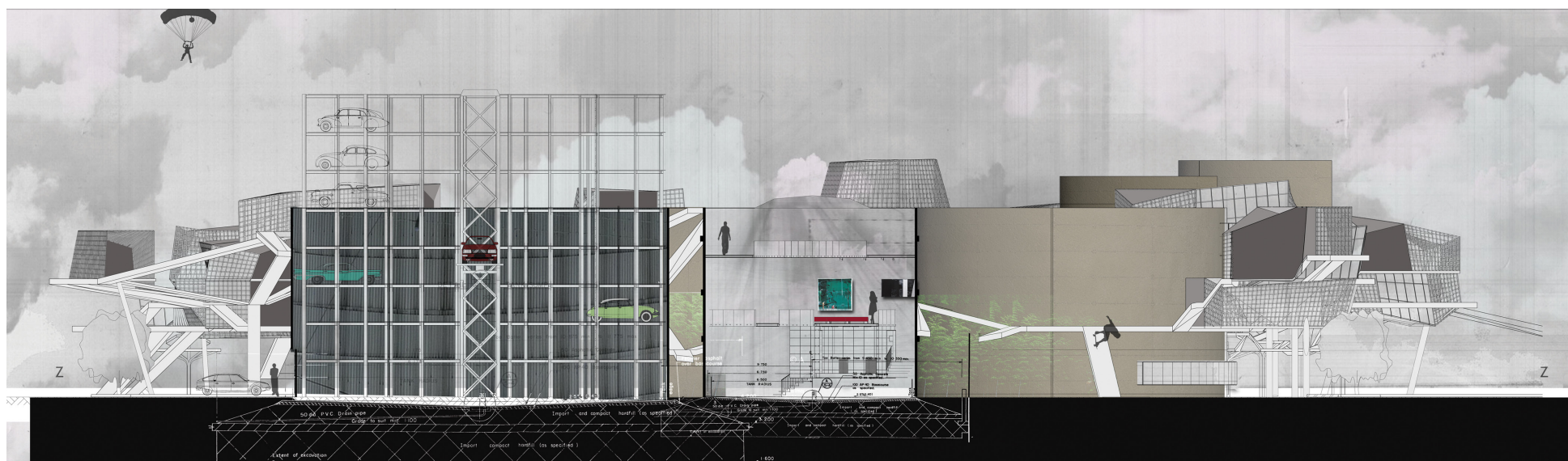


Figure 83: Section Z - Z through the site once remediation is complete. The tanks that are sectioned have been reused as carparking and gallery space. The frame now provides access and utilities to the residential units.

Around the larger tanks the hexagonal frame remains. This is now utilised as access and support for the residential units. The form creates private paths between the units, with the interior of the hexagonal frame used for plumbing and wiring services. Greywater is also piped in the frame (see below), or runs above, supported by the tanks.

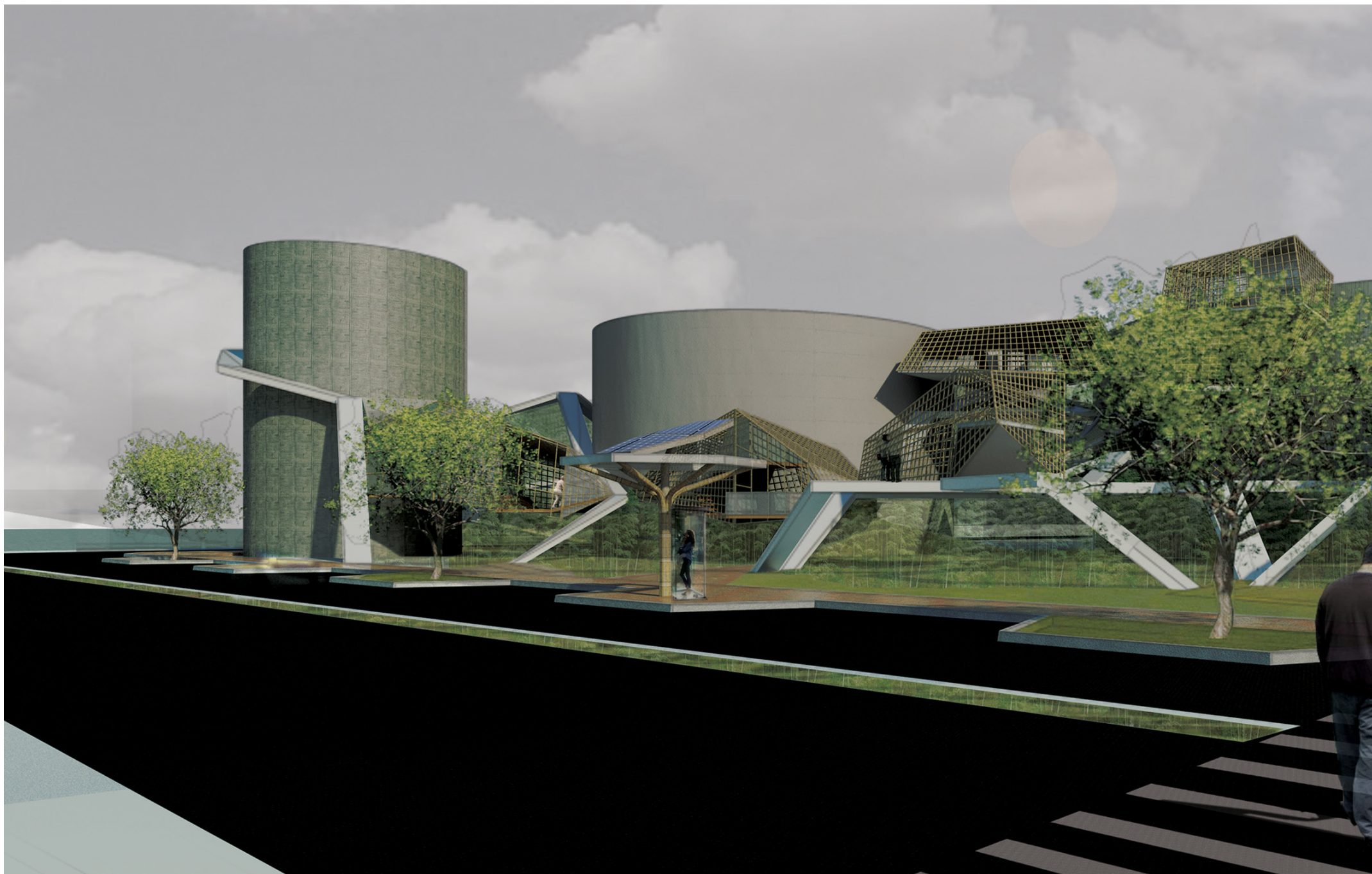
The residential units are designed as a range of sizes to cater for a wide range of situations. The larger units have three - four bedrooms, whereas the smaller units are one - two bedrooms. The sizes range from 45m<sup>2</sup> up to 120m<sup>2</sup>. They are detached - continuing the widely accepted New Zealand inhabitation style, but with creative and effective uses of space and without the allotment of land. Where possible, high stud heights are incorporated into open plan living areas to allow for loft sleeping areas and to provide for storage solutions. The units are timber frame where possible, with LVL I-joists or steel I-beams if required to span across the hexagonal frame. They effectively have two external cladding layers. The outer layer is built from the bamboo that is grown on-site. The vertical tubes are used for drainage, supported by the horizontal layer of bamboo, which is fixed to the second cladding, a cavity plywood system over a timber frame.



