An architectural design dissertation by Johann H. Boonzaaier

NURTURING ARCHITECTURE

SHIFTING CONVENTIONAL ARCHITECTURAL APPROACHES TOWARDS REGENERATIVE ARCHITECTURE

AN EDUCATIONAL ENTEMOLOGY RESEARCH FACILITY
IN THE FORGOTTEN ORIGINS OF PRETORIA CENTRAL

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AN EDUCATIONAL ENTEMOLOGY RESEARCH FACILITY IN THE FORGOTTEN ORIGINS OF PRETORIA CENTRAL

By Johann H. Boonzaaier

Submitted in fulfillment of part of the requirements for the degree of Master in Architecture (Professional)

Department of Architecture,
Faculty of Engineering, Built Environment and Information Technology.
University of Pretoria

Course Coordinator /
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PROJECT SUMMARY /

Programme /

Educational entemology Research Facility

Site Description /

Eastern boundary of the Pretoria Zoo, south of the Apies River, Located west of the Prinshof School.

Site Location /

Prinshof 349-JR portion 64 R/61

Address /

1 Prinshof St, Pretoria, 0084

GPS Coordinators /

25^0 44’ 11.57” S; 28^0 11; 39.75” E

Research Field /

Environmental Potential

Theoretical Premise /

Regenerative theory focusing on the conservation of insects and their habitats

Architectural Approach /

Finding a relationship between human, building and nature by adapting steward Brand’s 6 ‘S’ with regenerative theory, by incorporating site as a main building layer.

A C K N O W L E D G M A N T /

I would like to thank Dr. Arthur Barker for his support and encouragement this year, helping me to stay motivated and passionate.

A special thanks to my father, Johann Boonzaaier for his unending love and support throughout this year.

Thank you to Lizann Keuler for the editing of this dissertation.

Furthermore I thank my family and my friends that helped me stay calm in pressured situations.

Last but not least I would like to thank our Lord, blessing me through this incredible journey.

In accordance with Regulation 4[e] of the General Regulations [G.57] for dissertations and theses, I declare that this thesis, which is hereby submitted for the degree Master of Architecture [Professional] at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

I further state that no part of my thesis has already been, or is currently being, submitted for any such degree, diploma or any other qualification.

I further declare that this thesis is substantially my own work. Where reference is made to the works of others, the extent to which that work has been used is indicated and fully acknowledged in the text and list of reference.

Johann Boonzaaier

NURTURE /

[nur-cher]

Verb:

To feed and protect
To support and encourage, as during the period of training or development
To bring up; train; educate

Noun:

Rearing, upbringing, training, education, or the like.
Development
Something that nourishes; nourishment; food.

NURTURING ARCHITECTURE /

Architecture as a vessel to protect the growth, stabilization and enhancement of ecosystems in the form of nourishment and educational development

ABSTRACT /

The natural world consists of incredibly complex and integrated systems. Ecosystems and biodiversity all work cohesively to sustainably maintain the basis of our very existence on the planet. These interrelationships form the foundation of all living things and have zero impact on the natural environment. Mankind hugely influences "natural systems" through its introduction of "technological systems". This influence is traceable to the unsustainable extraction of natural resources, which became wide-spread in the industrial era.

Since the start of the industrial era, city borders have rapidly expanded often leaving the inner-city decentralized. Such expansion has made its mark on the central business district of Pretoria, where natural voids have been created in the city fabric. The environment in the CBD, through the impact of human activities, is in a state of decay, which is a threat to the very existence of the ecological environment. Architecture needs to return to its roots and find a spatial condition to co-exist with the natural realm in a regenerative manner. Thus utilizing nature's ability to solve problems that we currently struggle with. This dissertation focuses on regenerative architecture. The ecological environment, and certain insects in particular, provides us with countless solutions. Unfortunately, we sometimes mistake the innovation and services of insects as the aggravation of pests. The proposed program therefore centers on the research of these insects and on learning what they can provide for the greater good of humanity's future; a future where humans and nature have a mutually beneficial relationship.

This project also taps into the closed-loop-system of the regenerative theory in which, nothing is seen as a single entity, but rather as a system where anything is beneficial and interrelates to everything. This theory can only strengthen and densify Pretoria's inner city, filling the voids with systems and contributing positively towards the regeneration of resources.

UITTREKSEL /

Die natuurlike omgewing bestaan uit geweldige komplekse geïntegreerde sisteme. Die ekosisteem en biodiversiteit funksioneer in noue verband om ons bestaan op die planeet volhoubaar te ondersteun. Hierdie inter verwantskappe, is fundamenteel tot alle vorme van lewe en onderhou 'n gebufferde balans in die dinamiese funksionering van die natuurlike omgewing. Die mensdom oefen 'n groot impak op die natuurlike sisteme uit deur sy najaag van ontwikkeling en tegnologiese instellings. Hierdie impak word opgespoor in die nie-volhoubare onttrekking van natuurlike hulpbronne, wat wyd verspreid voorkom en algemene kennis geword het, veral in die industriële era. Sedert die begin van die modern industriële era, het stads grense vinnig gedesentraliseerd uitgebrei wat die binne stads area leeg van ontwikkeling en aantrekkings gelaat het. Sodanige uitbreiding het sy merk op die sentrale besigheids distrik van Pretoria gelaat, waar dit onnatuurlike leemtes in die stads weefsel geskep het. Die sentrale besigheids distrik omgewing het deur die impak van menslike aktiwiteite in verval geraak wat uiteindelik 'n wesentlike bedreiging vir die voortbestaan van die biodiverse ekologiese omgewing inhou.

Argitektuur het nodig om na sy wortels terug te keer deur die herontdekking van ruimtelike omstandigheids posisionering om met die natuurlike rykdom in 'n vernuwende wyse saam te kan bestaan. Dit is moontlik deur die gebruik en nabootsing van die natuur se vermoë om probleme waarmee ons worstel, op te los.

Hierdie navorsings verslag, fokus op vernuwende argitektuur. Die ekologiese omgewing en spesifieke insekte, bied talle oplossings aan ons. Ongelukkig egter word die innovasie en dienste wat deur insekte verskaf word, misken en gesien as 'n uitbreiding van 'n plaag. Hierdie voorgestelde projek daarenteen sentreer op navorsing op bepaalde insekte en om te leer wat hulle kan aanbied vir die groter welvaart van die mensdom se toekoms; 'n toekoms waar die gesamentlike voordelige verhouding tussen mens en natuur meer krities raak.

Hierdie projek sluit ook aan by die "geslote-terugvoer-stelsel" van die vernuwende teorie, waarin geen deel daarin as 'n enkel entiteit beskou word nie maar eerder as 'n sisteem van sisteme, waarbinne elke element voordelig en inter-afhanklik van die ander sisteem komponente funksioneer. Hierdie teorie kan daarom die sentrale stad area van Pretoria laat herleef en versterk deur die herskepping van leemtes en 'n positiewe bydrae lewer tot die vernuwing van natuurlike en mens gemaakte hulpbronne.

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1 / INTRODUCTION

1.1 / PROBLEM STATEMENT

1.1.1
GENERAL ISSUE

The threat of global warming has made news headlines for decades, and although numerous research projects have been launched to help counter this crisis, there has not been any significant change in the restoration of earth's resources.

Global warming is a result of human activity. The process of extracting minerals and resources from the planet's crust is destroying natural systems and so minimizes the biosphere. These extracted resources are processed through excessive "heating, beating and treating"[1] to mold and shape the product. During this process, large quantities of carbon dioxide are released into the atmosphere. This forms part of an invisible layer, making it impossible for heat to escape and ultimately causing the earth's surface to increase in temperature. Global warming strains natural systems.

Climate change is anticipated to increase environmental disturbances (Wells, et al, 2010). Drastic measures must therefore be taken to minimize disturbances in the future development and planning of cities. Current building regulations, like the SANS 10400-XA and SANS 204[2], achieve a certain sense of sustainability. They will, however, not achieve a regenerative solution as the standards set for buildings to be deemed 'sustainable' are very low (Littman, 2009: 8). Sustainability in architecture is inadequate to fulfill the future's need for regenerating the planet's biosphere, as it only stabilizes energy efficiency.

The natural world is an automatic system that 'recycles' and 'uses' resources in a closed loop, everything is connected as a whole and nothing is seen as a stand-alone entity. But we are abusing the resources in our biosphere at a rate faster than they can regenerate (Littman, 2009: 8). The built environment has a linear, one-way-flow. Its process of dealing with waste and resources and this closed de-generative structure results in the rejection of the entire system of the natural world. This rejection leads to the disturbance and degradation of the environment (Littman, 2009: 8).

We need to step back and accept that our current way of thinking about building processes and methods is in sufficient. It needs to be adjusted, our time and energy must be refocused on shifting ideas from sustainability to new and innovative ways of dealing with our current problem. The world is changing rapidly with the development of new technologies and materials, but at a cost. People must understand how nature controls their environment and learn to adapt to nature's way of solving solutions.

1.1.2
URBAN ISSUE

To the settlers of Pretoria and the Ndebele tribes residing

[1] "Heat, beat and treat" is a term used by Janine Benyus to describe the intense energy and processing required to create a product (Pawlyn, 2011: 35).
[2] SANS 10400-XA and SANS 204 regulations attempt to regulate energy use and encourage energy efficiency in buildings (SANS Documant).

in the area before them, the Apies River was a source of life. Farmers who settled here extracted water from the Apies River to sustain their farms. The river later played a significant role in Pretoria's establishment and formed the eastern boundary of the central district in 1879 (Jordaan, 1989: 27). Over time Pretoria extended its boundaries past the Apies River. The city's rapid development and expansion placed extensive pressure on Pretoria's water supply and has polluted the Apies River immensely leaving the once natural beauty that defined Pretoria a mere waste channel. Urban sprawl caused the decentralization of Pretoria's CBD as many of the old buildings in Pretoria did not meet the requirements for commercial use. This, and the search for up-to-date office space, has left certain parts of urban space without ownership. It has resulted in the decay of buildings and spaces between buildings due to a lack of maintenance.

The spaces thus formed in certain parts of the CBD have been occupied with informal activities, which led to the establishment of a crucial informal transport structure currently operating within the city central. This means that the development proposal for the Pretoria CBD, which focuses on the CBD but neglects the decayed spaces, must be reconsidered. Focus should be on densifying the city's original closed-grid-system by incorporating aspects of regenerative development into Tshwane's 2055 development proposal[3].

1.1.3
ARCHITECTURAL ISSUE

A regenerative architectural approach aims to reverse the degeneration of natural systems by providing technical and passive systems able to co-exist with the natural. These two systems should therefore promote the mutual benefits gained from each other in order to develop a greater overall expression of resilience and life (Mang & Reed, 2012: 3).

How can the combination of 'technical and passive systems' with 'natural systems' create a spatial quality for the human condition? Furthermore, how can humanity co-exist with nature? In the relationship between a building and its immediate natural environment there exists a borderline. It represents the very edge where these two components meet and inform each other where they overlap or combine. The transition between these spaces must be designed in a reciprocal manner, indicating a mutual exchange of knowledge (Company, 2013: 1). Architecture influences, modifies and shapes the landscape but the landscape should also influence, modify and shape the architecture.

The shift is thus for the architect to design without following the principles of conventional methods, and to rather design functionally beyond carbon neutrality, by finding inspiration in nature (Pawlyn, 2011: 1).

[3] Refer to chapter 4, Pretoria context

1.2 / RESEARCH QUESTIONS

- Can architecture facilitate human institutions that create opportunities for creative participation in the cycle of natural systems?

- Is it possible to apply 'regenerative design' principles[4] to the practice of revitalizing destroyed or abandoned natural habitats, to accommodate for a mutually beneficial habitat to both humans and nature?

Current urban conditions are generally detached from natural systems and all the beneficial 'services' they can provide humans.

- Can architecture create awareness and initiate an involvement to contribute towards an ecological paradigm[5]?

- Can architecture become an educational platform for the awareness of natural systems and the services they offer?

1.3 / RESEARCH OBJECTIVES

A primary objective is to determine the reconfiguration of Steward Brand's '6 S' theory towards an integration of the 'site, structure, skin and services'. The 'site' represents the characteristics of natural ecosystems and their benefits in creating a habitable space for human life. The 'skin' is the contribution of technical systems to the creation of a habitable space for insects in their natural environment. The aim is to holistically create a mutually beneficial environment where humans and insects can co-exist.

[4] These principles will be discussed in Chapter 3.
[5] The Ecological stream will be discussed in the Chapter 3

1.4 / RESEARCH METHODOLOGY

LITERATURE / Theoretical studies relating to concepts of regenerative architecture are investigated to appreciate the complex issues regarding ecosystems and the desire to go beyond sustainability.

MAPPING / Appropriate site investigation and mapping within the urban framework informed the development of a master-plan and group framework. A study of Eco-mapping deals with environmental issues regarding the ecological and physical conditions, landform, relationships on the site, circulations and movement patterns, existing vegetation and climatic condition. This method is used to establish the site characteristics that led to the informants of a design approach

APPLIED RESEARCH/

Data / The data is then summarized and applied to relevant aspects in order to complete the requirements for the design. The collection of site photos is essential in the study of site characteristics, scale, existing habitats and ecosystems and enables an appropriate design response.

analysis / The relevant data collected is then turned into evidence that supports the development of the dissertation and its arrival at an appropriate conclusion. The data is analysed to obtain the most relevant evidence relating to an outcome of the project. The data analysis is completed in computer investigations through the building of models and the delineation of presentation formats

1.5 / DISSERTATION OBJECTIVES

The objective of this dissertation is to encourage people to recognize the potential of natural ecosystems and how these can not only benefit our way of living, but also contribute to the resilience of Pretoria's CBD and lead to a more regenerative future.

The growth and expansion of city development leaves little room for ecosystems to continue their natural cycle. This proposal will safeguard ecosystems on the intended site, creating an enhanced natural environment with a platform that educates the public by making information freely available. The proposal will also make use of on-site resources, such that it gives back more than what is taken out.

The main objective of the dissertation is to explore ways of dealing with conventional methods of regulating temperature in a building using the 'skin' with nature being the primary source of inspiration. This is done through the combination of natural and technical systems. These systems thus form one component of a building that uses various materials in assorted ways and in heterogeneous climatic conditions.

1.6 DELIMITATIONS

The dissertation does not focus on the proposal of changing and altering the Apies River, although it is mentioned in the urban vision. The main focus is rather the distribution and discharge of water to the Apies River from the proposed site.

It is not the aim of the study to propose new building methods. The aim is, instead, an exploration of new possible ways of using materials. We have developed a world where it is impossible to build without modern day technology, thus conventional methods of building are not excluded in this dissertation.

The program of the scheme is too large to explore in this dissertation. Therefore, detailed focus is only on a certain part of the design. The rest of the program is designed at an urban level in the group framework and is the explanation of, and response to, the urban vision for the entire site. The entomology department focuses on specific insects relevant to the program of the building, which is the insect ‘order’ of pollinators, no other insect species are investigated. This is not a biomimicry project, therefore no principles of the inner workings of the insects are used as design informants. The principles of ecosystem conservation for the insects are the main focus.

1.7 ASSUMPTIONS

It is assumed that the effects of the proposed water filtration that feeds into the Apies River will be implemented in various sections along the River, and will have a positive eco-systemic effect downstream, where the river flows through Pretoria North and terminates at the Pienaars River. A further assumption is that the soil on site, which is excavated and re-used as a part of the group framework, will be adequate for the use of berms or rammed earth as construction methods. It is also assumed that a new entrance to the zoo will be created in addition to the proposed new department in this dissertation. Two abandoned buildings located in the zoo area are to be demolished and their materials used for the proposed construction.

A final assumption is that the sports grounds on the school property will be altered to create a new zone for the proposed research building, and that relevant regulation will be implemented to create new sports field for the school.

1.8 IMPORTANCE OF STUDY

The importance of the study is; the reaction to the search for a regenerative future and to the way the built environment is one of the leading contributors to global warming. The crux is to find an alternative reconfiguration of building materials; enabling the building 'skin' to create a habitable space that does not damage natural ecosystems and regenerates the earth's resources. The proposal follows a principle of giving back to the environment more than what is taken away. The project creates new ways of exploring sustainability in the architectural field, as well as in other fields such as landscape architecture, entomology research, and ecosystem conservation. A critical outcome of this dissertation is to establish that collaboration between architecture and many other fields is required to achieve a sustainable future, research fields cannot function as separate entities, but must work together to achieve a shared goal.

2 / HUMANITY VS ENVIRONMENT

2.1 / IN THE BEGINNING

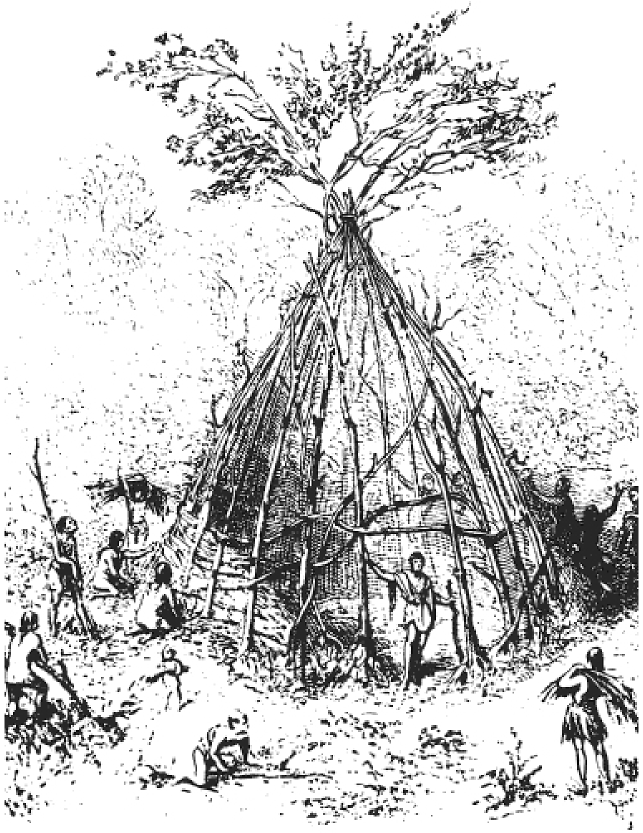
Since man's earliest recorded history there has been a need for protective shelter against the elements. According to Vitruvius, man started with temporary shelters of leaves and rocks, which imitated the nests of birds (Fletcher, 1961: 7). Around 8 000 BC, man's shelter evolved into a more permanent structure. Mud brick houses were constructed and signs of social gatherings were seen in the development of small towns of about 10 acres in size.