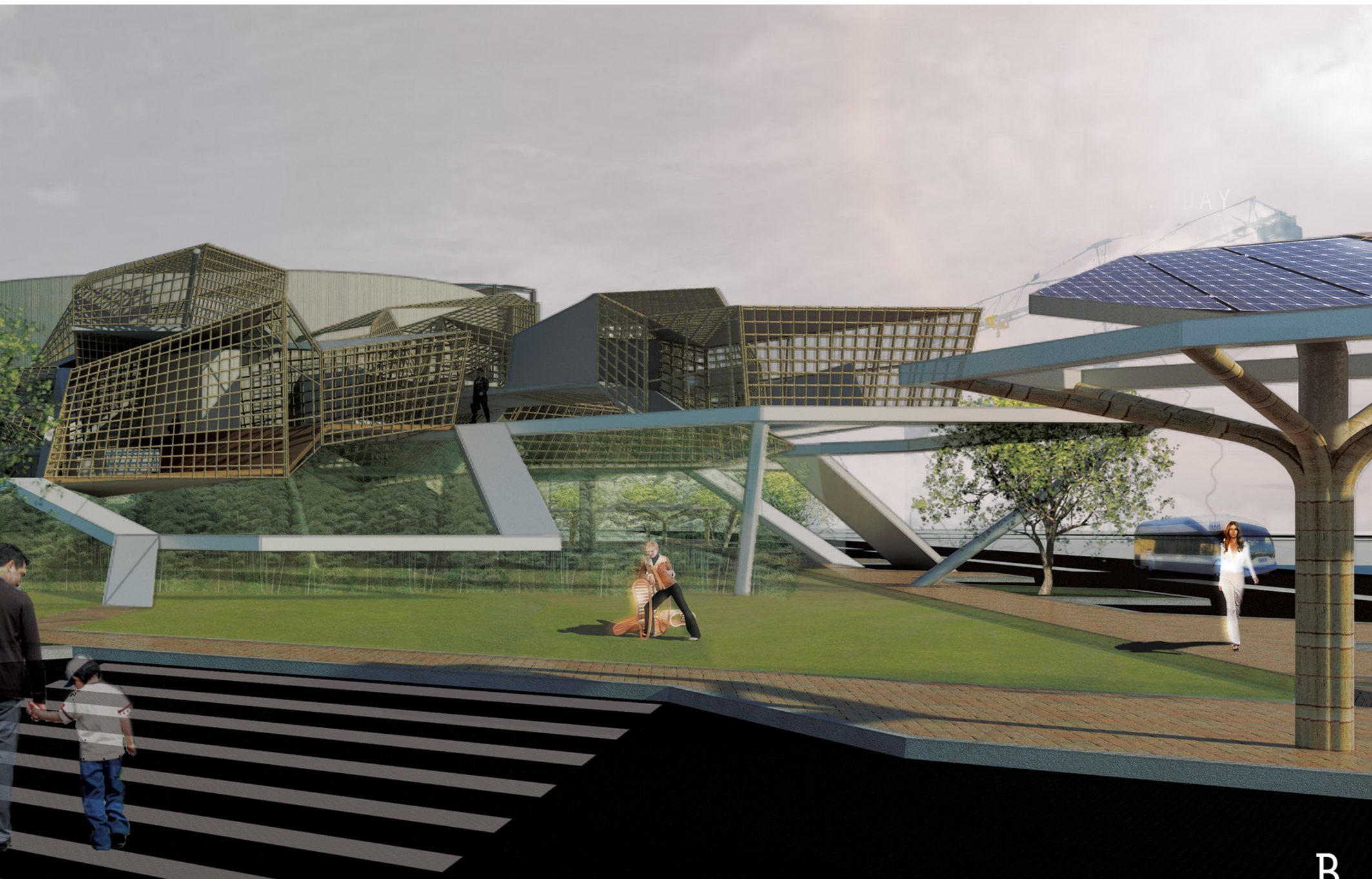
Figure 84: Hexagonal structural framework detail (stage two). The frame is now used for access. It is fully clad in panels that use a TiO<sub>2</sub> coating based on that of Prosolve panels. Handrails attach to the structural steel and services run through the centre.

Figure 85 (following pages): Perspective view of the site looking back towards Auckland CBD. The drawing expresses the complexities of the scheme.





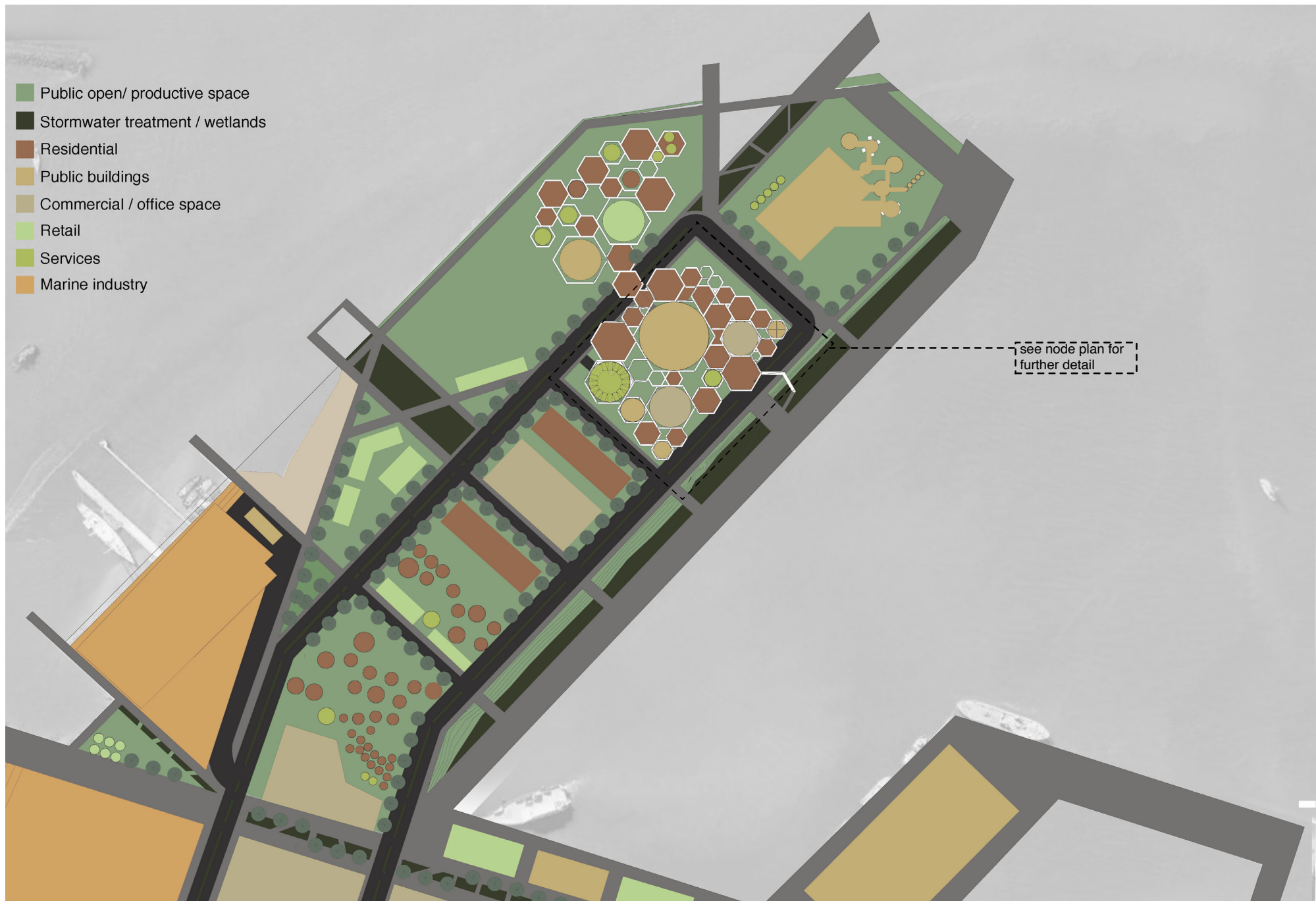




B



- Public open/ productive space
- Stormwater treatment / wetlands
- Residential
- Public buildings
- Commercial / office space
- Retail
- Services
- Marine industry