In 6 500 BC mud houses evolved into a more complete form. Small details show that humans shaped their houses in an increasingly intellectual manner to form improved livable space inside the house. Walls were shaped into seating and storage spaces, and entrances into houses were stepped up from the ground to keep water out. The materials extracted from the earth's surface were mud to make bricks for walls and stone to shape a corbeled dome for the roof (Gascoigne, n.d). The rounded shape remained the obvious form for a house; considering the tools of the era and the natural materials that could be gathered.

In the 4th Millennium BC an understanding of climate also started to affect building structures. Bundles of reeds were bound together and plastered with mud to create weatherproof shelters. In Egypt, sun-dried mud bricks were the building blocks of man's first monumental buildings. But around 2620 BC, Egyptians started to use stone, and later cut stone, to create pyramids. This in itself was a great innovation for that time (Gascoigne, n.d). Colossal temples in ancient Egypt, erected between 1500 – 1350 BC, were constructed with very large stones; these temples became an image of power and victory and was the start of a lasting tradition in architecture.

The first sign of cement as a structural material was found in Greek buildings from around 200 BC. The Greeks found that lime binds sand, water and clay. The Romans, however, used finely ground volcanic rock instead of clay, which helped in creating the great arches and aqueducts of Roman architecture. This cement of the Romans was the strongest mortar in history, until the development of Portland cement (Gascoigne, n.d). Roman architecture thrived as new technologies were created. The pivotal point in the rapid decline of natural resources was not reached until the age of industrialization, refer to figure 2.5.

2.1_ "The primitive hut" by Marc-Antoine Laugier. The primitive hut came from nature, rooted in functional and structural basis. (http://mellowmerriment.blogspot.co.za/2012/08/thesis-part-ii.html).



2.2_ A dipiction of the primitive hut in a tent form, with wood as the supporting structure with animal skin for covering. (http://25.media.tumblr.com/tumblr_m1b18bpWqY1qzlcoro1_400.jpg).

2.2 INDUSTRIALIZATION: IMPACTING THE ENVIRONMENT AND SOCIETY

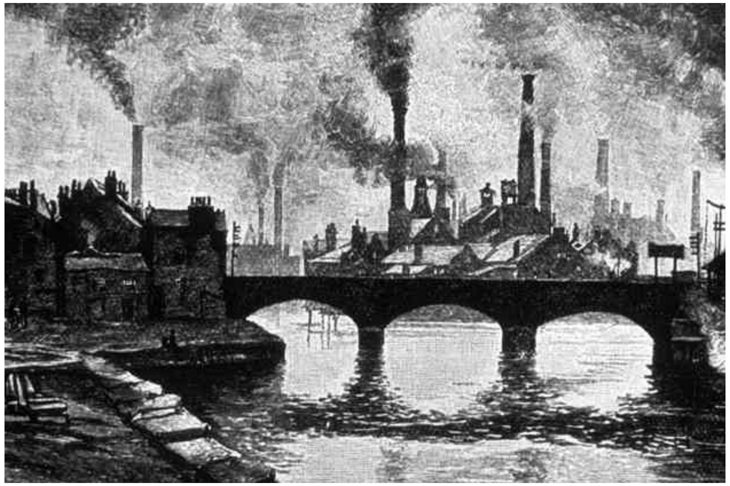
The industrial-era continues to play a significant role in the development of the built environment. The advancements of the time greatly influenced industries worldwide (Mang et al, 2012: 10). The first industrial revolution was significant as it entailed a shift from hand methods of production to machine production; with coal fueled factories being the norm from 1760 to 1840. The Crystal Palace was built in the 1850's and was seen as a technological wonder of the world and triumphed over fabricating materials in a continuing order (Sloterdijk, 2005: 12).

Starting in the 1860s, oil and other combustibles were also used as alternative fuels (Speight, 2011; 157). Industrialization in general generated tremendous increases in the productivity of industries and gave rise to economic growth and advances in transportation and trade, as well as city expansion and urbanization (boundless, 2015).

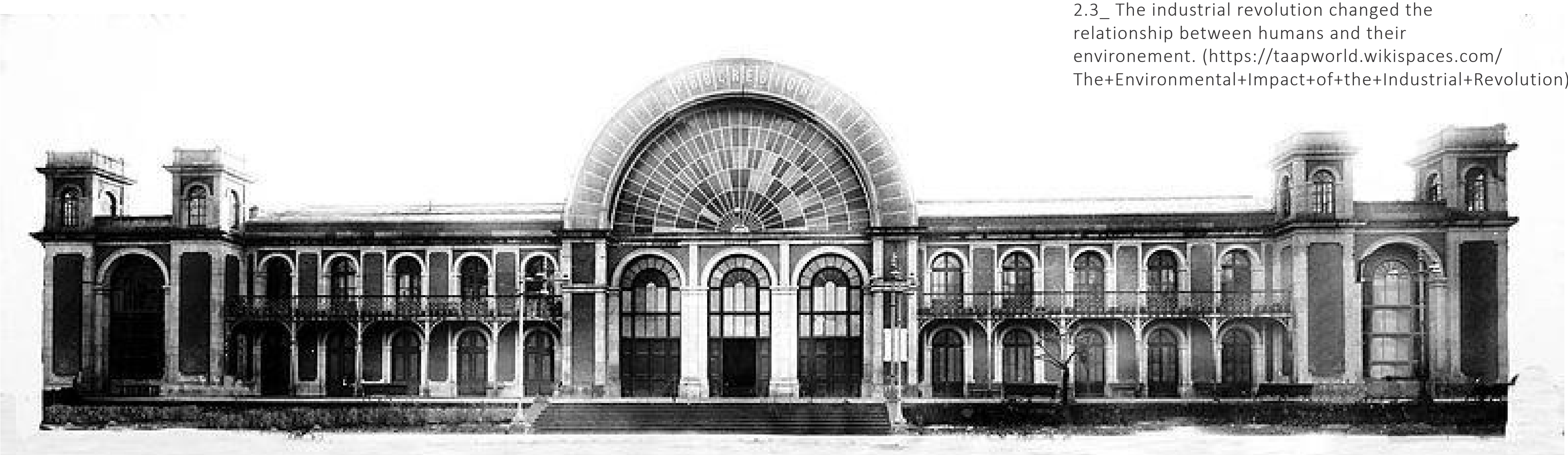
However, the human "need and greed" to expand cities in the best and quickest ways possible resulted in negative environmental and ecological outcomes. The primary source of energy for industries was the burning of coal. At the outset, the surface extraction technique was used, but as the industrial revolution progressed this changed to deep shaft mining. Deep shaft mining not only exhausts the natural resources available but also places enormous stress on the environment and ecological systems (Environment Insider, 2014). The constant burning of immense quantities of coal (to generate electricity) resulted in pollution. This pollution was a by-product of economic development in industries and seen as an unavoidable part of city life in general (Wiek et al, 2011: 1).

From the ashes of environmental pollution, a new recognition of the natural world arose. Transcendentalism as an intellectual movement emerged in the 1830s and 1840s (Boundless, 2015). Henry David Thoreau, one of the authors of transcendentalism, studied the philosophy of natural history and predicted two sources of modern day environmentalism, namely ecology and environmental history (Environment Insider, 2014).

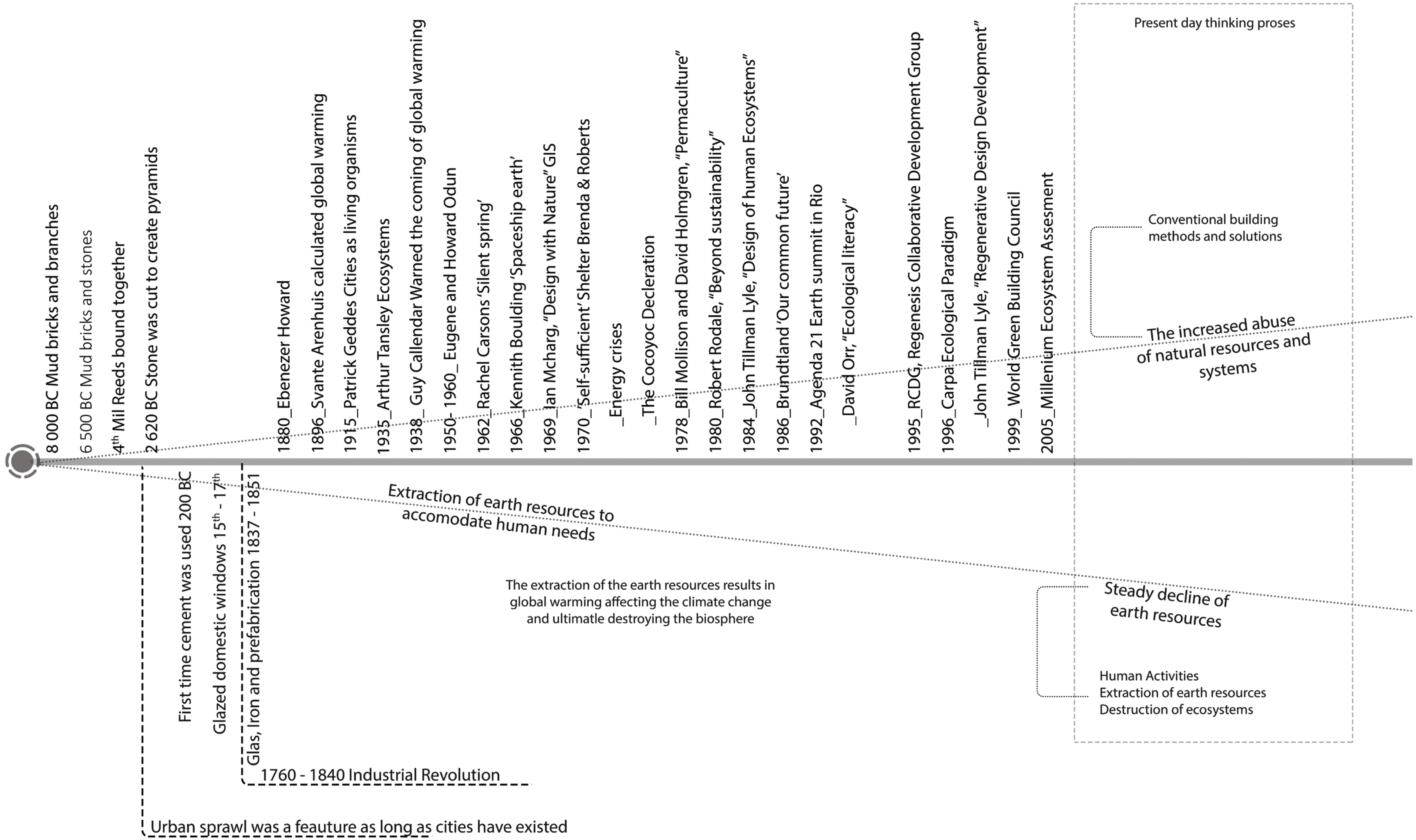
The world is facing ecological destruction at the hands of humanity. The media tends to blame government and corporations, diverting focus from the root problem: that humanity faces extensive environmental challenges (Westley et al, 2013: 1), (Wiek et al, 2011: 1). An example of one of the challenges we face is the destruction of habitats through deforestation allows for urban sprawl and causes water pollution, air pollution and climate change, all of which result in global warming. These environmental challenges impact natural resources, ecosystems and human health. Water and air pollution, spreading from rapidly growing cities and industries that developed in the industrial era, have dangerous effects on humans and the environment (Environment Insider, 2014). The Millennium Ecosystem Assessment presents growing evidence of the effects of global warming becoming visible much earlier than predicted, and that these effects are indeed accelerating climate change (Du Plessis, 2006: 5). It also finds that, because of climate change, almost two-thirds of crucial services that nature provides mankind are rapidly declining worldwide. In consequence, it can be said that we are living on borrowed time (Du Plessis, 2006: 5).

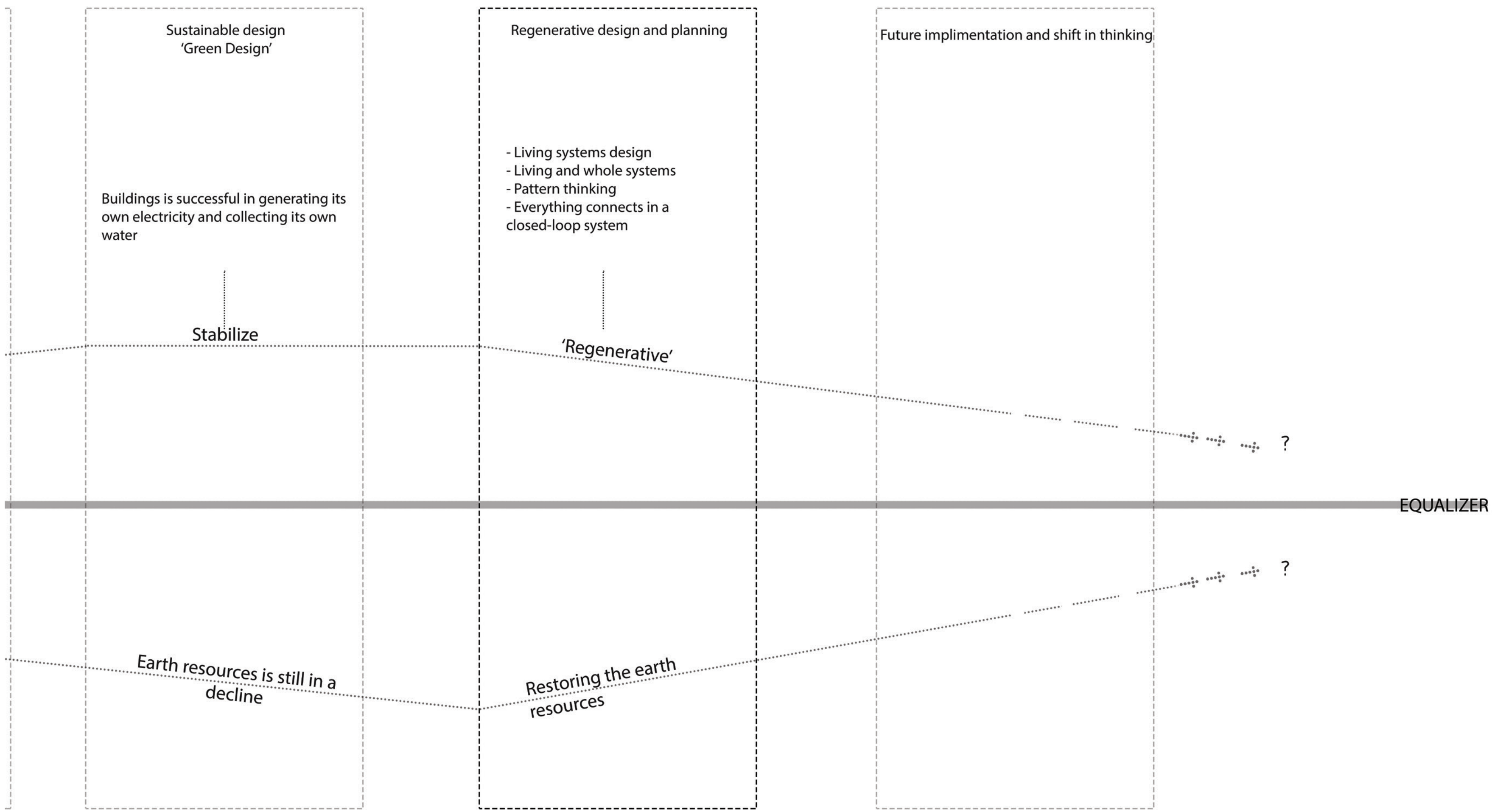


2.3_ The industrial revolution changed the relationship between humans and their environement. (https://taapworld.wikispaces.com/The+Environmental+Impact+of+the+Industrial+Revolution).



2.4_ The Crystal Palace in 1851. Technological wonder of the world. After it had been converted into a giant hothouse and imperial cultural museum, it betrayed the contemporary tendancy to make nature and culture jointly into indoors affairs. (http://www.ispaopp2013conference.pt/p-about-porto)


Present day thinking proses
8 000 BC Mud bricks and branches
6 500 BC Mud bricks and stones
4th Mil Reeds bound together
2 620 BC Stone was cut to create pyramids
1880_Ebenezer Howard
1896_Svante Arenhuis calculated global warming
1915_Patrick Geddes Cities as living organisms
1935_Arthur Tansley Ecosystems
1938_ Guy Callendar Warned the coming of global warming
1950- 1960_ Eugene and Howard Odun
1962_Rachel Carsons 'Silent spring'
1966_Kennith Boulding 'Spaceship earth'
1969_Ian Mcharg, "Design with Nature" GIS
1970_'Self-sufficient' Shelter Brenda & Roberts
_Energy crises
_The Cocoyoc Decleration
1978_Bill Mollison and David Holmgren, "Permaculture"
1980_Robert Rodale, "Beyond sustainability"
1984_John Tillman Lyle, "Design of human Ecosystems"
1986_Brundtland 'Our common future'
1992_Agenda 21 Earth summit in Rio
_David Orr, "Ecological literacy"
1995_RCDG, Regenesis Collaborative Development Group
1996_Carpa Ecological Paradigm
_John Tillman Lyle, "Regenerative Design Development"
1999_World Green Building Council
2005_Millenium Ecosystem Assesment
Conventional building methods and solutions
The increased abuse of natural resources and systems
First time cement was used 200 BC
Glazed domestic windows 15th - 17th
Glas, Iron and prefabrication 1837 - 1851
Extraction of earth resources to accomodate human needs
The extraction of the earth resources results in global warming affecting the climate change and ultimatle destroying the biosphere
Steady decline of earth resources
Human Activities
Extraction of earth resources
Destruction of ecosystems
1760 - 1840 Industrial Revolution
Urban sprawl was a feauture as long as cities have existed



2.5_ Timeline describing the progression of the history of architecture towards an ecological paradigm. (http://www.historyworld.net/wrldhis/PlainTextHistories.asp?ParagraphID=dor) adapted by (Author, 2015)

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2.3 / PROBLEMS WITH SUSTAINABILITY

Many initiatives have been launched regarding the development of sustainable buildings and construction. Unfortunately, the contribution of these initiatives to the global sustainability project is insufficient in scope and pace; falling short of a pivotal contribution to a more sustainable world (Du Plessis, 2006: 2). If sustainable design achieves carbon neutrality[5], then the factors which remain to sustain life are water quality, air quality, food production, biodiversity, etc. The list can keep on growing, but, the fact of the matter is, none of these factors can individually sustain life.