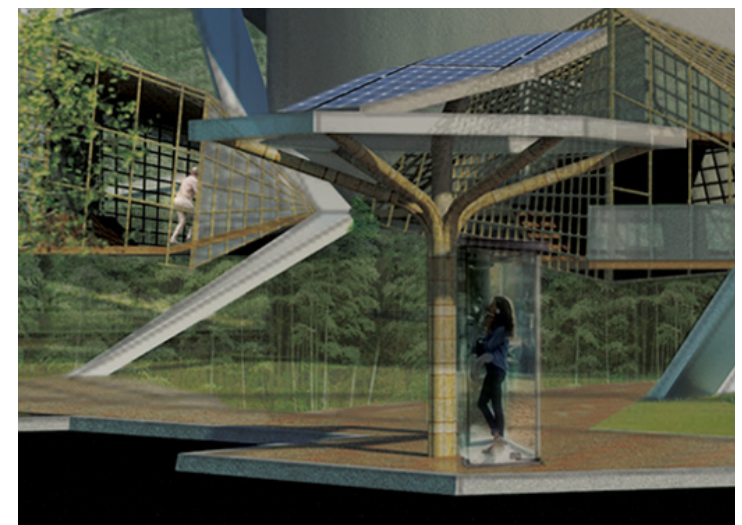
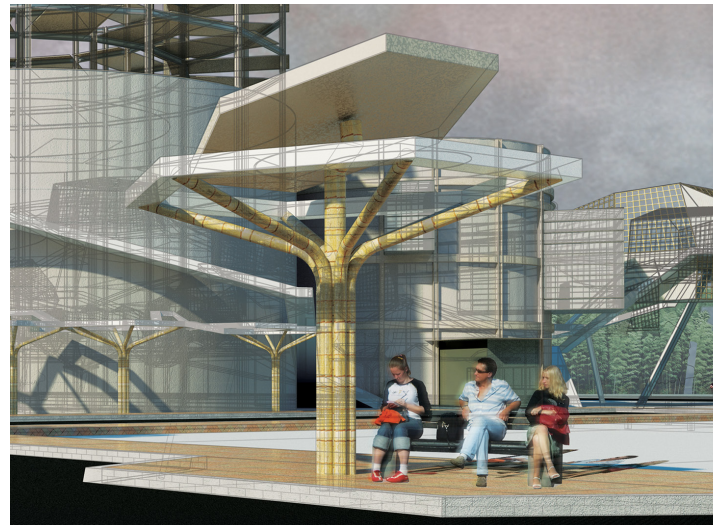


The wider masterplan incorporates more traditional buildings in the plots between the tanks; however, these plots are limited where possible to leave cleansed land available for non-built use. The masterplan allocates space for the marine industry, commercial, residential and productive sites and a significant portion of space as open or green space. These are envisioned as public sheltered areas and promenades with access to amenities and relevant retail spaces. It is important to find a balance between public open space, private open space and the productive spaces suggested by Bogunovich to provide a showcase of how new urban inhabitation can be locally and regeneratively focused. These productive spaces are planned as a mixture of food or plant production, energy generating sites and natural treatment facilities, similar to the wetlands mention in Bradbury and Hinton.

The layout of the site follows a similar pattern and street grid to the existing proposal. Having a loop road creates more traffic across the site, an important safety aspect. The roads are wide with on-street parking, provisions for public transport and non-motorised transport. Activating the vehicular paths, on-street parking and mixed use transport results in slower moving traffic. The existence of Wynyard Wharf is utilised for a public promenade and provides further pedestrian, non-motorised vehicle access and access to the water. The promenade is continuous around the site to encourage public usage across the site. This helps address the outer third of the peninsula development, which typically, is hard to make financially successful. To generate interest in this end of the site, a landmark building is proposed at the northern-most section of the reclamation. This has not been designed or specified but from public consultation, an art gallery, museum or music venue have all been previously suggested (The New Zealand Herald, 2006).

Figure 86 (opposite page): Masterplan of proposed Wynyard Quarter. The proposal draws inspiration from existing plans but allocates space very differently, privileging green and open space.

Figure 87, 88: On-site energy generation. These structures have a number of uses: solar power generation, rain water storage and shelter for the public. It is also envisioned they could be used for amenities or kiosk-type shops.



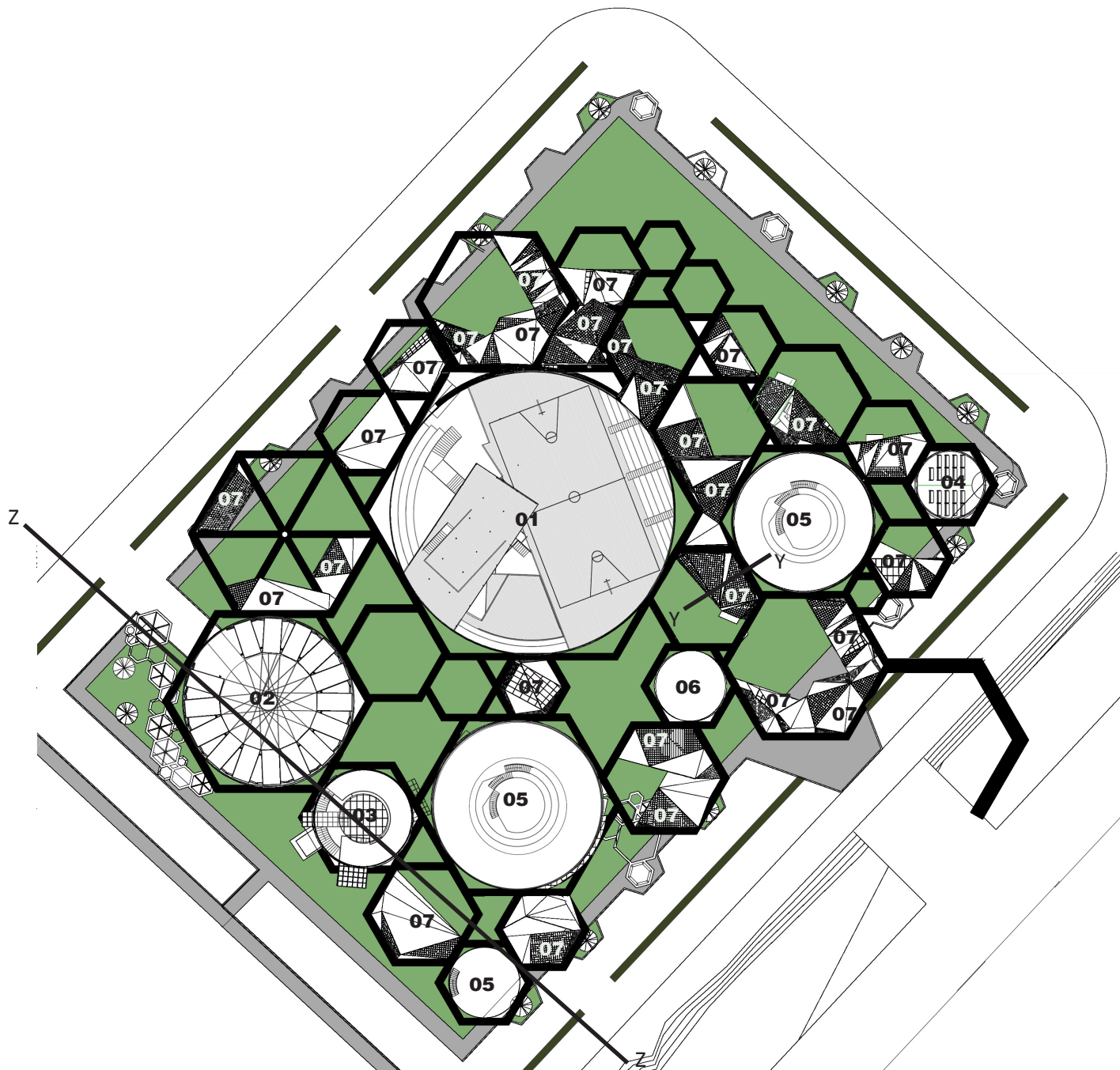


Figure 89: Nodal plan.