There is an increasing awareness that buildings cannot be designed without taking their environmental impact into consideration. A sustainable building can be defined in the broader context as one that has a minimum impact on the natural- and built environment. The building itself has a minimum impact on the immediate surroundings and regional setting (John, et al, 2004: 320).

But, something is amiss in how we understand the word 'sustainability'. Gladwin (Cole, 2012: 5) explains that the human mind has formed fixed opinions over time, favoring simplicity, certainty and immediate notions. The concept of adaptive learning, which allows thinking towards sustainability, is consciously obstructed. These patterns of thinking render the human mind incapable of appreciating, let alone beginning to address, the challenges of sustainability. Green building assessment tools emerged from the necessity of overcoming this mind-set (Cole, 2012: 5). The foundation stones for green buildings, which ultimately led to the development of the assessment tools such as LEED and BREEAM (Du Plessis, 2006: 3), are listed as follows:

1. The return to the use of natural building materials and the effective use of resources, like recycling.

2. Buildings should aim to be self-sufficient, for example, by gathering solar energy, collecting filtered water, waste management; all to be achieved with appropriate technologies.

3. The integration of the building with the site condition.

4. An ultimate improvement in the air quality of a building.

An advance in the management of natural resources and of building stock will lead to a definite improvement in environmental quality, accompanied by the reduction of scarce resource use and energy consumption (John, et al, 2004: 320). According to Cole (2012: 3), the characteristics of green building assessment tools can be defined as follows:

[5] Carbon neutrality is a term used to describe the action of organizations, businesses and individuals taking action to remove as much carbon dioxide from the atmosphere as each put in to it. The overall goal of carbon neutrality is to achieve a zero carbon footprint (www.webopedia.com/TERM/C/carbon_neutral.html)

1. Individual performance of certain components of the building is evaluated to a relative standard, which is either implicit or explicit, but is not considering the absolute consequence on human and natural systems.

The critique is that components should not be evaluated individually, but rather as a complete system; every component should be identified as part of an interconnected system.

2. The benchmark of the assessments is technically framed and based on metrics that are quantifiable, measurable and comparable. It is assumed that it offers an accurate measure to understanding of the overall green building performance.

Systems in nature cannot be compared or measured, thus the benchmark should rather be the performance of nature. A benchmark that is technically framed is limited.

3. The success ascribed to buildings in their Green Star rating is measured through simple addition of the weighted scores obtained in individual performance issues.

Weighted scores limit the potential of nature, and do not allow for a full understanding of natural systems.

4. Maintaining the health of natural systems is implied in the performance criteria, however, it is not emphasized or clearly communicated in the conceptual base and structure of the assessment tools.

Incorporating natural systems should be the main focus of.

5. The assessment tools are framed by a linear approach towards the conservation of resources, which fails to resolve the cyclical process of resources.

The natural cycle of resources should be adapted; namely, a closed loop were no waste is generated.

Since the establishment of green building assessment tools the number of registered LEED projects has increased dramatically and solid environmental gains have been recorded (Cole, 2012: 2). However, despite this result, there is still not any significant progress towards the cessation of global warming. This is perhaps due to the fact that sustainable design or “Green” architecture at present is more focused on doing “less harm” than anything else. This is simply not sufficient for our development of an ecologically sustainable future (Cole, 2012: 3). Sustainable design is a constantly developing concept, which has resulted in a number of “Green” building iterations. Leading “Green” practitioners are searching for answers and pushing the boundaries of current assessment methods. They are emphasizing an eco-efficiency approach (Du Plessis, 2006: 2).

2.4 / CONVENTIONAL THINKING

Worldwide, it is becoming clear that conventional modern architecture and the built environment are not sustainable over the long term. Therefore, changes are being made in building methods and approaches. These aim to use energy and materials more efficiently (John, et al, 2004: 319).

There is an increasing realization that the built environment is a requisite part of the natural world and natural systems (Peres et al, 2015: 40). The way we think about buildings and the built environment must change if we are to engender a significantly positive effect on the natural world. The problem on a global scale is: how can one pare the scale down to an architectural solution?
The construction sector of the built environment holds an important place in the global economy. It also has some of the biggest negative impacts on the environment (Smith et al, 1998: 3). Methods of construction are established in today's textbooks on how buildings work. When we challenge and argue building methods, we argue with 'tried and tested' decisions made over a long period of time. We argue with nameless ancestors, and we will lose the argument (Brand, 1994: 2). The term 'architecture' is always seen in its wider use as 'unchanged deep structures' (Brand, 1994: 2).

Nevertheless, we cannot solve the problem of sustainability by using the same method over and over again. To find a building solution we must first understand how the building functions. We can gain comprehension by looking at Frank Duffy's layered building perspective. Frank Duffy is a leading theorist in the change rate of buildings. He distinguished four independent layers of longevity and of building components in buildings (Brand, 1994: 12):

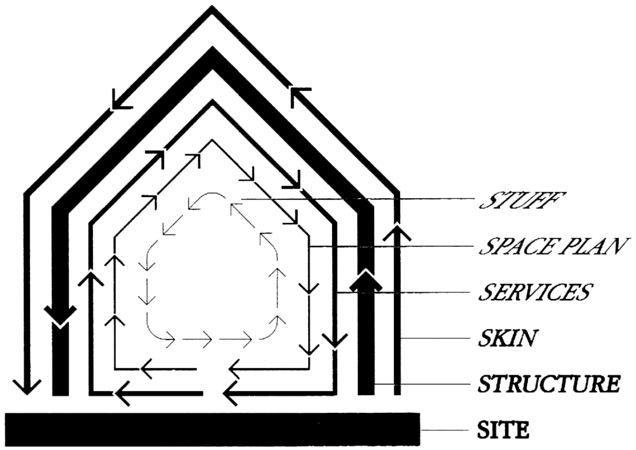
Shell: Structure, which lasts the lifetime of the building.

Service: Cabling, plumbing, air conditioning and moving parts, which are the elevators. It has to be replaced every 15 years or so.

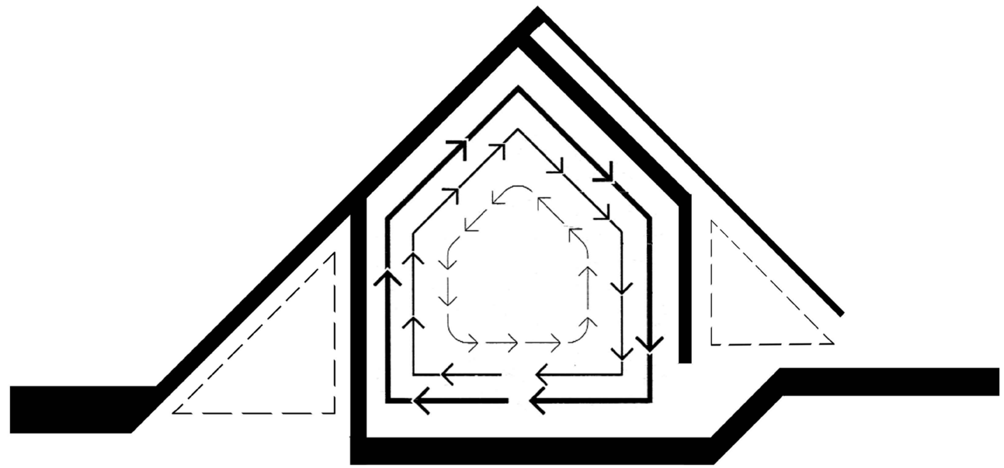
Scenery: The interior layout of the building; partitions, dropped ceilings, etc. The layout can vary in its change, every 5 – 7 years.

Set: The furniture of a building, which can be shifted by the occupants.

Duffy (1994: 17) advises designers to steer away from solving a five-minute problem with a fifty-year solution. He states that these layered approaches work well when it comes to building practice. The most important aspect of a building is the components that make up the shell; called the envelope of a building. The envelope of any building consists of walls, floor and roof. These components protect the interior of a building against



2.6_ Steward Brand depiction of Duffy's building layers into six 'S' (Brand, 1994: 13)



2.7_ Steward Brand depiction of Duffy's building layers adapted to include the site as an integral part of the building layers (Brand, 1994: 13 edited by author, 2015) external elements, such as, wind, rain, sun, noise and heat. Thus, the living conditions for humans are improved inside a building (John, et al, 2004: 322). The envelope acts as a climate moderator, a role it has performed since the earliest history. It evolved with technology over time, keeping pace with environmental requirements and the continuous changes in social and economic patterns (John, et al, 2004: 322).

Steward Brand expanded Duffy's four 'S' perspective into a six 'S' theory, which includes interior work (Brand, 1994: 13):

Site: The geographical urban setting or location. The site is eternal.

Structure: It consists of the whole envelope of the building; foundation, load bearing walls and roof. It is perilous and expensive to change. Lifespan of less than 60 years.

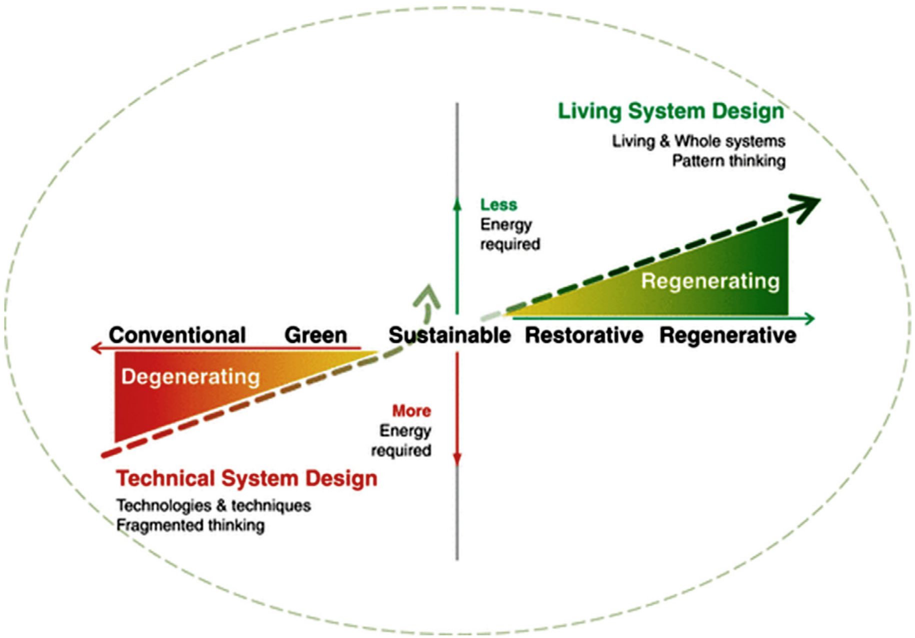
Skin: Exterior surfaces, such as, paint or cladding. This changes every 20 years.

Services: The working systems of a building; wiring, plumbing, HVAC, and moving parts. Buildings are demolished early if their outdated systems are too deeply embedded to replace and can't be accessed easily.

Space plan: The interior layout of a building; walls, ceilings, floors, doors.

Stuff: All interior furniture or accessories that can be changed by the occupant.

It is critical to note that the comprehensive function of a building envelope, the exterior wall in conjunction with the roof and floor, is to moderate solar radiation, temperature extremes, moisture content, dust and wind (John, et al, 2004: 322). The changing architecture of the present and fast pace expansion of cities and industries mean that numerous new designs are available and made possible by the use of new materials and construction techniques. Sadly, some designs are being approved without proper understanding, consideration and assessment of our current environmental status (John, et al, 2004: 322).



2.8_ Framework for sustainability, Contrast of Technical System Design and Living System Design (Mang et al, 2012: 10)

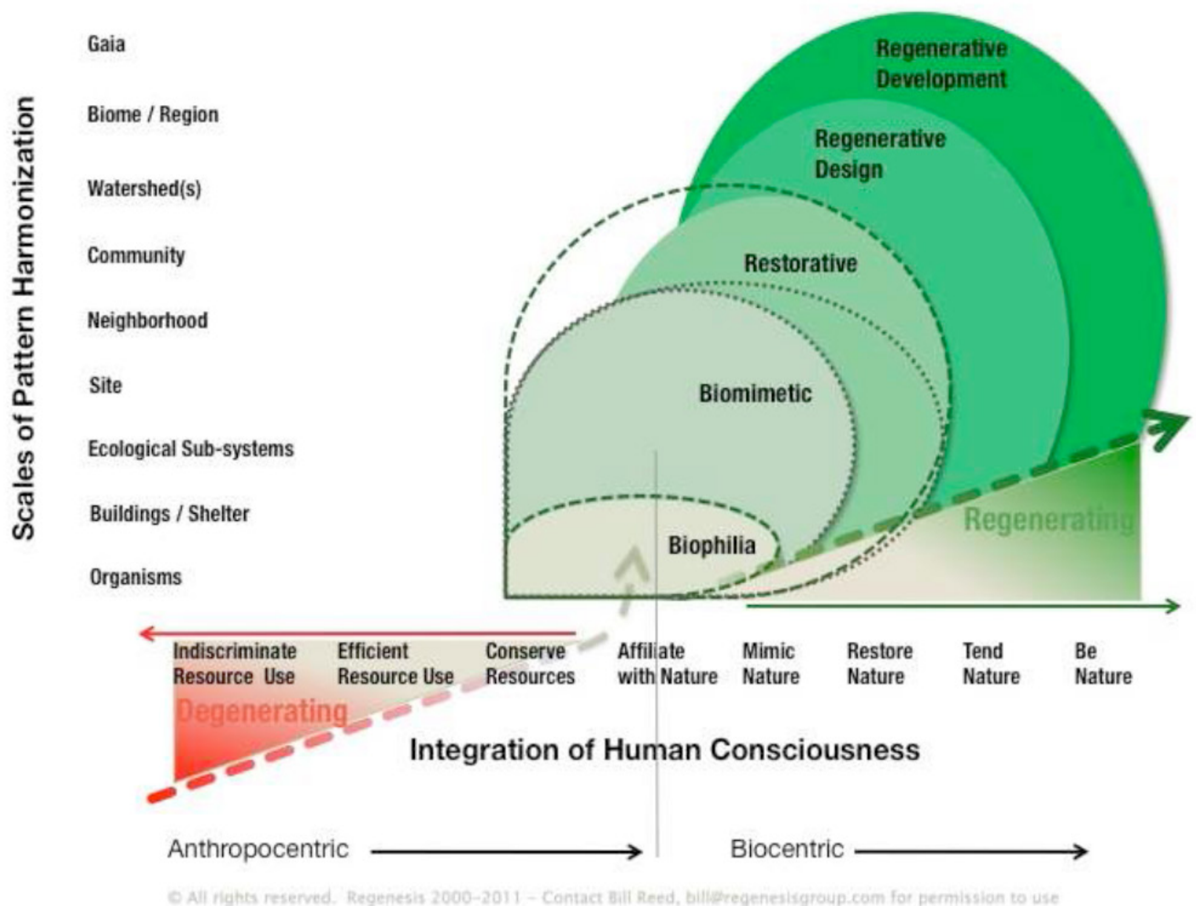
2.5 / CHANGE OF THINKING / Paradigm shift

It is critically important to reach carbon neutrality. This will give us more time to ascertain how we are to sustain life and how to achieve a mutually beneficial relationship between humans and nature. If we try to solve this problem technically we will just end up with a sustainable building.

"To follow the path towards sustainable building solutions is only a slower way to die... we need to turn around."
Bill Reed, 2010, Health schools conference

By looking at technical systems design inversely, we can arrive at living systems design. This refers to observing patterns in nature and discerning how to work with life as a whole living system (Refer to figure 04). To sustain life, we must know what life is. Life is a complete evolving complex of self-sustaining processes and is bound to a closed interconnected system; where everything is linked in some form or another. We need to start taking a systems approach, because everything is connected. Accordingly, we simply cannot focus on problems as individual entities but must rather view them as a whole. Bill Reed (2010, video) describes three aspects of systems, whether they be living or technical: Elements in interrelationships (because life is all about relationships) where every system must have a purpose.

This shifting world view, towards an ecological paradigm,



2.9_ Levels of Ecological Strategies for Sustainability. Regenerative- acknowledges that humans are "nature". In order to create sustained ecological health, humans must evolve a conscious and integral interrelationship where humans and nature are in a mutually beneficial being and becoming relationship.(Mang et al, 2012: 13).

implies that humanity should work with nature to not just reduce negative impacts but also pursue a net positive result by working together as a single interconnected intelligence (Du Plessis, 2006: 2). Meadows' (Cole, 2012: 5) strategic guidance indicates that natural complex systems cannot be controlled, although they can be designed and then re-designed. He also implies that humanity cannot undertake the future with this new world view and have full confidence that there will be no surprises; humanity must learn from these surprises and even profit from them. This approach requires the conventional human mind-set of being experts to be replaced with a belief that we are 'co-learners' with nature. The basis of systems thinking approach is thus the establishment of a network of mutual learning (Cole, 2012: 5).

Humans are an inseparable part of nature, therefore humanity has the ability to adapt and rethink our way of life and development. The notion of living and building in harmony with nature has existed since the time of ancient Greece. It was revived by Vitruvius and revived again by the 19th century romantics. Du Plessis (2006: 3) believes that the idea behind this notion was both pragmatic and nostalgic; a spiritual aesthetic pursuit to reconnect with nature. Pawlyn (2011: 1) describes three shifts that are necessary for humanity to sustain life;

1- Shifting from a linear one-way-flow of managing resources and waste to a closed-loop model were no waste is generated6
2- Shifting from a fossil-fueled economy to a solar economy.
3- Shifting to an increase in resource efficiency

All living things have a constant need for shelter and nutrition. Humanity is destroying both by means of agriculture and building institutions. However, through the adoption of natural processes, there is an opportunity to heal the planet. Architects must view the environment they work in as a whole living organism, which has a purpose. They must identify the complexities within the environment and understand the patterns of life. Architects then have the opportunity to solve a world problem through small, strategic, architectural insurgence (Reed, 2010).

Therefore, if there is to be meaningful change in the 21st Century, there must be a change in the mindset towards the ecological, social and economic systems of the built and natural environment (Peres et al, 2015: 40). This has to start from a different point of departure; one such different point being the support of an ecological world view.

[6] linear 'one-way-flow' and 'closed-loop-system' will be explained in the theory chapter 3

DESIGN APPROACH

3 / THEORY

3.1 / BRIEF HISTORY

3.1.1
THE BIRTH OF ECOSYSTEM DESIGN

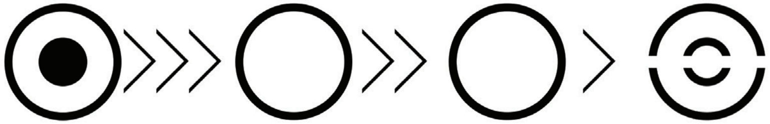
The concept of ecology in architecture was first introduced by Patrick Geddes (Vidler, 2010: 26). His study of urban growth patterns stimulated by the mass movement of people was published in 1915 (Mang, et al, 2012: 3). Geddes believed that a city is a living organism and that an understanding of a city's context is required before the problem of unsustainable growth can be solved. It is accepted that his work was inspired by 1880's 'To-morrow: A Peaceful Path to Social Reform', a book written by Ebenezer Howard (Mang, et al, 2012: 3). In his book, Howard applied ecological thinking to human settlement. It made clear his desire to use natural systems instead of engineered ones to reconnect humans with nature (Mang, et al, 2012: 3). Patrick Geddes is, however, accredited with the origin of ecological design. Twenty years later, in 1935, an entirely new concept of ecology was popularized by Arthur Tansley. He proposed the term 'ecosystems' to describe the relationship between living things and their non-living habitats (Mang, et al, 2012: 4). The years that followed saw the conclusion of many projects centered on ecosystems. Tansley also influenced the work of Ian McHarg in 1969[7] and Robert Rodale in 1980; both used the word 'regenerative' to explain the concept of architecture going beyond sustainability to the renewal and regeneration of agricultural resources (Mang, et al, 2012: 6). Since the start of the 1900s, the issue of sustainability, leading to environmental conservation and ecological responsibility, has been present in architectural discourse (Vidler, 2010: 26). Its potential has not been fully realized and sustainability foundered in the face of development pressure and financial constraint. It has prevailingly eluded the architectural profession (Vidler, 2010: 26). The regenerative design approach, emerging at present, might be a potential breakthrough to the renewal and regeneration of resources.

3.1.2
THE EMERGING FIELD OF REGENERATIVE DESIGN

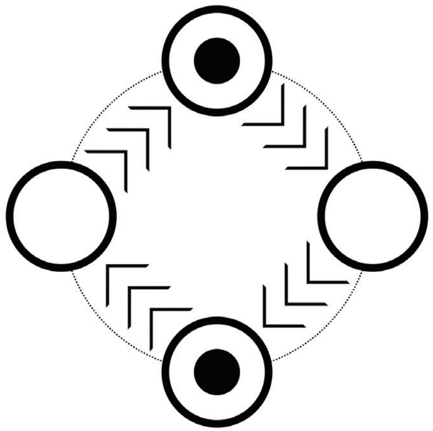
In 1984, John Tillman Lyle defined human ecosystems as "places where humans and nature might be brought together again for mutual benefit". His book 'Design of Human Ecosystems' introduced key concepts that formed the basis for his successive works on regenerative design (Mang, et al, 2012: 6). In 1996, he published the first handbook guide to regenerative design called 'Regenerative Design for Sustainable Development'. It established the principles, framework and strategies for a design tool that proposes the reverse of environmental damages originating from the industrial revolution (Mang, et al, 2012: 7).

"Where nature evolved an ever-varying, endlessly complex network of unique places adapted to local condition."
John Tillman Lyle. (Mang, et al, 2012: 7).

[7] Ian Mcharg 'Design with Nature', pioneering a technology for ecological land-use planning based on understanding natural systems



3.1_ “One-way-linear-flow”, from source to sink.
Humans replaced natures continual cycling and recycling of materials and energy process with a one-way-linear-flow. a one-way system destroys the landscape on which it depends. (Author, 2015)



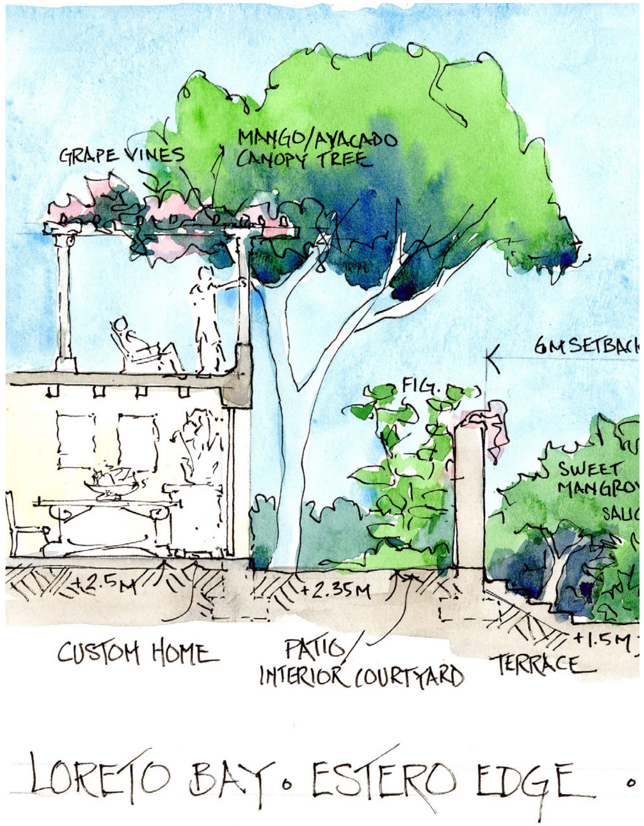
3.2_ Nature’s regenerative design. Cycling flows at sources. Continuous replacement, through their own functional processes of the energy and materials used in their operation (Author, 2015)

The continual depletion of resources, caused by conventional industrial development, leads to the degradation of the environment. It is seen as a ‘one-way-linear flow’ of processing materials and energy and it replaced nature’s cycle of renewing materials and energy (Mang, et al, 2012: 7).

Figure 3.1; Lyle calls this ‘one-way-linear-flow’ a degenerative system. He states that a radically different approach is required, which he named regenerative design (Mang, et al, 2012: 7).

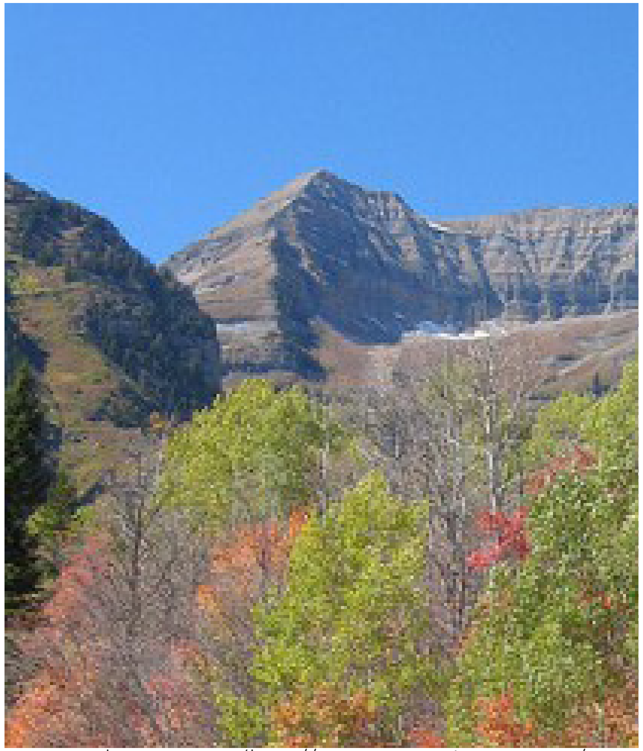
3.1.3
THE ESTABLISHMENT OF THE REGENESIS GROUP

The Regenesis Group, established in 1995, was founded by educators in the field of permaculture (sustainable land use planning). The Group seeks to transform the development industry into an industry that contributes to the health of the planet rather than undermining it. The Regenisis Group act as consultants on existing projects where external pressures are experienced due to environmental implications. They are a world leader in the field of regenerative development, which defines the leading edge of sustainable practice. The group has been involved in 200 projects; across North- and South America, the Caribbean, Africa, and in the Middle East. The Group recognizes that the site is a complex and dynamic system of systems; that needs to be seen as an entirety before the building process starts. Every site has a unique character that originates from its underlying landform as well as the climatic, ecological, historical and social forces that shaped it.
Regenerative development conceptualizes projects as engines of positive or evolutionary change for the systems into which they are built (Haggard, n.d; 1).



3.3_ Loreto Bay Village. (http://regenesisgroup.com/wp-content/uploads/2015/02/Agua-Viva-Estero-Edge-June-14.1.jpg).

LORETO BAY VILLAGES / Baja California Sun, MX is a 6000-unit eco-resort and mixed-use community development on the estuary of the sea of Cortez. The Regenisis Group collaborated with the planning-; design and construction-; and marketing teams to ensure that the development supports and advances the health of the community and the natural systems that draw people there.


3.4_ Sundance Resort. (http://www.regenesisgroup.com/wp-content/uploads/2015/02/110798006_e080003846_z-400x284.jpg)


3.5_ Playa Viva. (http://regenesisgroup.com/wp-content/uploads/2015/02/PrivCasitaEX2-e1423724536251.jpg)

SUNDANCE RESORT / Sundance Utah
This five-star hotel is located on a glacial moraine through which runs a previously undetected earthquake fault. The company was at risk of losing millions of dollars on liability risk. Regenisis Group saved the hotel by assessing the larger pattern of how the landscape worked as a system. They served as ecological planning consultants and addressed concerns regarding soil and geological stability.

PLAYA VIVA / Juluchuca on the Mexican pacific coast is a 200-acre sustainable resort and residence community. The Regenisis group assisted the developers by designing the master plan, which includes 160 acres set aside for a nature preserve and turtle sanctuary. Playa Viva recycles 75% of its construction waste, solar energy provides 100% of its power and it will donate 1% of all revenue to the community for the creation of an organic farming program that will provide jobs for local farmers.

SUMMARY / It is important for a designer to have prior knowledge of the site characteristics before construction commences. The site must be understood as a whole that consists of systems within systems. Only then can the most important and valuable aspects of the site be considered as design informants.

3.2 / LIVING SYSTEMS APPROACH

3.2.1 TRANSITION FROM DEGENERATIVE TO REGENERATIVE

Figure 3.6 explains the transition from degenerative to regenerative design.
It is recommended that both spectrums in this diagram be addressed in unison; as a whole system. It is thus a combination of the high performance approach (focused on reducing the impact on the environment) and an understanding of living systems (focused on the mutual relationship between nature and humans) (Reed, 2007: 2).

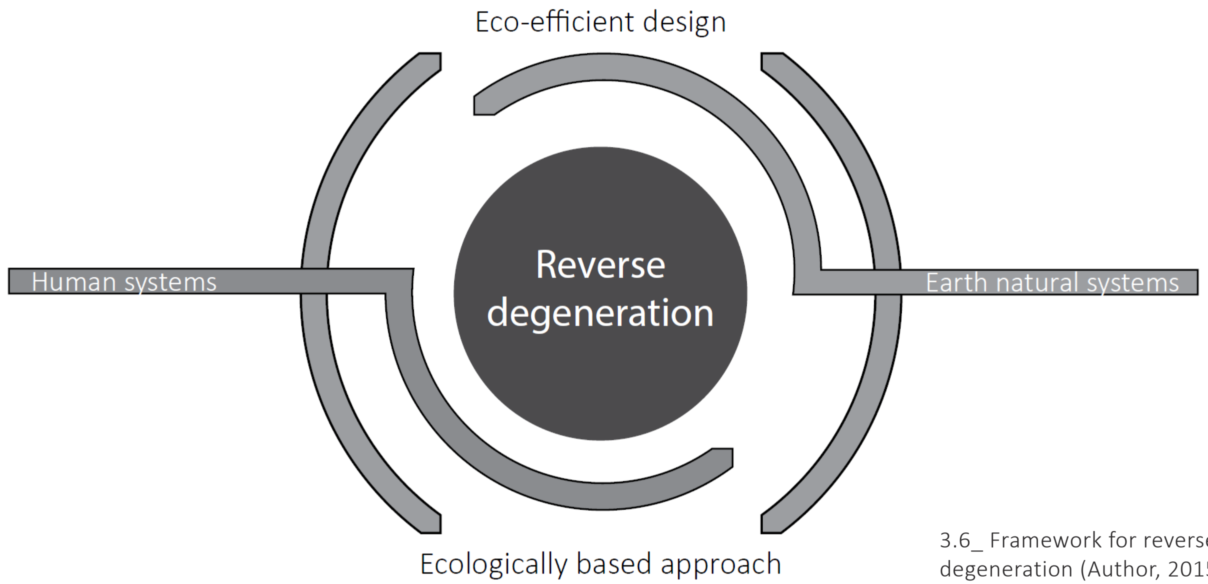
3.2.2 RECIPROCAL RELATIONSHIPS

The ecological world view acknowledges both the necessity of change and that it is the diversity of life on earth and its quality that needs to be sustained (Peres et al, 2015: 40).
The emerging field of regenerative development and design rose from the ecological stream. At the moment it is redefining sustainability regarding what the built environment encompasses and what its role must be (Mang, et al, 2012: 9). Life is a process of reciprocal relationships, meaning there exists continuous exchanges between two or more living organisms which are beneficial to all parties involved.

"Life is a process by which living things support and are supported by a larger whole" (Reed, 2007: 1).

Life evolves constantly and is never in a static state (Reed, 2007: 1). Reed (2007: 2) defines restoration as a system that can progressively self-organize and evolve. As something cannot be restored to its original state the aim must then rather be restoration than enables an innate ability to self-organize and evolve. Reed (2007:2) remarks that regeneration views all the extensions of life and restores them in parallel. Our role as the human inhabitants of this planet is to have a positive impact on the environment. The following are basic principles to follow in order to achieve this positive impact (Reed, 2010):

1. At the moment we are occupying the land, we should rather inhabit the land.
2. Instead of living lightly on, we should commit and live fully with nature.
3. We should look at our goal as a whole, and should not try and fix pieces of the issue.
4. Therefore, we should re-purpose our role as



3.6_ Framework for reverse degeneration (Author, 2015)

“Living systems are capable of regeneration, resiliently adapting to pressures in order to sustain life.”
(Peres et al, 2015: 40)

humans.

5. We should develop a mind-set that can see life’s development and our role within it.

The purpose is for humans to build a relationship with the natural world and its processes. The only way to build such a relationship is to acquaint ourselves with the natural world and learn about it. Acquaintance with the natural process and patterns will become devotion, which will lead to safe-guarding.

3.2.3
REGENERATING

Framing restoration as a whole means an engagement between earth systems, biotic systems and the characteristics of a place.

Figure 3.6; Advocates of the regenerative design approach in the built environment propose that an ecologically based approach must be integrated with the eco-efficient design. Such integration will ultimately reverse the degeneration of both the earth’s natural systems and of human systems (Mang, et al, 2012: 9). For example, human settlements can actively regenerate the condition of their environment as a whole when they participate with the natural systems and the processes. Regenerative design encourages a co-evolutionary partnership between natural systems and the human condition, instead of human management or domination of the natural environment. This boosts social and natural capital instead of weakening it (Cole, 2012: 3). Regenerative design theory protests the current approval of “Green” building practical tools. It conveys the positive message that a building can give back more than it receives and through that action can abolish the building’s social and cultural capital (Cole, 2012: 4). Regenerative design should lay the foundation for future development and benefits, while consciously focusing on pressing current environmental issues, such as, climate change and the loss of biodiversity.

3.2.4
UNDERSTANDING THE PATTERNS OF PLACE

Every site for which a building needs to be designed is unique and the design process starts with an understanding of the life process in that place (Reed, 2007: 5). For an ecosystem to be restored, a certain pattern must be established so it can commence regenerating itself. A site needs to be seen as a living organism; an organism is a living system; every living system has a purpose.

Reed (2007: 5) explains three aspects that provide a foundation for a regenerative relationship with a place:

1. Experience the whole system of that place and understand its greater potential to evolve towards a more resilient place.
2. The story of place. Other stakeholders need to be inspired by the place as a living system.
3. Apply a constant dialogue process as part of the design and operating process, to regulate the goal of the stakeholder within the nature of the place.

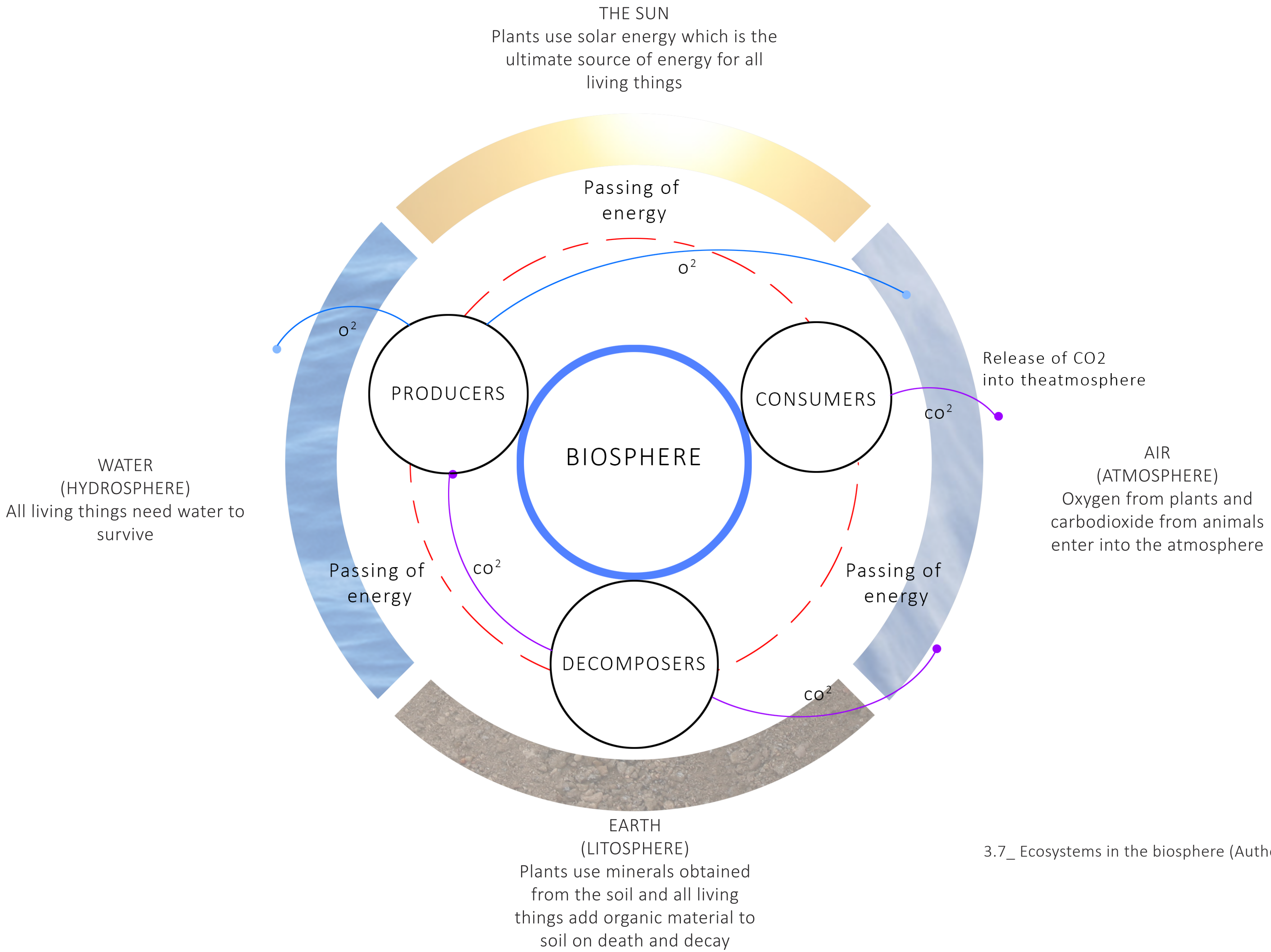
For a regenerative approach, design needs to accept and react to the unique characteristics of places (Cole, 2012: 3). Therefore, the shift towards a regenerative design approach must endorse the complicated and steadily evolving interrelationships between natural systems, technical systems and humans (Cole, 2012: 3).