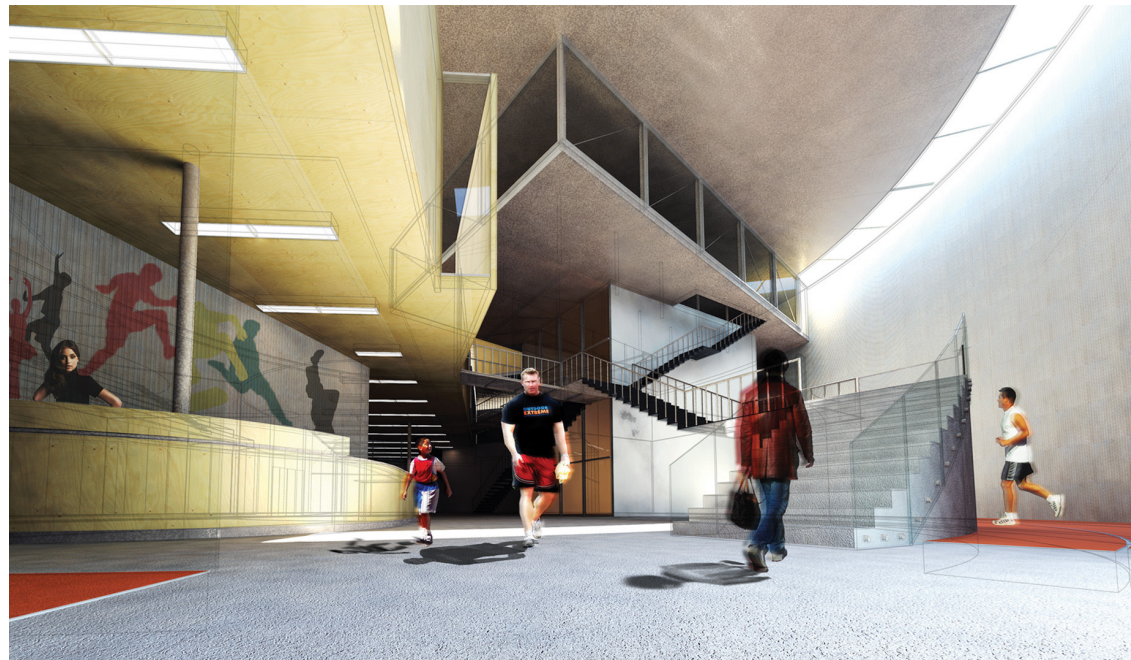
- 01. - Gym
- 02. - Parking
- 03. - Gallery
- 04. - Church
- 05. - Office / commercial
- 06. - Greywater treatment
- 07. - Residential
- - Raised pathways / access
- - Open space / bamboo crops
- - Footpath



Figure 90: Interior view of the gallery space. Natural light is mediated through skylighting and the opaque glazed boxes creating a highly internalised and effective gallery.



Figure 91: Gym. Also a very internalised space, the vast nature of the tank makes this an intriguing space. The interior structure is largely self supporting.





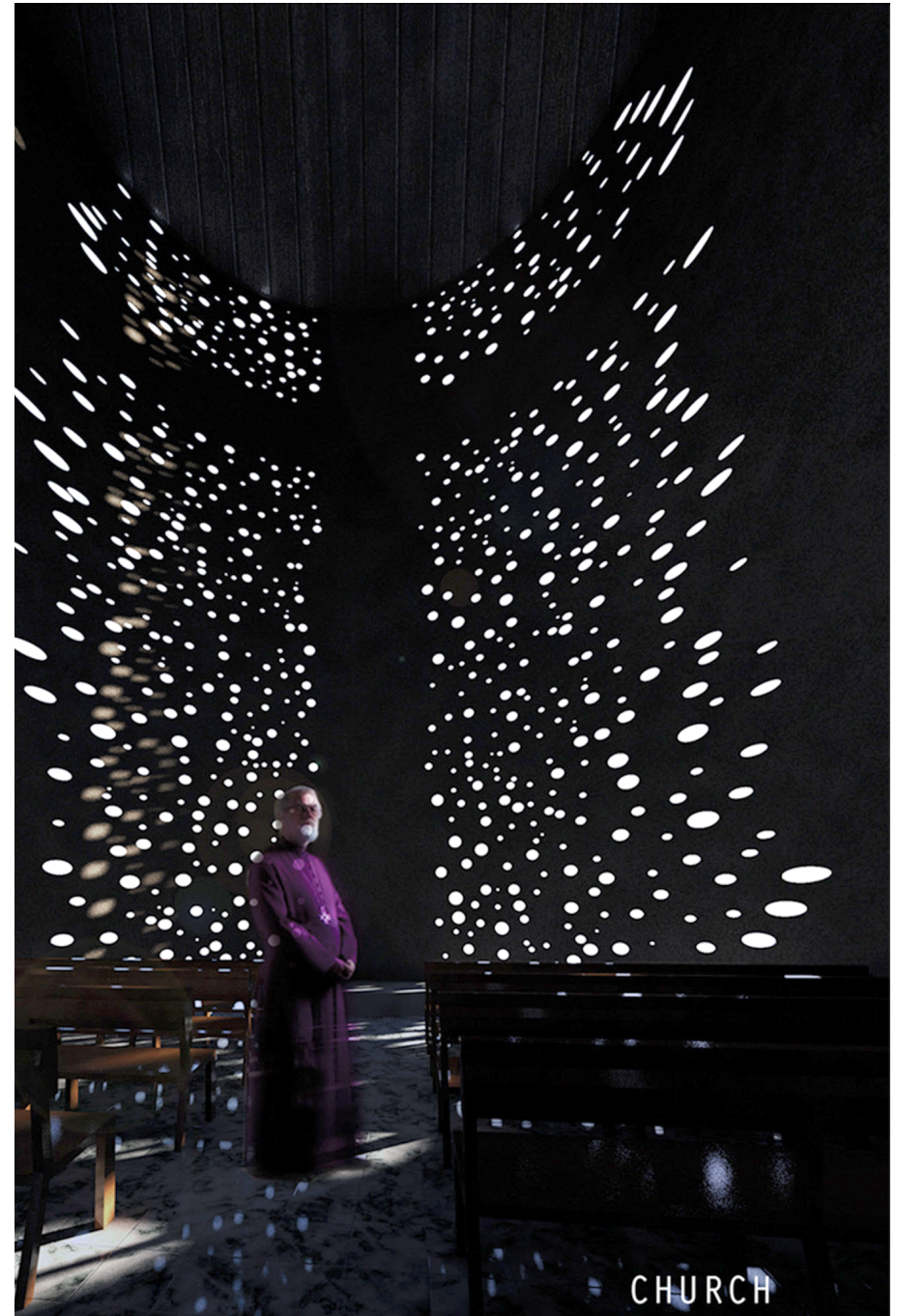
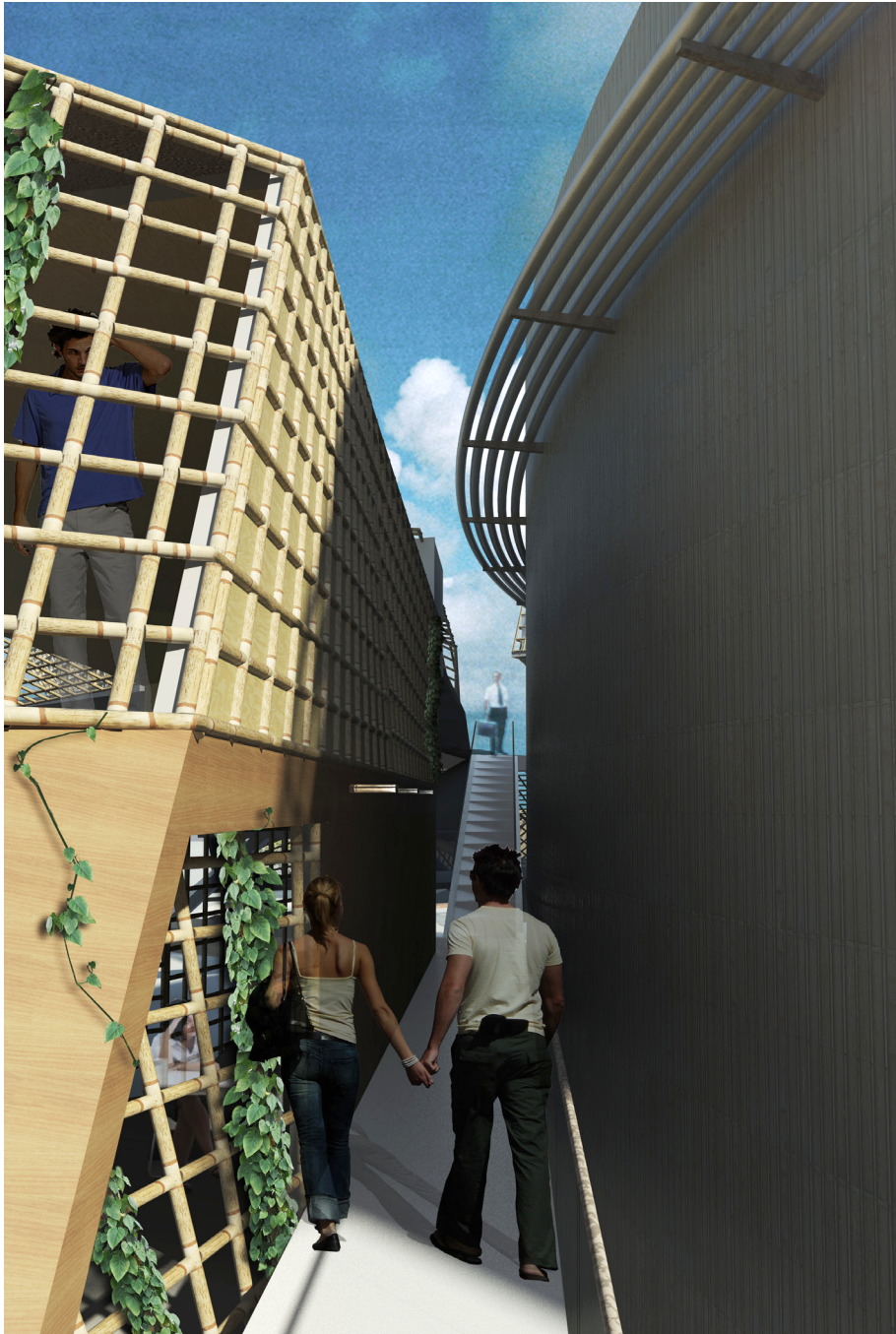