3.3 / ECOSYSTEMS IN NATURE

Despite the fact that humans have a deep-rooted need to be part of nature, they still abuse natural systems as resources, without concern over the long-term consequences (Peres et al, 2015: 41). The destruction of natural systems through human activities threatens the very existence of human beings. It is an urgent requirement that natural cycles be allowed to continue on their natural path of flow (Daily, 1997: 4). The deterioration of the environment reveals a set of demanding challenges for scientists worldwide (Daily, 1997: 1). These challenges are rapidly accumulating and cannot be controlled in isolation anymore. For action to be instigated for the conservation of the remaining of the planet's natural resources, it is imperative that the general public be informed and guided to understanding the challenges facing mankind (Daily, 1997: 1). The character and value of natural ecosystems should be incorporated in publicly distributed information.

"Environmental flow is the quantity, timing and quality of water flows required to sustain ecosystems, human livelihoods and the well-being that depends on these ecosystems" (Pahl-wostl et al, 2013: 342).

Figure 3.7; An ecosystem is a set of living organisms (biotic) in partnership with non-living components (abiotic) that interact harmoniously with their environment, as a system of energy flows and nutrient cycles (Esparza et al, 2009: 29), (Water and ecosystems. Global water partnership: 1).
The goods and services that flow from the processes of



3.7_ Ecosystems in the biosphere (Author, 2015)

natural ecosystems are considerably underestimated by society, even though they need to be incorporated in our daily lives (Daily, 1997: 2). This necessity is on account of the significance of ecosystem services to the resilience of social-ecological-systems (SES) (Pahl-wostl et al, 2013: 341). Ecosystem services sustain and inform human life through the processes of natural ecosystems. They also maintain the biodiversity that directly supports life on the earth (Daily, 1997: 3) (Pahl-wostl et al, 2013: 341). There is an increased need for ecosystem services, which are being harmed through the destruction of ecosystems due to the above-mentioned external factors (Global water partnership: 1) (Österblom et al, 2013: 1).
Gretchen Daily (1997: 4) lists the following types of ecosystem services that support life functions, such as, cleaning, recycling and renewal:

1. Support of diverse human cultures.
2. Moderation of temperature and the force of winds and waves.
3. Partial stabilization of climate.
4. Maintenance of biodiversity, from which humanity has derived key elements of its agricultural, medicinal, and industrial enterprises.
5. Dispersal of seeds and translocation of nutrients.
6. Control of the vast majority of potential agricultural pests.
7. **Pollination of crops and natural vegetation.**
8. Generation and renewal of soil and soil fertility.
9. Detoxification and decomposition of waste.
10. Mitigation of floods and droughts.
11. **Purification of air and water.**

None of the services listed above can be viewed as a single entity with its own functioning organisms. They must rather be viewed as a functioning whole that benefits, as a living system, the entire spectrum. Soil organisms, for example, play a valuable role in the circulation of material matter in all ecosystems; they alter the chemical and physical deportation of nutrients to plants and to larger organisms (Daily, 1997: 4). Simultaneously, if the service of pollinators were terminated, there would be severe social and economic ramifications (Daily, 1997: 4).

To conclude, human beings are inadequately prepared for the consequences that they themselves have unknowingly set in motion. Natural functions can simply not be replaced by artificial functions.

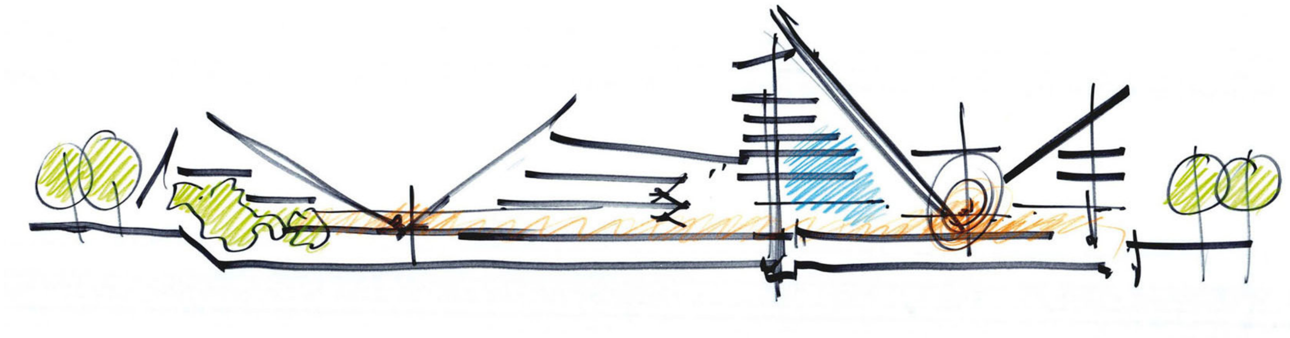
3.4 / SUSTAINABLE APPROACH IN ARCHITECTURE

For the state of many ecosystems there is no solution or cure. There is, therefore, an expanding urgency of the “How?” question (Osterblom et al, 2013: 1). The buildings below show designs that use nature as the main driver for a sustainable outcome.

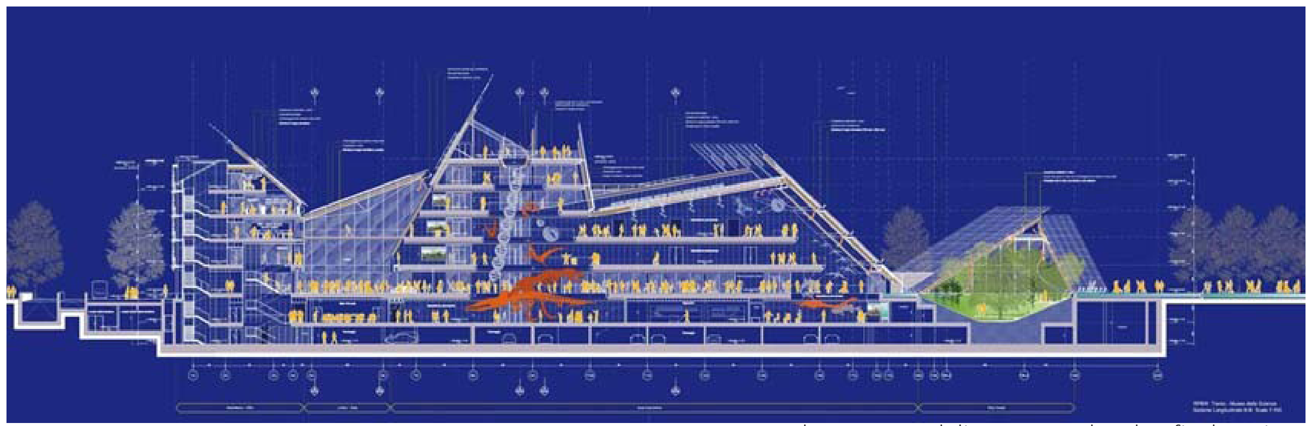
RENZO PIANO / MUSE National Science Museum
Location: Trento, Italy

This building is designed to have a sustainable impact on the bigger city framework and on the micro level. Renzo Piano achieves this by connecting the Adige Riverfront with the city center and by creating a public attraction through the revitalization of a former Michelin tires manufacturing plant, which was mostly a brownfield site (Loomans, 2015: 1).

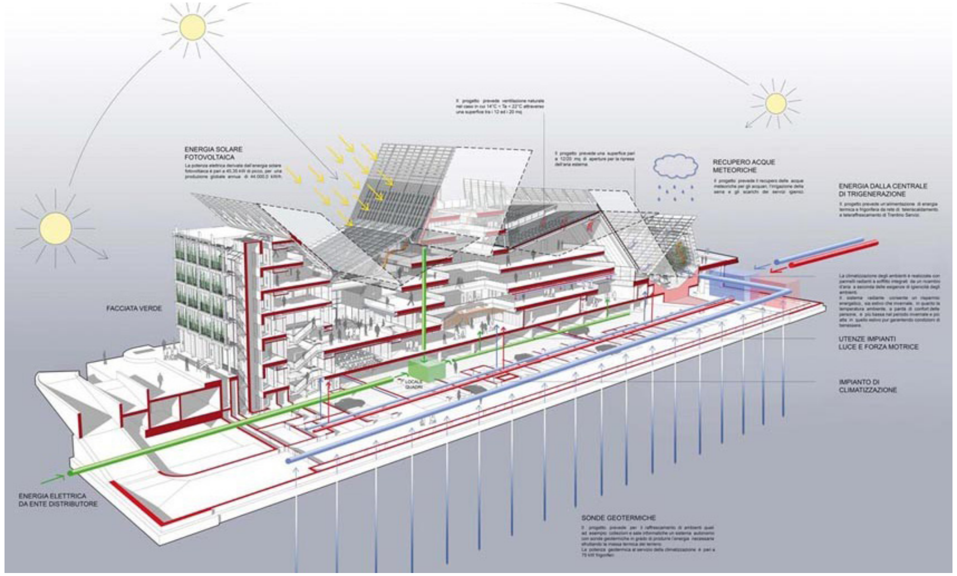
The building reduces energy use by taking advantage of photovoltaic panels on the roof; geothermal energy; and an excellent passive cooling design. The use of potable water is reduced by 50%, as rainwater collected on the roof is used to irrigate the indoor garden.



3.8_ Conceptual diagram of the MUSE museum (http://www.rpbw.com/project/146/muse-museo-delle-scienze/)



3.9_ How the conceptual diagram translated to final sections (http://www.archdaily.com/423101/muse-renzo-piano/52213764e8e44eeef9000036-muse-renzo-piano-diagram)



3.10_ Diagram showing the systems incorporated in the design (http://www.archdaily.com/423101/muse-renzo-piano/52213757e8e44e711f000023-muse-renzo-piano-diagram)

3.11_ Photo of the finished building (http://www.archdaily.com/423101/muse-renzo-piano/522136ffe8e44e711f00001e-muse-renzo-piano-photo)

DR KEN YEANG / EDITT Tower

Location: Waterloo Road Junction, Singapore

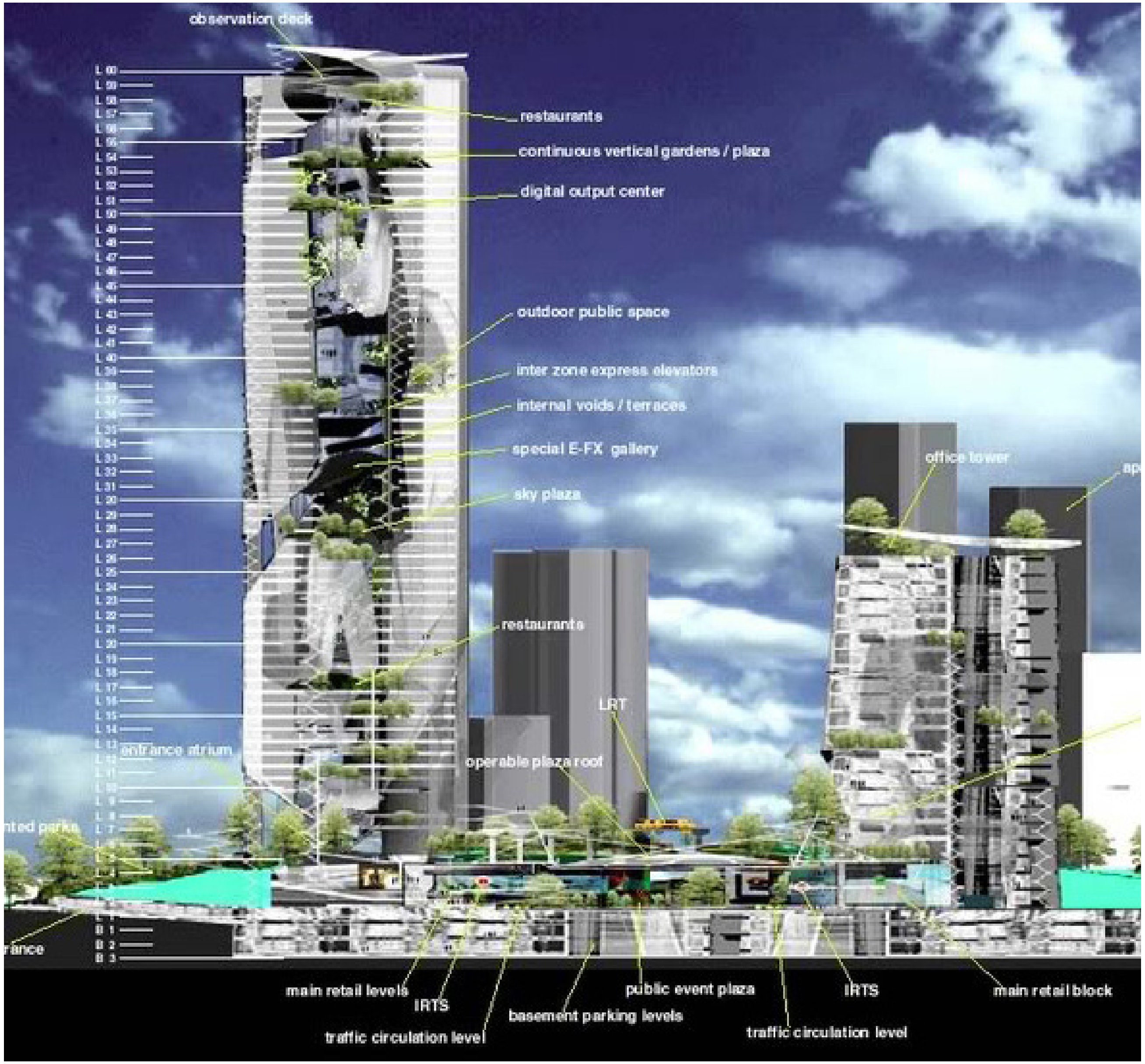
EDITT stands for "Ecological Design in the Tropics". The building is designed to increase its location's bio-diversity and rehabilitate its ecosystem in Singapore's 'zero culture' metropolis (Kain, 2012: 1). The design includes passive systems; the building is wrapped in organic vegetation to allow for passive cooling and natural ventilation.

The skyscraper also makes use of photovoltaic panels that provide 39.7% of the building's required energy. Rainwater is collected and integrated with gray-water systems to provide for both plant irrigation and toilet flushing, at an estimated 55% self-sufficiency rate (Kain, 2012: 1).

SUMMARY /

The MUSE museum building is sustainably designed and displays great knowledge of the environment, where climatic factors were a major design informant. However, it lacks implementation of ecosystemic design and of man's relationship with nature.

The EDITT tower can be considered a regenerative design as it makes provision for the rehabilitation of ecosystems to enhance existing bio-diversity. Ken Yeang understands that designing with nature can be extremely beneficial.



3.12_ Diagram of the EDITT Tower (https://archiandesigns.files.wordpress.com/2014/08/editt-tower-singapore-by-the-architect-ken-yeang-of-malaysia-3.jpg)

CONTEXT

4 / PRETORIA CONTEXT

4.1 / PRETORIA FORMATION

According to Jordaan (1989: 26) an urban environment is successful when three conditions have been met. These conditions must consider the:

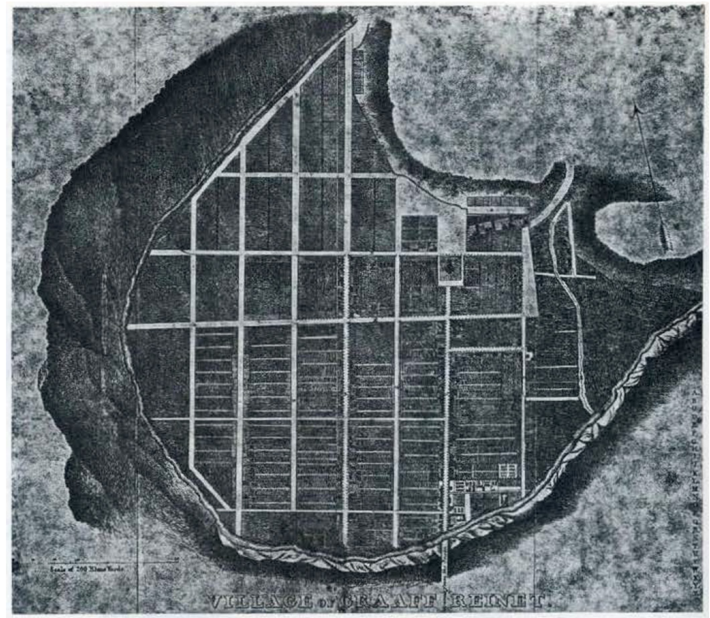
1. Natural context
2. Cultural choices
3. Universal city models.

If these three aspects are implemented in city planning, human requirements will automatically be satisfied. The city will become timeless because of its ability to withstand the development and changes that time brings about (Jordaan, 1989: 26).

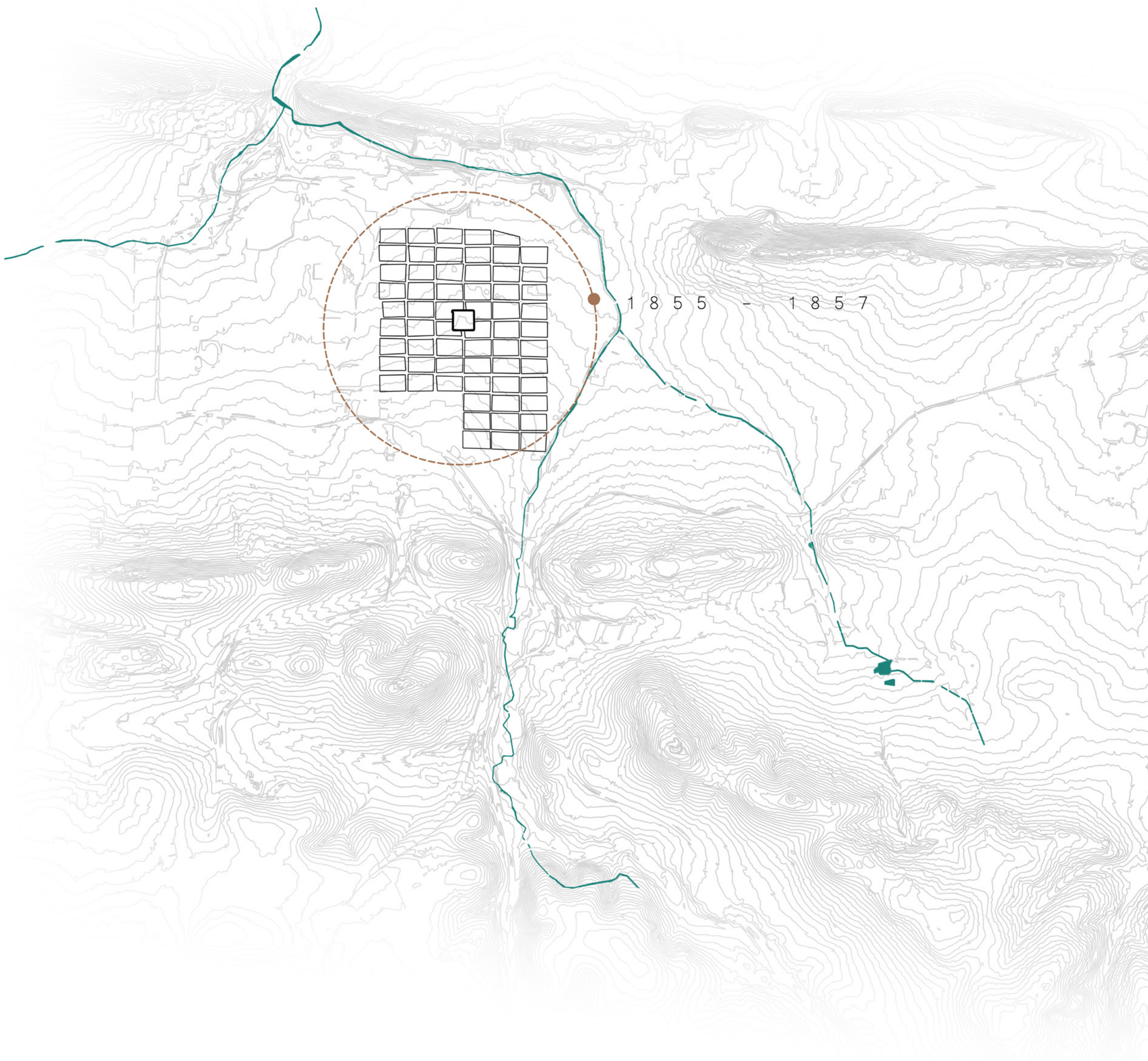
Pretoria was founded in 1856 when the Voortrekkers settled in east-west running valleys. The area is bordered by the Magaliesberg mountain range in the north; rolling hills to the south; and the Apies River to the east (Corten et al., 2014). A street grid pattern, with the eastern edge shaped by the Apies River, was implemented and can still be seen in present-day Pretoria.

The city's form follows the universal city model. It is static and of very simple geometry and was devised with prior knowledge, coming from South Arica's colonial background, of the need for social control over a settlement. The spatial organization of Pretoria is inspired by its street patterns, which is the most important element in how a city functions and also has visual implications (Jordaan, 1989: 26).

The city's gridiron street layout, between the mountain range and river, was a culturally accepted model copied from Graaff-Reinet's layout (Jordaan, 1989: 26). Pretoria's grid pattern is very strong and is considered to be one of its main historical features, as it stood the test of time through years of change and developments (Clarke & Corten, n.d.).



4.1_ Graaff-Reinet's city layout, the one on which Pretoria's layout is based on (Jordaan, 1989: 26).



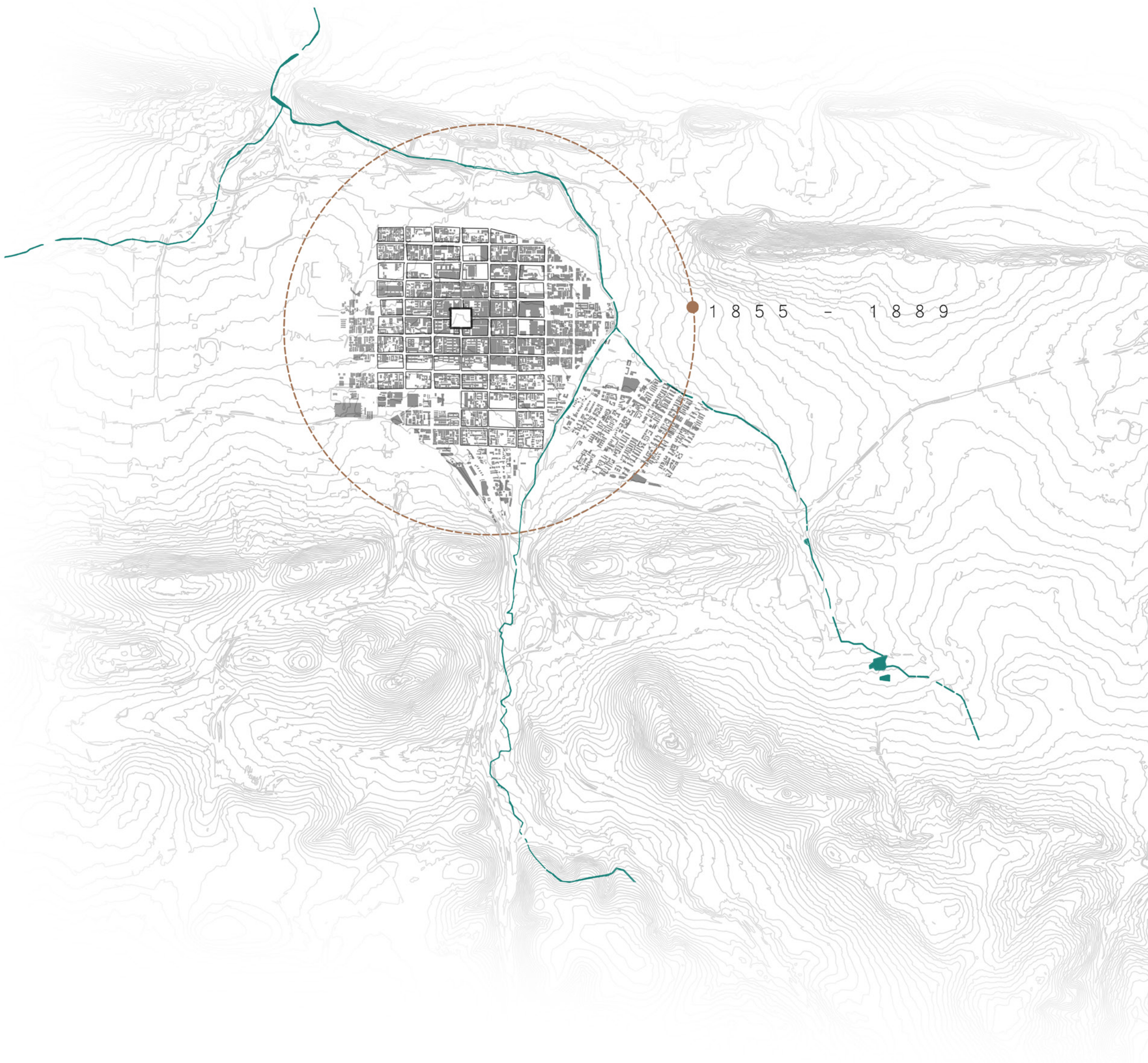
4.2_ Pretoria's First grid layout between 1855 and 1857 (Author, 2015)

4.2 / PRETORIA DECENTRALIZED

Pretoria was planned and developed as a closed grid (Marcuse, 1987: 290-291). It was arranged with clear and visible limitations, for example, city walls, major outer termini for Central Street, and green belts. According to Rose-Redwood (2008: 52), Marcuse (1987: 290-291) refers to the "closed gridiron plan as a complete and encompassing plan for a physically defined and bounded area; the open gridiron is an initial step towards plotting an unknown and perhaps unlimited area capable of indefinite expansion." Marcuse (1987: 290) views the layout of an open grid as the intention to expand. The grid pattern of Pretoria's streets became the main axis around which the city expanded; from the closed grid to an open grid in the surrounding area.

The industrial era not only pushed the degeneration of natural resources to an elevated level but also sparked development in transportation. From about 1760 to 1840 the transition from hand-made production processes to machine driven processes took place and included a rapid conversion from burning bio-fuels to burning coal. The industrial era ignited the innovation of steam transport; increasing the technological and economic growth of cities (Gascoigne, B. 2015).

In the late 1800s, the discovery of gold at the Witwatersrand impacted the growth of Pretoria tremendously; changing it from a rural settlement to an urban society (Corten et al., 2014). The city expanded mainly towards the east (at the Apies River). Pretoria became disconnected from its natural environment; the expansion of the city resulted in enormous pressure on local water resources and on the management of waste water, and so the Apies River



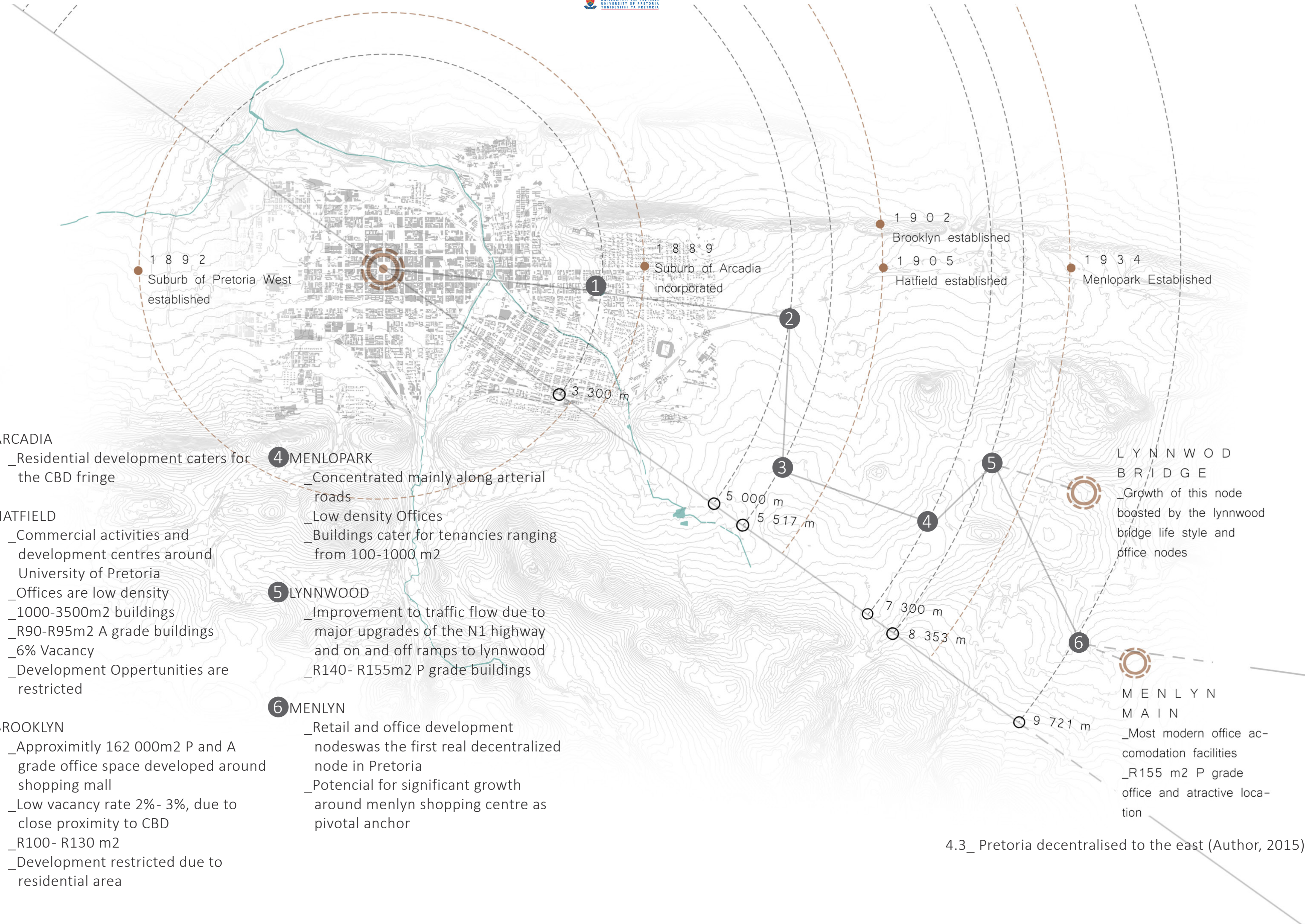
4.2_ Pretoria's layout developed beyond the Apies River 1889 (Author, 2015)

became the quickest and easiest way to discharge the city waste. Disconnection between the natural- and built environment endangers the tangible functions of cities. It also threatens the physical well-being of the city's inhabitants (Peres et al, 2015: 40).

Pretoria also struggles with the problem of decentralization. As the CBD is dominated by offices and governmental precincts, the private sector moved towards the city border and formalized other office nodes, in effect decentralizing the inner city (Sacommercialpropnews.co.za, 2015). The formation of office nodes away from the CBD can be based on various factors (Sacommercialpropnews.co.za, 2015):

1. Pretoria was built on old town planning principles, which deprive the city of adequate parking space.
2. Buildings are inefficient according to modern designs and human needs.
3. There is poor public transport, which promotes the use of private transport; impacting traffic.
4. Maintenance is costly due to older buildings that are incompatible with modern technology.

The result of this sprawl and decentralization of the Pretoria CBD is undeveloped voids in the city fabric, which are decaying due to lack of ownership. They have been occupied by private owners, especially in the natural setting alongside the Apies River. One reaction that can restore the physical well-being (disconnect from natural environment, sprawl and decentralization, decaying voids in the city fabric) of the city and its inhabitants is to view the city as an ecosystem (Peres et al, 2015: 40).



1 ARCADIA
- _Residential development caters for the CBD fringe

2 HATFIELD
- _Commercial activities and development centres around University of Pretoria
- _Offices are low density
- _1000-3500m2 buildings
- _R90-R95m2 A grade buildings
- _6% Vacancy
- _Development Oppertunities are restricted

3 BROOKLYN
- _Approximitly 162 000m2 P and A grade office space developed around shopping mall
- _Low vacancy rate 2%- 3%, due to close proximity to CBD
- _R100- R130 m2
- _Development restricted due to residential area

4 MENLOPARK
- _Concentrated mainly along arterial roads
- _Low density Offices
- _Buildings cater for tenancies ranging from 100-1000 m2

5 LYNNWOOD
- _Improvement to traffic flow due to major upgrades of the N1 highway and on and off ramps to lynnwood
- _R140- R155m2 P grade buildings

6 MENLYN
- _Retail and office development nodeswas the first real decentralized node in Pretoria
- _Potencial for significant growth around menlyn shopping centre as pivotal anchor

4.3_ Pretoria decentralised to the east (Author, 2015)

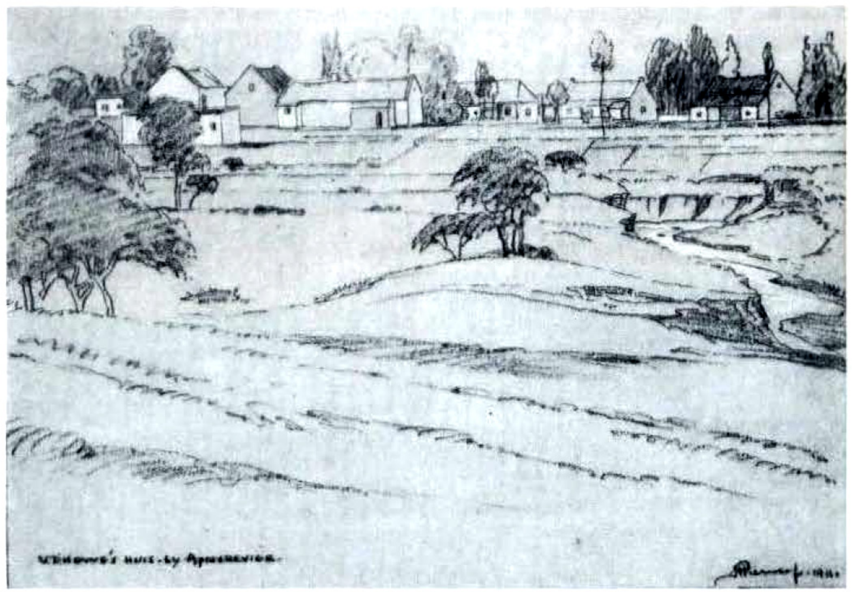
4.3 / IMPORTANCE OF THE APIES RIVER

"The River is soft, and flows with variable change and refers to a woman's emotional support, which feeds and nurtures."
Gerrit J Jordaan. 1989: 26