Figure 92, 93 (L-R, opposite page): View along the hexagonal framework between residential unit and a tank. Over time it is envisioned that vines will grow up the sides of both the residential and tank structures, softening the industrial aesthetic. Greywater pipes can be seen traversing the tank above the frame.

Church. Small circular holes are cut in the exterior of the tank. These do not affect the strength of the shell and create amazing interior lighting effects.

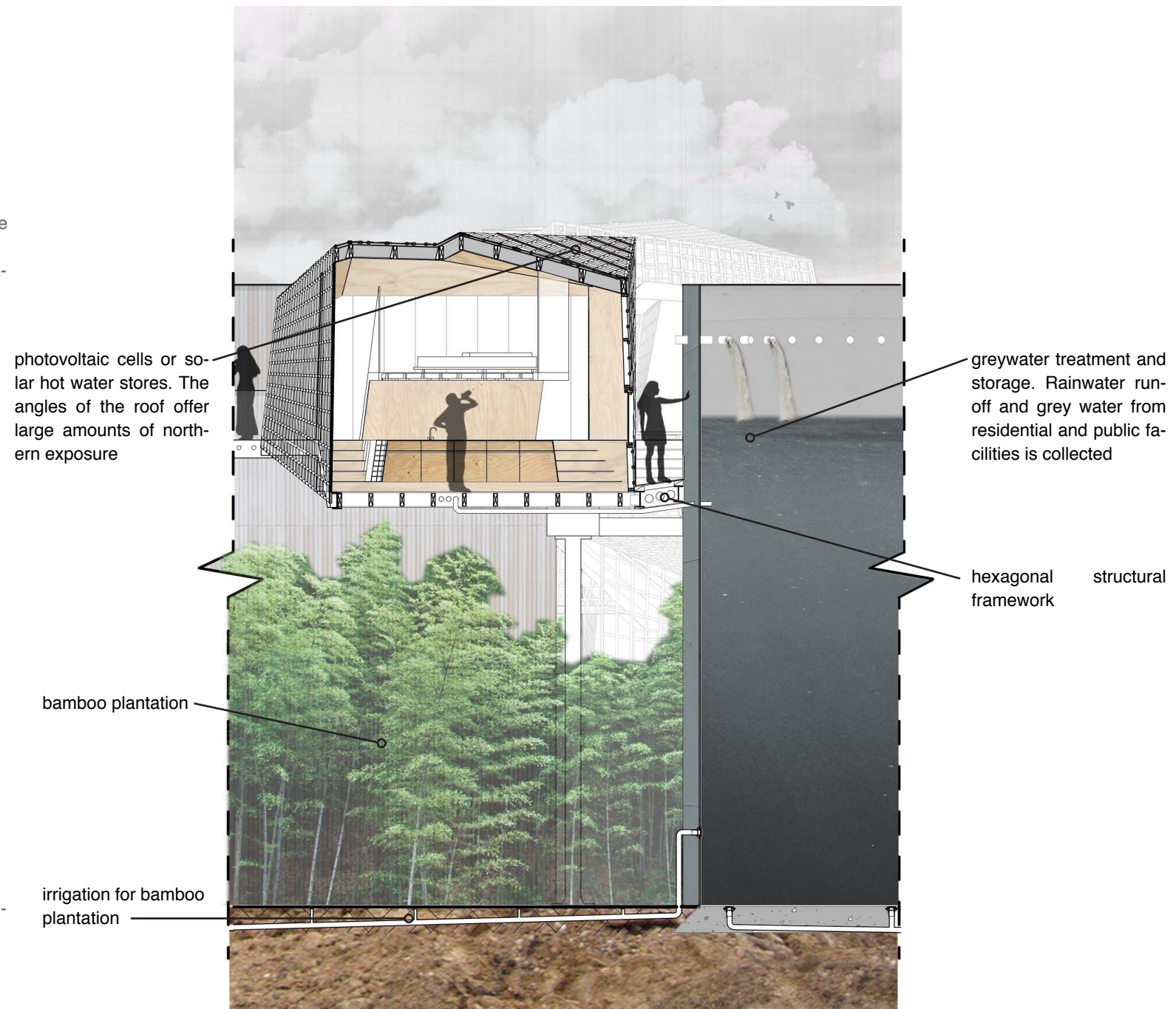


Figure 94: Section Y - Y, through residential unit, hexagonal frame and greywater treatment tank. After treatment process, greywater is utilised for irrigation of the bamboo that grows between the tanks.

Figure 95: 2 bedroom apartment plan  
scale 1:100

- 01. - Entry
- 02. - Kitchen / dining
- 03. - Lounge
- 04. - Bathroom
- 05. - Laundry
- 06. - Bedroom

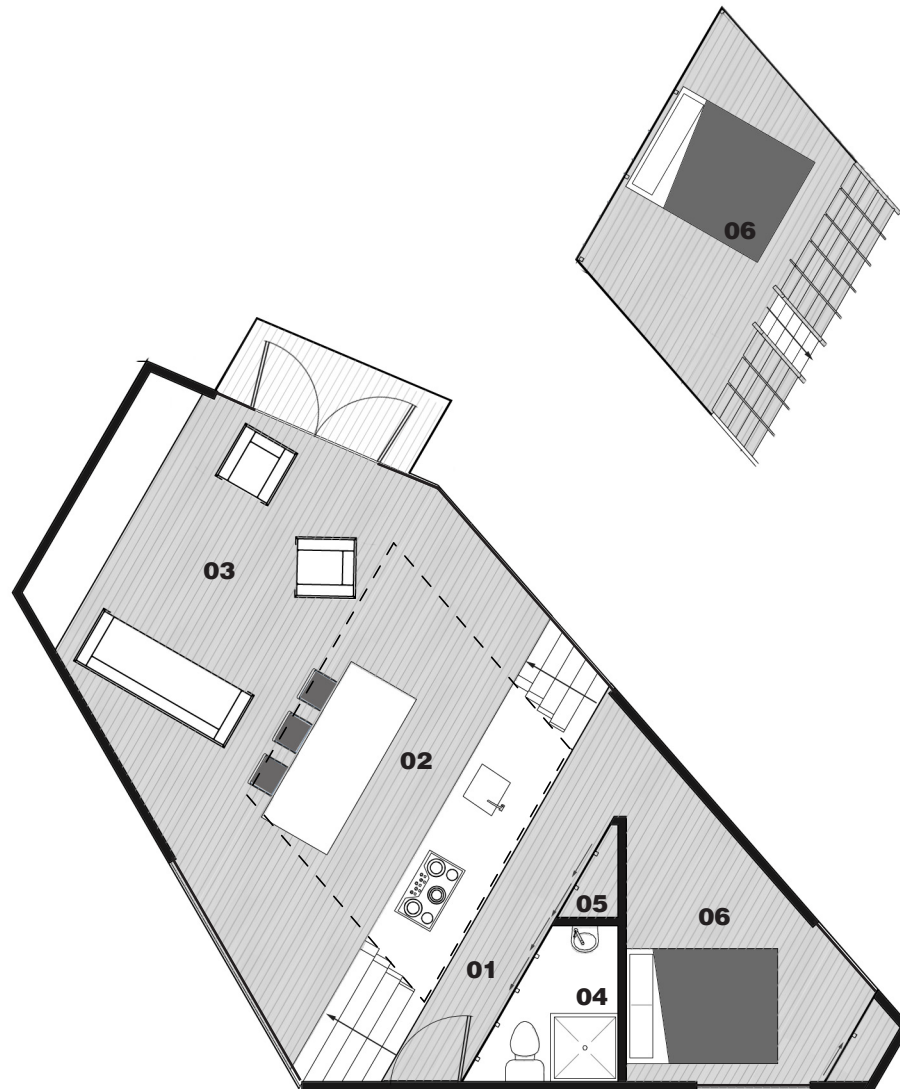


Figure 96, 97 (opposite page): Interior views of a 2 bedroom apartment. The loft and condensed areas creates an effective use of space and details such as exposed framing continue the industrial aesthetic of the development and functionally can be used for storage.

Sections of the units are opaquely glazed for privact. This results in a latern like ef-  
fect at night, cotrasting against the impos-  
ing forms of the tanks.





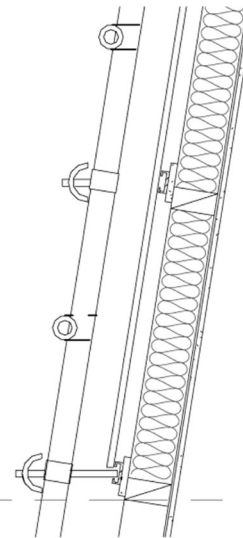
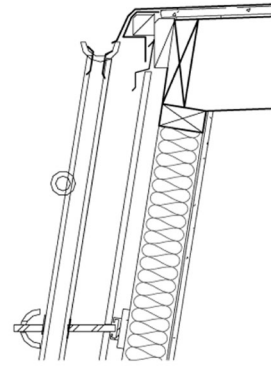
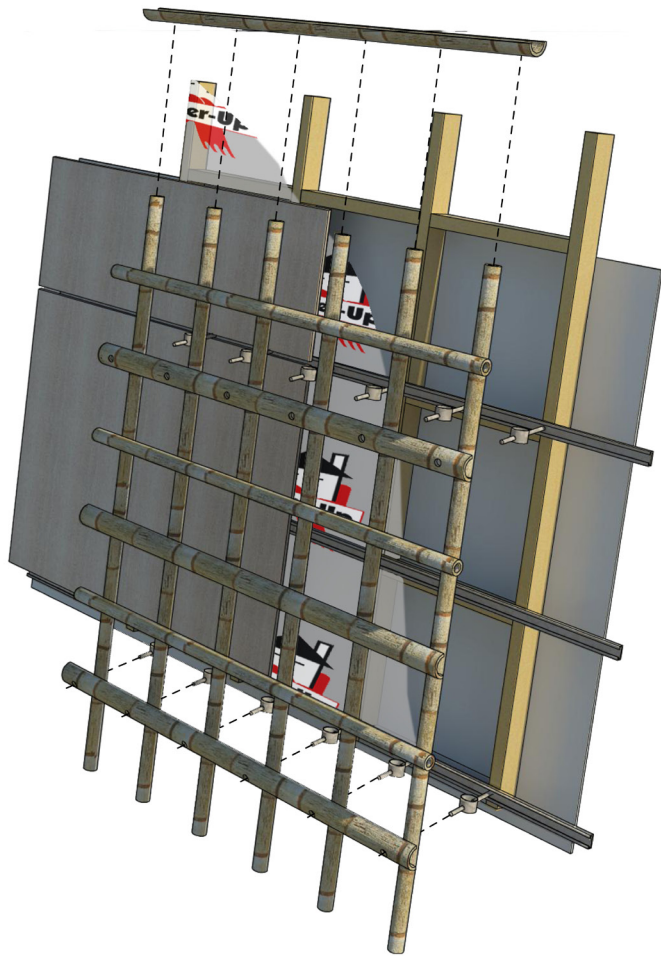


Figure 98: Bamboo cladding and timber frame wall details. Bamboo splinters when subjected to screws or nails. Therefore it must be bolted or tied. This makes de-construction much simpler, which is another positive for using bamboo. The vertical elements are used as downpipes for the drain. They are fixed to horizontal drained cavity battens with a circular shoe fitting, which in turn fixes the horizontal bamboo. This horizontal bamboo is used for privacy, to facilitate the growth of vines.



### *Stage three - Extended lifespan*

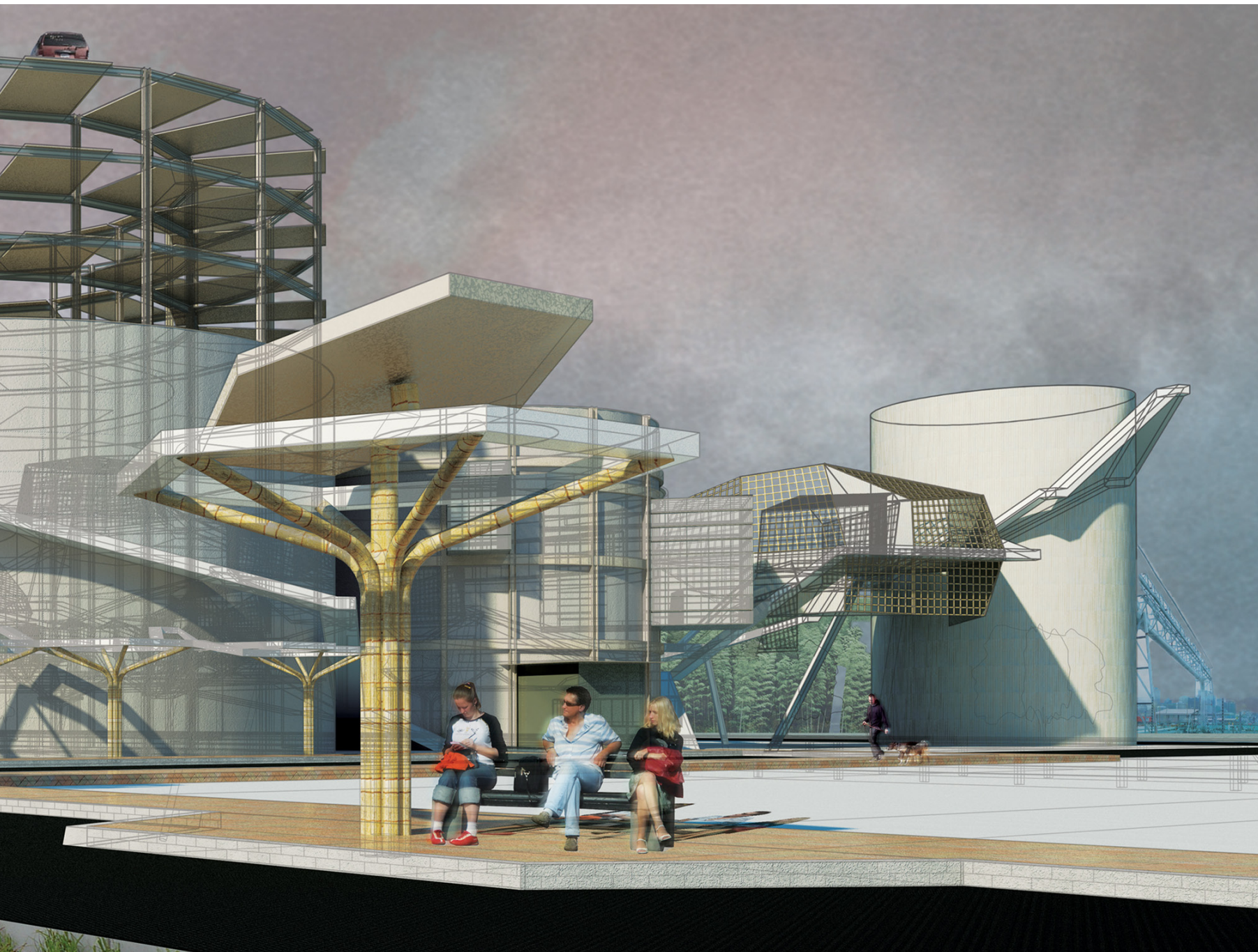
As stated in Chapter three, the lifespan of development is a crucial issue to address ecological and environmental impact. The re-use of the tanks and the hexagonal frame provide a long lifespan for the site. Due to the size of the tanks, their uses can be flexible with internal changes not affecting the outer shell. However, as any building, they do have a design lifespan. Dependent on the success of the development it may be necessary to eventually replace the shell structures with more conventional buildings, or single sections replaced as required. The frame provides a long term constructed solution. This allows for the infill units to adapt as the needs and functions of the development evolve. The use of timber in the infill units creates structures that can be extensively recycled. At the end of their lifespan they can be disconnected from the hexagonal frame, deconstructed and replaced with new units.