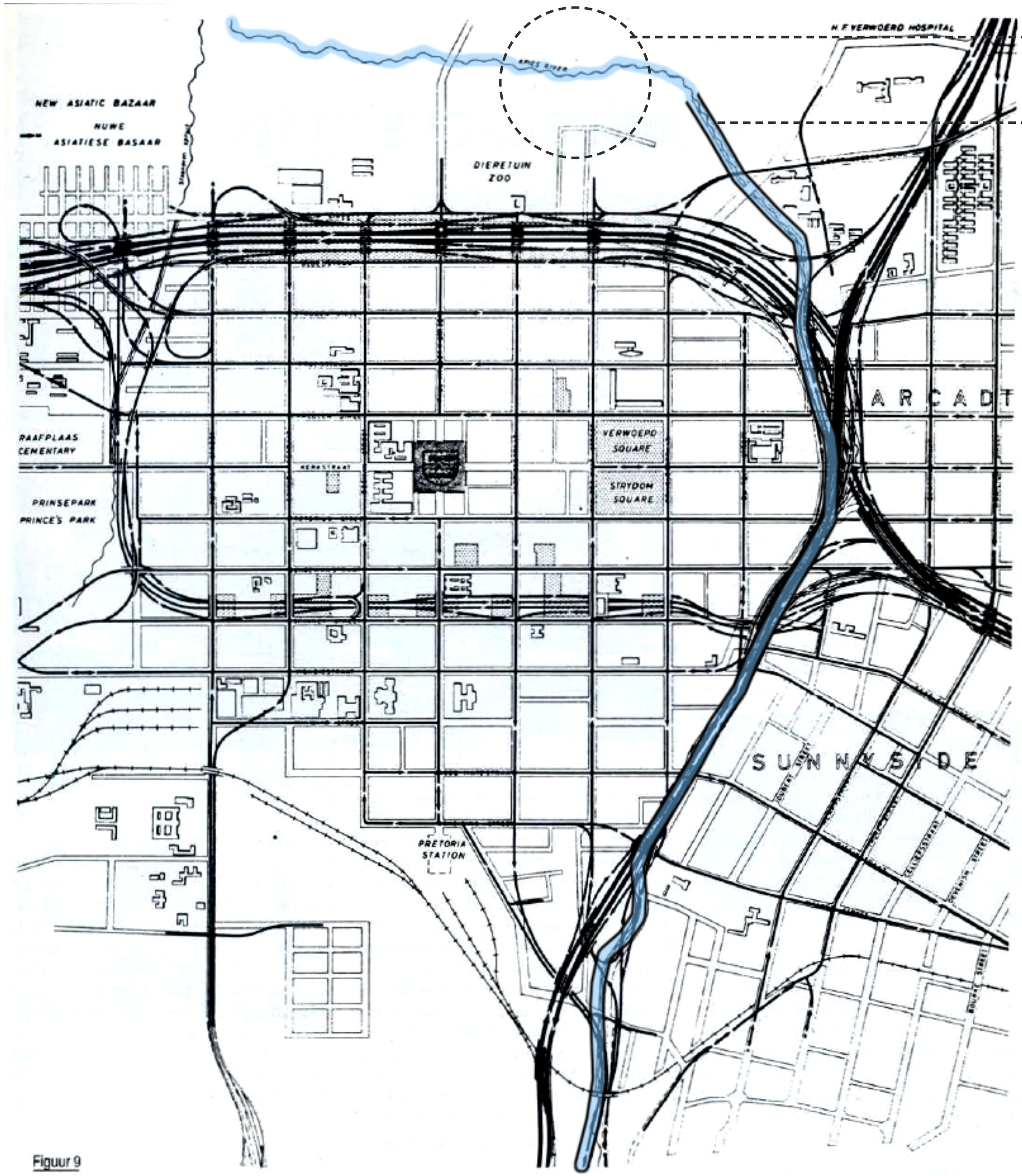
History has shown that food and water security are major aspects in the placement of cities and how they function (Falkenmark, 2014: 1). However, due to population increase (which affects urban sprawl, water and food demand); economic development; and climate change (due to human activities) the stress on food and water supply results in major environmental pressure (Pahl-wostl et al, 2013: 341).

The Apies River, which shaped the eastern boundary of the Pretoria CBD, is the district's most valuable working natural resource (Jordaan, 1989: 28). In the early days of Pretoria's formation, the Apies River was a life source for farmers, who led water in irrigation ditches from the river to their agricultural fields (Jordaan, 1989: 28). However, since the development of the city and the accrual of expansion pressures this once defining landscape border has been degraded to a waste water drain; it is neglected and forgotten.

The physical characteristics and hydrological patterns of the river have been altered through years of city development and extraction of water. This led to numerous ecological pressures, which include pollution; disturbance of indigenous plant species; and physical disturbances (waste dumping, riverbed disruptions and embankments) (Rüde, 2006). It has ultimately affected agriculture activities located next to the Apies River to the north of the CBD.



4.4_ A painting by Jacob Pierneef of the Apies River in its natural state, 1911. Van der Hove's farm house is situated in the background (de Villiers, 1989: 21)



4.5_ The natural boundary of the Apies river was degraded to a storm water channel due to development that expanded creating pressure on waste and storm water discharge (Jordaan, 1989: 29) edited by (Author, 2015)

4.4 / URBAN VISION

4.4.1
LOCAL GOVERNMENT PROPOSAL

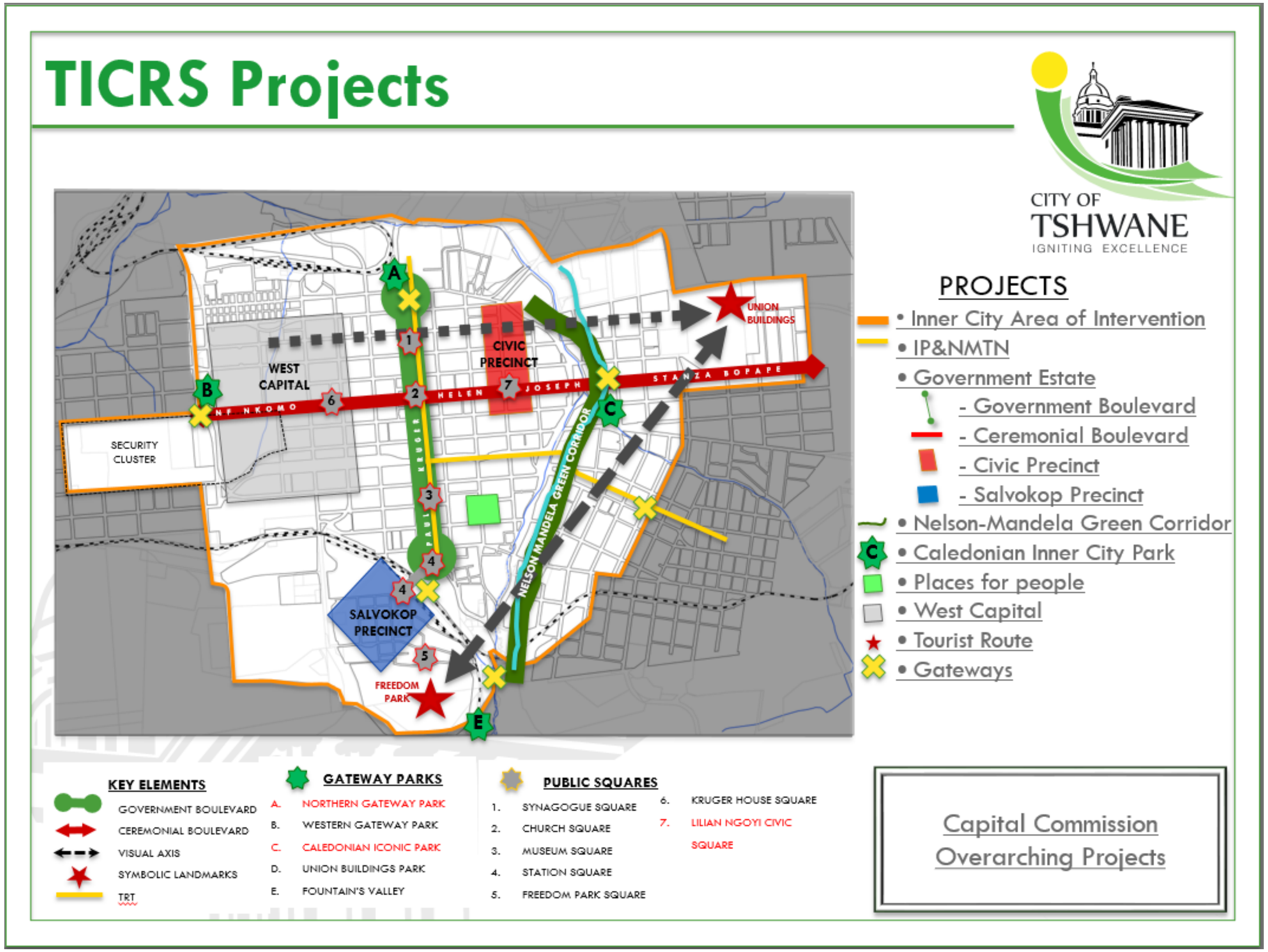
The urban vision focuses on the Tshwane 2055 city proposal. It is a possible development and works within the guidelines of the 2055 city proposal. In this dissertation, it is assumed that the Tshwane 2055 vision will be implemented. The group framework is a continuation of the Tshwane vision; the proposed development focuses on the north-eastern quadrant of the Pretoria CBD.

The city of Tshwane aims to create a high quality of life for its citizens, by developing a city that is inclusive, livable and resilient. The vision for 2055 strives to create a tangible socio-economic- and spatial transformation for all its residents through "game changing" interventions and strategic actions.

The strategic objectives include:

1- Define the capital core
2- Strengthen the government precinct
3- Support mixed-use private sector development
4- Develop cultural identity and tourism potential
5- Create a quality public environment
6- Provide for the integration of movement
7- Ensure effective city management

4.4.3
GROUP FRAMEWORK



4.6 _ Diagram illustrating the projects as a whole to be implimented by the year 2055 (Tshwane Vision, 2015).

4.4.2
NELSON MANDELA GREEN CORRIDOR / Green strip at the Apies River

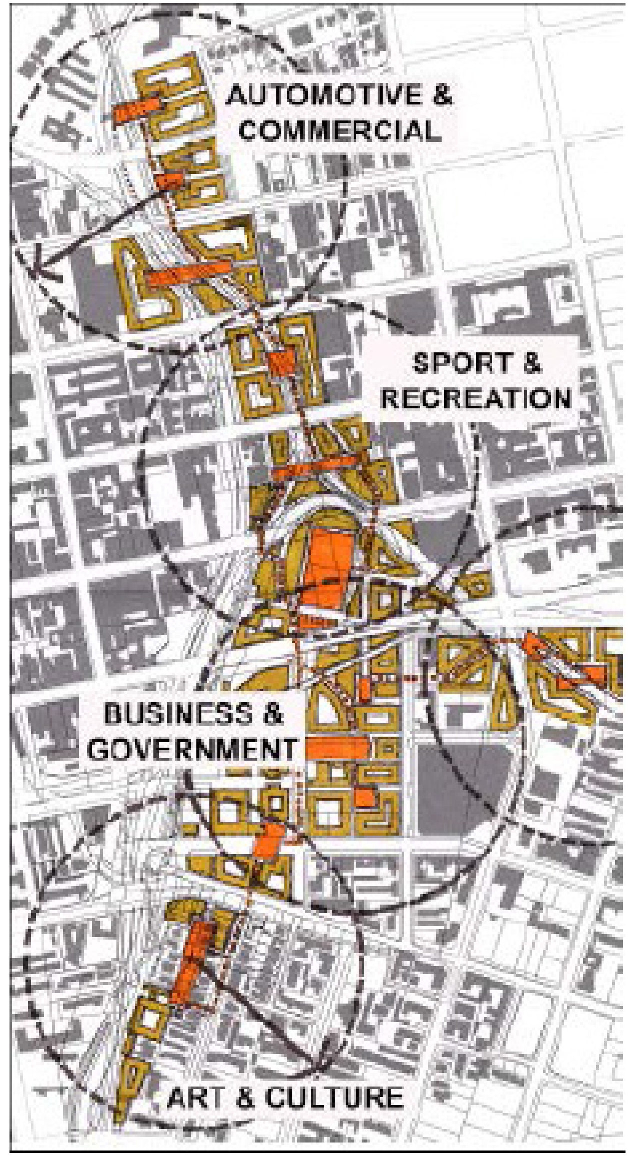
The vision states the intent to create a resilient city. It describes resilience in a city context, "Urban resilience is both a city's capacity to withstand and recover from an external shock and its ability to adapt and transform to changing circumstances" (Tshwane vision, 2015; 109). The purpose of the Tshwane vision is also to enhance quality of life in the city through the implementation of new urbanism and cradle-to-cradle (C2C) principles.

New urbanism principles are:

1- Walkability and connectivity; a high quality pedestrian network in the public realm with pedestrian friendly streets.
2- Traditional neighborhood structure
3- Mixed housing
4- Quality architecture and urban design
5- Sustainability: minimal environmental impact of the development and its operations, to thus promote efficiencies.

C2C focuses on eco-effectiveness. It calls for the way things are designed to be reconsidered (Tshwane vision, 2015; 110). This already constitutes an adequate step towards a more sustainable approach; unfortunately, it focuses only on improved energy efficiency, but lacks the connection with nature. Sustainability is a main driver for innovation, creativity and prosperity (Tshwane vision, 2015; 110), but thinking should shift towards a more regenerative developmental approach, which includes the enhancement of natural systems.

The Nelson Mandela Green Corridor is part of the Tshwane Vision to incorporate the Apies River in its developmental strategy. The goal is to create different precincts (as seen in Figure 4.7) that activate the river bank as part of the livable city environment. These precincts include the Caledonian Stadium (at the junction of the Apies River and Walker Spruit); splash pools and a skate park; markets and restaurants; and finally the damming of the Apies River (Tshwane vision, 2015; 110). This forms the Nelson Mandela Green Corridor, which is limited to a certain part of the Apies River and does not utilize the full potential the river offers. Further investigation is therefore needed to create a more regenerative approach.



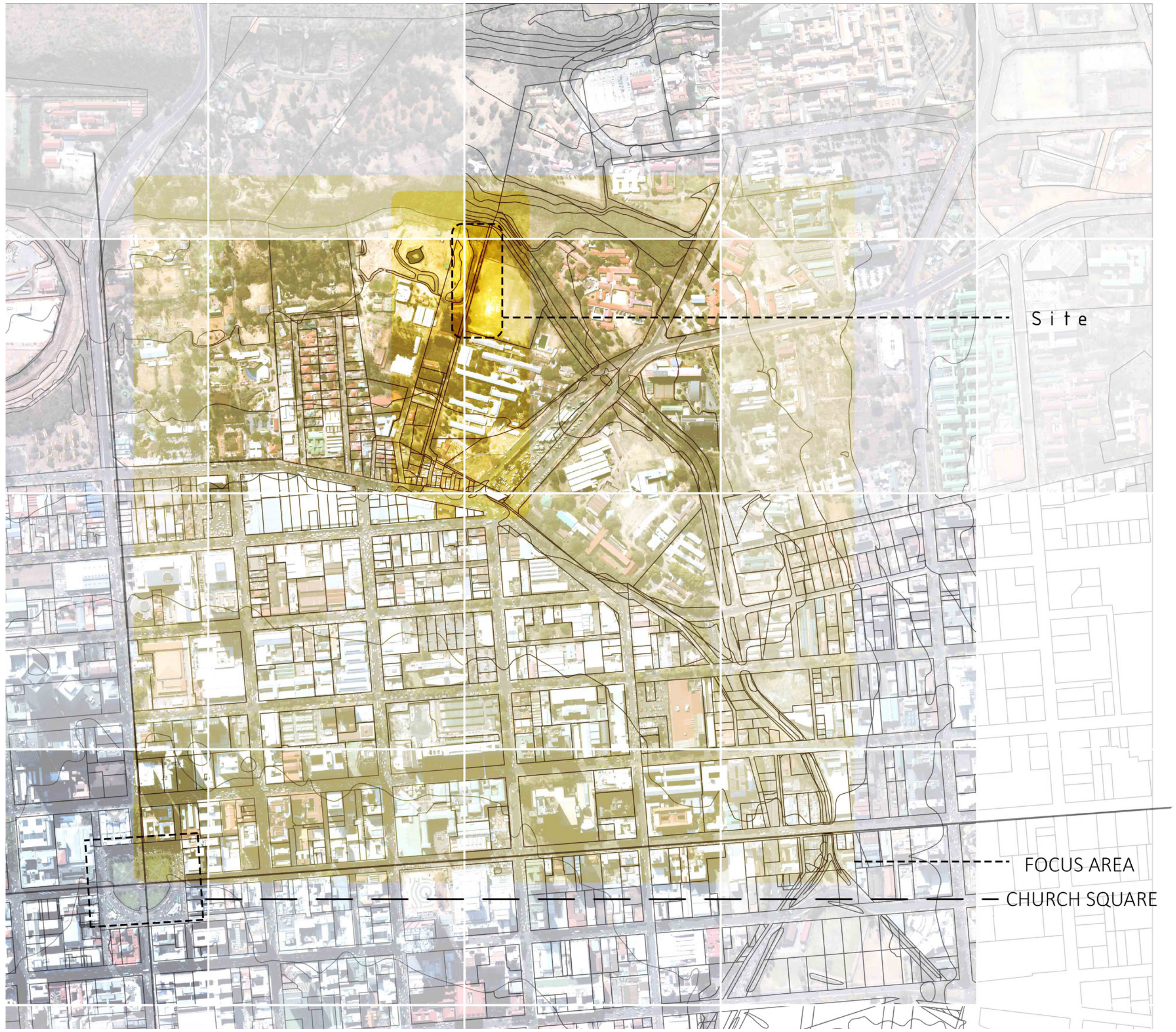
4.7_ Diagram illustrating the precincts developed as part of the Nelson Mandela Green Corridor (Tshwane Vision, 2015)

4.4.3
GROUP FRAMEWORK

As mentioned above, the group framework focuses on the north-eastern quadrant of the Pretoria CBD. Utilizing the neglected potential and missed opportunities in this quadrant that could be a great contribution to the future development of Pretoria as a city. The group framework focuses on neglected spaces that have been abandoned and then forgotten as the city developed; resulting in the decay of these in-between spaces.

4.4.4
FOCUS AREA / Micro urban framework

This dissertation focuses on the Apies River as part of the Tshwane 2055 development proposal. It emphasizes the importance of recognizing the Apies River as an important regenerative design driver. It proposes that life should be given back to the Apies River and advocates the construction of water channels and wetlands in walkways between the street and building edge of the CBD. This would create a Green urban strip condition that collects the surface run-off from the city's hardscapes, such as, roofs, streets and walkways.



4.8_ Group Framework focus area in the North-East quadrant of Pretoria's CBD (Author, 2015)

4.9_ The implementation of the Green strip from the Tshwane vision, The group framework proposes the zoning continues (Author, 2015).

These water channels are to strategically lead towards the Apies River, in order to discharge filtered water back into the river. The exposed water channels, cultivated with reeds and plants, create awareness of the Apies River and bring nature into the city. They will not be placed throughout the city, but only where the ground contours allow water to flow towards the Apies River using only gravity. One of these water channels will lead into the proposed site where the new building is to be activated.