With regards to functions upon the ground, the limited footprint of building allows for adaptive landscapes. As James Corner (2006) comments, successful “urban infrastructure sows the seeds for future possibility, staging the ground for both uncertainty and promise” (pg. 30). These ideas are tied into the development through open space. Productive spaces can be easily altered and, dependent on people movements and trends, their relationship to public usable spaces can be moved or realigned (and vice versa).

Figure 99 (following pages): Perspective view of the nodal development looking north, with the gym tank (left), carpark tank (centre) and art gallery tank (right) visible. Swales separate traffic and control pedestrian movement, making for safer crossings.











# Discussion and Conclusions

The following chapter discusses the strengths, motives and drivers behind the research and examines the suitability of the design response. The basis of this critical assessment is the notion of 'architectural regeneration,' specifically concerning site remediation and urban inhabitation patterns. Subsequently future design steps and possibilities are considered. Finally, this chapter concludes, identifying the solutions drawn from this research and design study.

## *Discussion*

George Orwell notes in *The Decline of the English Murder and Other Essays*:

There are four great motives for writing (or any other creative endeavour):

Sheer egoism

Aesthetic enthusiasm

Historical Impulse (to record)

Political Purpose in its broadest sense - a desire to push the world in a certain direction, to alter other people's ideas of the kind of society they should strive for (pg. 183).

This research is initiated by the acknowledgement that current lifestyle and societal patterns of the Western World need to change significantly and quickly. It aims to contribute to the larger body of knowledge concerning inhabitation patterns and site remediation. It notes that we need to do more with less and approach the issues associated with increased population and changes in global climate creatively. It needs to be acknowledged that while technology can aid in the regeneration of the earth's systems it is not a comprehensive solution. Attitudes and behaviour regarding building, consumption and separation between humanity need to be readdressed.

Albert Einstein eloquently stated “we can't solve problems by using the same kind of thinking we used when we created them” (Space and Motion, 1997). As such, this thesis attempts to identify a progressive design solution by bringing together new technologies and time tested, traditional methods in new creative ways to resolve existing issues.

### *Site remediation*

The research and design offers solutions to the issues associated with site remediation. It assesses the site specific conditions and due to the presence of heavy metals and SPH's, incorporates bioremediation into the architectural features and make-up. It is assumed that this process can be undertaken in the tanks; however, more extensive testing needs to be initiated. The advantage of ex-situ bioremediation is that the process becomes highly visible on site and can be associated with new methods of dealing with site contamination. The disadvantage of the bioremediation process is that it occurs over an extended period of time to remove pollutants to a safe level. Currently soil is usually removed to landfill, typically due to cost implications. This research does not dwell on cost. Instead, it focuses on the environments potential to enhance development.

Although cost is largely monetary, environmental costs are also considered. The hexagonal structural framework is made of steel, which has a high embodied energy. This is justified over concrete or timber because of the expected lifespan and the reduction in man hours allowed by the steel frame during construction due to the ease of steel connections and fabrication. Regular treated timber has been ruled out, but LVL or glulam may be feasible options but require additional investigation.

The cladding for the frame utilises technology used in Prosolve 370e panels. To ensure their effectiveness in a

different formation, testing is required to ensure the air cleansing ability and also the best material to be used. Currently this is a thick plastic, but may need further reinforcement to endure the impact of planned use.

### *Urban regeneration*

The design accepts the need for a multi-use development to ensure the viability of such a large scale project. The tanks and frame structure easily allow for changes in function to occur at small and medium scales and offer significant future proofing for changes in function. More investigation is required to obtain an appropriate balance between public facilities and commercial functions as well as how much land would be required to generate energy and other productive and long term measures, such as stormwater treatment area.

Focusing on a wider masterplan and simultaneously, a specific node or area creates difficulties in between the scales. Inevitably there are other aspects of the large site that need to be addressed and more intently developed. To ensure the full extent of the peninsula is utilised the 'landmark' building at the seaward end of the site needs to be developed further. This site is critical to the success of the overall design, as it needs to draw visitors from across the site and from around the city and region. In saying this, the 'build it and they will come' mentality is not appropriate. Neither does the building have to be public. It can be as Bogunovich suggests a "wind, sun and sea-powered and/or hydrogen plant" (2009).

The overall solution effectively addresses both site issues and the requirements of an urban development. However, such megastructures have been criticised. In the past the few that have been built have had mixed successes. As Reyner Banham noted in 1976:

[Peter] Hall's critique [of megastructure] had two cutting edges: one was the destruction of existing urban fabrics... He then went on to explain what the replacement was likely to be, and now megastructure felt the other cutting edge directly, being attacked not only for what it was, but also the intellectual pretensions of its exponents (pg. 204).

Part of the issue is the 'utopian' nature that is invariably associated with such large scale work. This project has utopian aspects within it. Despite this, the project is not thought of as utopian. Rather, the project focuses on the potential of the earth to be utopia if behaviour and consumption are altered.

## *Other issues*

As the project is devised as a three staged development, time is an integral factor. The design aims to limit the influence of time by offering two levels of intervention, as both a larger structure and smaller, removable units. The solutions put forward are founded in history but seek the future. It is acknowledged that, as with most future orientated work, the actual reality and technologies that are available will be significantly different. This may also be the case with climate and sea levels.

Changes to Auckland's layout may also have a large bearing on development. The route of second harbour crossing, to alleviate pressure on the harbour bridge, has been suggested as spanning right across the site. This is the draw-back to such a site specific response but due to the unique issues associated with each brownfield site, a generic framework is not an appropriate solution.

Overall, the project successfully addresses the three main areas of contamination concern and integrates them into an architectural and urban solution that implements an alternative solution to current inhabitation patterns. It offers a regenerative solution that strives beyond sustainability, breaking down the separation of the built and ecological environment.

## *Future development:*

The project offers significant scope for future development. The stages described create a framework that has a long lifespan. This allows for changes in programme and use to be easily incorporated. To predict these would require more in depth study of facilities and amenities surrounding the site. As the design presents a master plan and then focuses on one specific node there is scope for more detailed planning at a wider level. The first programme to define further is for the northern-most site. Due to its prominence and location the selection of this use is vital to the development.

To continue to push the agenda of a productive landscape further investigation into useful materials and resources could also be undertaken. These may be food, energy or construction based and may help to define the northern site.



## Conclusions

New Zealand's international image and integrity has been damaged. The issues that New Zealand faces, regarding climate, pollution and population growth are serious. The research shows that, despite this, there are creative and successful solutions to these problems. To integrate these into design and undertake remediation and regeneration through architecture requires careful consideration, but can be implemented through simple interventions. The main factor required is a change in focus; away from monetary focus and instead to environmental focus. This needs to occur immediately to avoid further environmental damage and to begin remediation of existing damage.

The biggest behavioural change needs to be considering the way in which we live. As urban responses, architecture and urban planning play very important roles. The creation of mixed use sites with green space allows for localised consumption and recreation. There are important planning lessons to be learnt from the Japanese Metabolists - who dealt with sprawl and lack of space almost 50 years ago. These issues have previously been poorly addressed by New Zealand developers and a different rationale and process needs to be undertaken. It is time for New Zealand to stop appearing green and start taking significant steps to reducing environmental impact.

The project successfully investigates and addresses the issues of regeneration, both of site and urban conditions. It sits between the two streams of thought, technological and theoretical and extracts the positives of these two elements to create an informed solution that recognises past, present and future use. It confirms that regeneration of contaminated sites can be incorporated into architecture, both through technology and programme. The final design outcome is intentionally bold and eye catching. However, it does not strive to be iconic. Instead it is an exemplary architectural solution that influences behavioural change and regenerates damaged environments.



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# Appendixes

The following documents are sourced from the Auckland City Council Archives and were accessed 17/08/2010.

Appendix One is from the Harbour Edge Advisory Team (AKC) (1990) *Waitemata Waterfront - Harbour Edge Development Group - Vision for the Auckland Harbour Edge*. Auckland: Auckland City Council (ACC).

Appendix Two is believed to be an appendix of Harbour Edge Advisory Team's report, but the exact source is unknown, except that it was prepared for the Auckland City Council (unknown)

### CONCLUSIONS AND RECOMMENDATIONS

This report has outlined the following:

- The known extent and degree of soil contamination within the study area.
- The known extent and degree of groundwater contamination within the study area.
- The known types of contaminants in both soil and groundwater in the study area.
- The information gaps regarding soil and groundwater quality in the study area.

The review has found that there is significant soil and groundwater contamination within the study area. A large proportion of the study area has not been investigated, and there is potential for further contamination to be found.

The shallow groundwater in the study area has been found to have plumes of floating hydrocarbon product in former and existing oil industry sites. Dissolved hydrocarbons in groundwater include polynuclear aromatic hydrocarbons (PAHs) and benzene, toluene, ethylbenzene and xylenes (BTEX). Groundwater has also been found to contain elevated concentrations of a wide range of metals and metalloids, and near the Lighter Basin groundwater has also been found to contain nutrients and other contaminants indicative of landfill leachate. Groundwater in the study area does not meet the New Zealand drinking water standard (1995), and the concentrations of many inorganic and organic contaminants exceed Dutch Intervention guidelines.

Soil in the study area has been found to be contaminated with hydrocarbons including PAHs and BTEX in former and existing oil industry sites. Soil has also been found to contain elevated concentrations of a wide range of metals and metalloids, in particular lead at former and existing oil industry sites. Soil in some areas was found to contain manufactured gas plant (MGP) waste, which is likely to be a source of PAHs, metals and other contaminants. Soil near the Lighter Basin, and elsewhere to a lesser extent, has been found to contain inorganic and organic refuse.

Investigations within the study area have been almost entirely restricted to former and existing oil industry sites and the Lighter Basin area. Much of the study area has not been subjected to soil and groundwater investigation.

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This report should be used very cautiously for planning and development decisions on the future use of the land in the study area. The development of any parts or the whole of the study area should consider the following:

- The need to quantify the soil and groundwater quality.
- The need to conduct risk assessments for various development options of the study area.
- The need to prepare and follow proper health and safety plans for field investigation and site development purposes.

It is understood that the future development of the study area has not been finalised. The development of the study area or part of the study area will also need to consider soil and groundwater remediation options on parts of the study area which may present unacceptable risks for some uses. If the study area is developed in parts, then remedial solutions must consider the impact of soil and groundwater contamination in adjacent sites during development, remediation and post-remediation.

A work programme with cost estimates to bridge the soil and groundwater contamination information gaps within the study area will be provided to ACC in a separate letter by Woodward-Clyde. Based on the known and possible contaminants and hazards, a health and safety plan for field works to obtain soil and groundwater quality data will also be provided as a separate plan to ACC. The site investigation procedures should also follow strict protocols (for example the type and source(s) of petroleum hydrocarbon contaminants) to avoid legal liability issues under the Resource Management Act (RMA) 1991.

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## Appendix Two

DEPARTMENT OF PLANNING & DEVELOPMENT SERVICES

APPENDIX : THE MATERIALS STORED AND HANDLED AT THE WESTERN RECLAMATION AREA AT PRESENT AND PROPOSED. THE MATERIALS IN ITALIC PRINT ARE THOSE NOT IDENTIFIED BY THE ARC HAZARDOUS SUBSTANCE QUANTITY THRESHOLD SCHEDULE.

| Petroleum products     | class | max. store (m³) |
|------------------------|-------|-----------------|
| Petrol                 | 3a    | 9               |
| Avgas 100              | 3a    | 3492            |
| Jet-A1                 | 3a    | 5670            |
| Hexane                 | 3a    | 440             |
| Kerosene               | 3b    | 1130            |
| Diesel                 | 3b    | 18790           |
| Aromatic hydrocarbons  | 3b    | 1720            |
| Light fuel oil         | 3c    | 6120            |
| Heavy fuel oil         | 3c    | 17470           |
| <i>Lubricating oil</i> | -     | 12000           |
| <i>Bitumen</i>         | -     | 13100           |

| Oils and waxes       | class | max. store (m³) |
|----------------------|-------|-----------------|
| Paraffin             | 3c    | 640             |
| <i>Tallow</i>        | -     | 5020            |
| <i>Vegetable oil</i> | -     | 5012            |

| Gases                 | class | max. store |
|-----------------------|-------|------------|
| Ammonia (ARC 2 tonne) | 2f    | 6 Tonnes   |
| Chlorine (ARC 100 kg) | 2e    | 920 kg     |
| CNG (ARC 2000 l)      | 2b    | 400 Nm³    |

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| Alcohols       | class | max. store (m³) |
|----------------|-------|-----------------|
| Ethanol        | 3a    | 180             |
| Methanol       | 3a    | 490             |
| Isopropanol    | 3a    | 305             |
| 1,2 Propandiol | 3a    | 319             |
| Butanol        | 3b    | 150             |

| Solvents                                | class | max. store (m³) |
|---|-------|-----------------|
| Acetone                                 | 3a    | 1250            |
| Methylated spirits                      | 3a    | 180             |
| Perchloroethylene / tetrachloroethylene | 3a    | 190             |
| Toluene                                 | 3a    | 1550            |
| Turpentine                              | 3b    | 2502            |
| White spirits                           | 3b    | 1945            |
| Xylene                                  | 3b    | 2000            |

| Other chemicals                        | class | max. store (m³) |
|--|-------|-----------------|
| N-Butyl acetate                        | 3a    | 180             |
| Butyl acrylate                         | 3b    | 320             |
| <i>Carboxylic acids</i>                | 8     | 383             |
| <i>Caustic soda / sodium hydroxide</i> | 8     | 2100            |
| <i>Dioctyl phthalate</i>               | -     | 540             |
| Methyl ethyl ketone                    | 3a    | 1044            |
| Methyl isobutyl ketone                 | 3b    | 428             |
| Methyl methacrylate                    | 3a    | 580             |
| <i>Methyl proxitol acetate</i>         | -     | 50              |
| <i>Methylene chloride</i>              | 6     | 550             |
| Monopropylene glycol                   | 3b    | 540             |
| <i>Polyols</i>                         | -     | 943             |
| <i>Sulphuric acid (74%)</i>            | 8     | 1               |
| Styrene monomer                        | 3b    | 500             |
| Toluene diisocyanate (ARC 10kg)        | 6     | 565             |
| Vinyl acetate monomer                  | 3a    | 1330            |
| <i>Zinc dialkyldithio phosphate</i>    | -     | 232             |