The evolution of cities and the modern way of shaping cities come from an enlightened world view, in opposition to previous beliefs that disconnected nature from humans and their habitats (Peres et al, 2015: 40). "The disconnection from natural systems in Pretoria is ironic, since its connection to water was integral to its establishment" (Peres et al, 2015: 40). Many are recognizing that a lack of water quality and quantity is an environmental problem; making the regeneration of this natural resource critical to the resilience of Pretoria (Peres et al, 2015: 40), (Wells et al, 2010: 130). For a city to become resilient in the face of environmental pressure it requires the complexities of ecosystems in a green infrastructure (Wells et al, 2010: 130).

4.10_ The Group Framework proposes the implementation of water channels on the walkways that collects water in the city's hard surfaces, (Author, 2015).

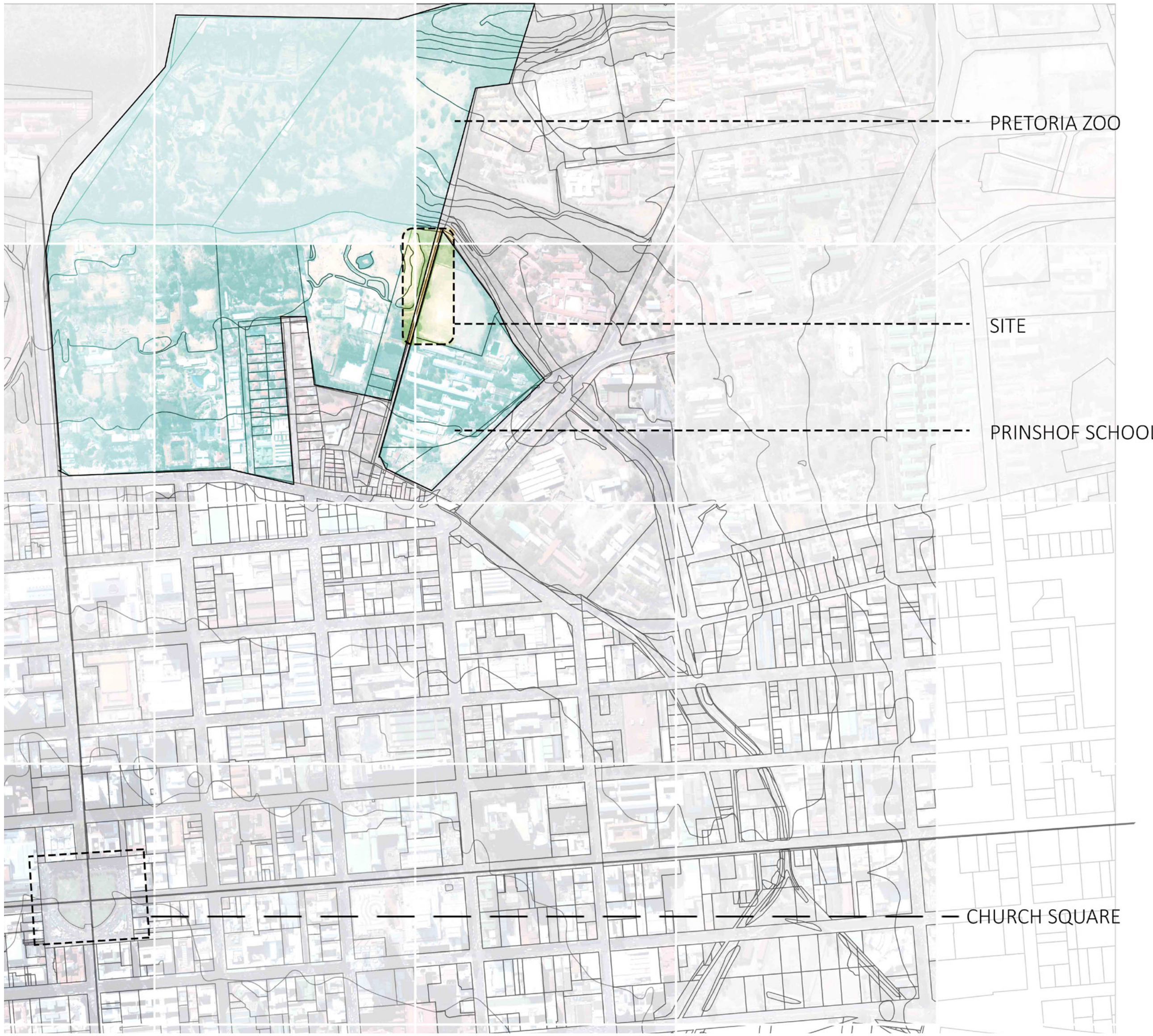
4.11_ Fig 1- 5 shows the existing condition of the Apies River, (https://www.google.com/earth/ edited by Author, 2015).

5 / SITE CONTEXT

5.1 / SITE SPECIFICS

The site of interest is on the boundary between two properties; the Pretoria National Zoo on the west and the Prinshof School on the east (refer to Figure 00). It holds a great deal of potential in terms of both its placement and connection between the inner city and the Apies River. The river, which is to the north of the proposed site, is currently seen as a dead space or a 'no-go' area. As seen in Figure 00, waste and storm water run-off discharge into the canalized Apies River, resulting in unpleasant smells and views of polluted water. Some parts of the Apies River, obscured from public view, are occupied by the homeless and street dwellers, making it unsafe to walk next to the river.

The site is chosen because of its hidden potential. Natural resources can be utilized and programs informed by the existing functions in the area. In the group framework, the Apies River is activated as a green park; fashioned as wetlands that filter and clean the water. Public walkways are created to reconnect people to nature. There is a 6-meter-high hill on site, which is the backdrop for the zoo's animal camps, refer to Figure 5.4 on page 52. Behind the hill is the zoo's dump site; filled with waste gathered within the zoo area. The site also maintains a plantation and nursery structures where trees and plants are cared for, but these structures are in a state of physical deterioration. The Prinshof School sport ground forms the eastern boundary of the site. Figure 5.3 shows the sport grounds' current condition, ascribable to a

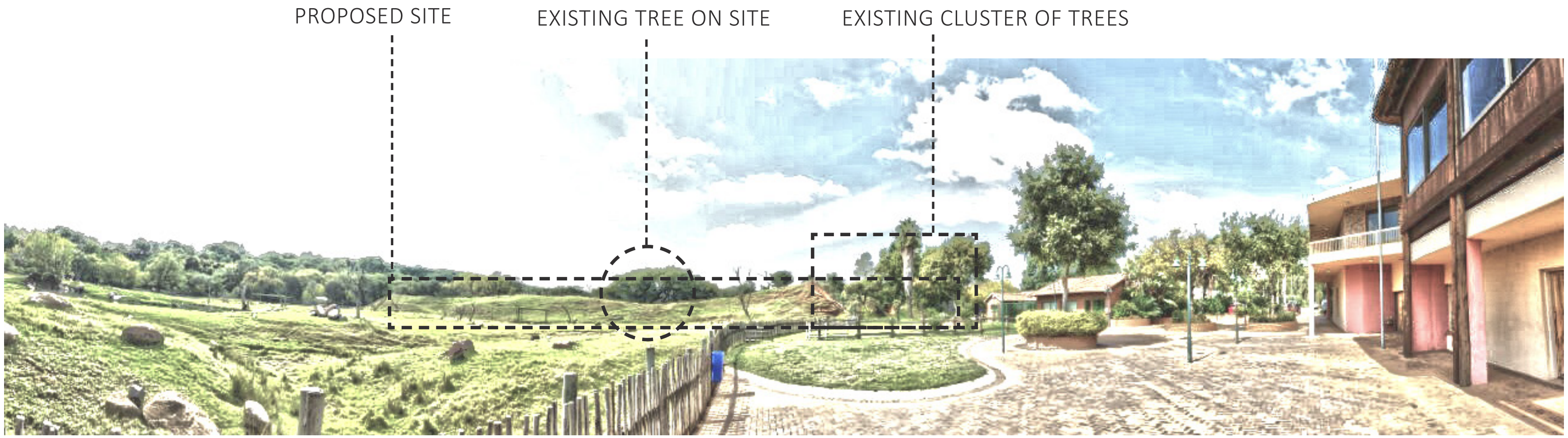


5.1_ Location of proposed site (https://www.google.com/earth/ edited by author, 2015).

5.2_ Zoning: Prinshof School, Zonong of existing site (https://www.google.com/earth/ edited by author, 2015).

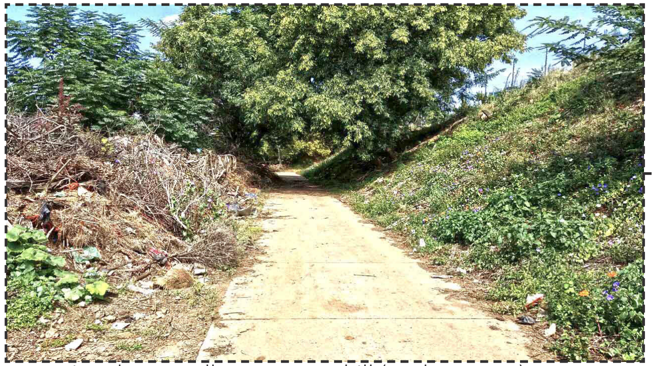
lack of activity from the school. The grounds are used by the students, but not to full capacity. The site gradually slopes downwards to the north and into the Apies River and in the past fed the river with water run-off. This set in motion all the necessary requirements in the natural cycle flow of the biosphere. Excessive land development over the years has, however, caused the connection to the river to be lost; natural ecosystems that once thrived on that site have then also been lost. Therefore, the project aims to reconnect water run-off and the river and, by doing so, to reclaim the natural flow of ecosystems.

5.3 _ View of site from the school sports ground (Author, 2015).



5.4 _ View of site from Pretoria Zoological gardens, Eland camp (Author, 2015).

5.5 _ Site photo, dumping site (Author, 2015).



5.6 _ Site photo, walkway next to hill (Author, 2015).

5.7 _ Site photo, entrance to site showing contrast between hill and damaged ecosystems (Author, 2015).

5.10 _ Aerial view of site (https://www.google.com/earth/ edited by author, 2015).

5.8 _ Site photo, view of dumping next to walkway (Author, 2015).

5.9 _ Site photo, Insect habitats on site (Author, 2015).

5.2 / MICRO-CLIMATE ANALYSIS

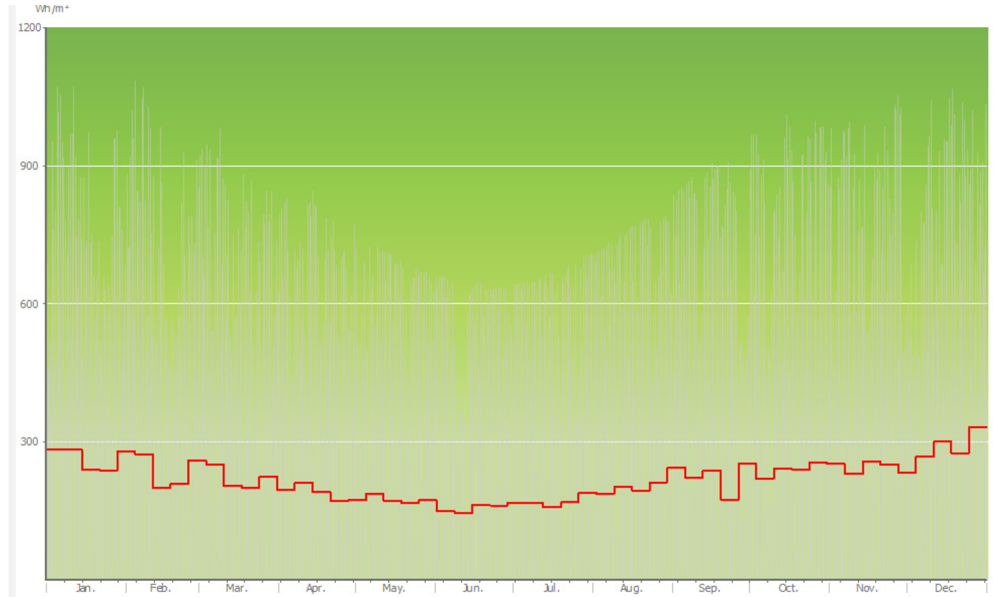
Micro-climate is the analysis of the general climate on a specific site. It is influenced by topography; the ground surface and plant cover, as well as man-made forms.

Micro-climate analysis is continued in the Eco-Mapping section. An overview of the proposed site is given here, in terms of the existing factors that influence the climate of the site.

5.2.1
CLIMATE DATA

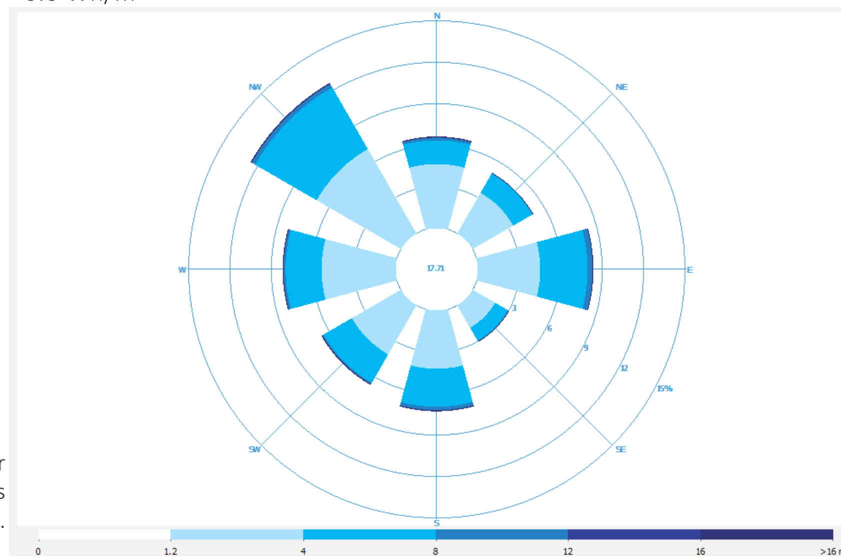
The climatic data was analyzed using the Eco-design Star tool from Archicad. Within this tool, climatic data was sourced from ZAF_Johannesburg.683680_IWEC.epw which gives the exact climatic measurements of a specific area. The proposed site's coordinates were used to pin point the exact climatic data and analysis, refer to figure 5.11- 5.14:

1. Solar radiation
2. Air temperature
3. Relative humidity
4. Wind direction and speed

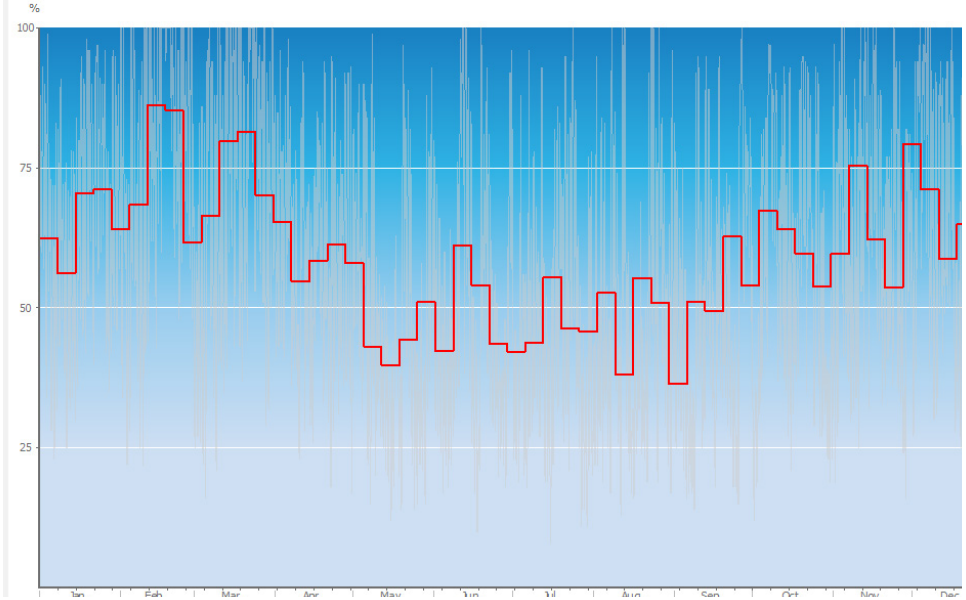


SOLAR RADIATION /
Measured on a weekly basis
Max: 1130 Wh/m^2
Average: 225.45 Wh/m^2
Min: 0.0 Wh/m^2

5.11_ Solar radiation measurements for proposed site sourced from Archicad's Eco-design tool(Author, 2015).

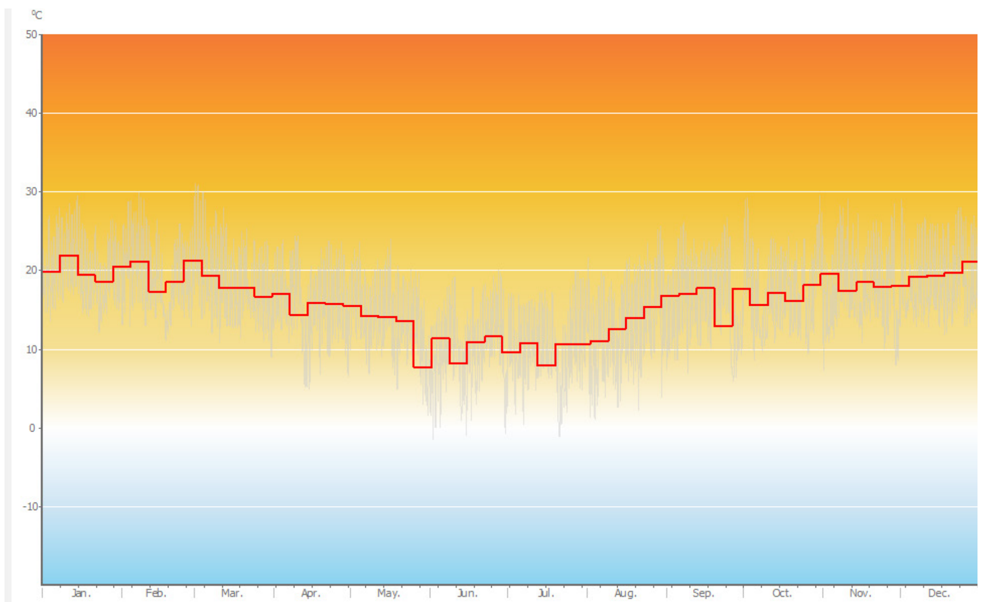


5.12_ Wind direction and speed for proposed site sourced from Archicad's Eco-design tool(Author, 2015).



RELATIVE HUMIDITY /
Measured on a weekly basis
Max: 100 %
Average: 58.77 %
Min: 8 %

5.14_ Relative humidity for proposed site sourced from Archicad's Eco-design tool(Author, 2015).

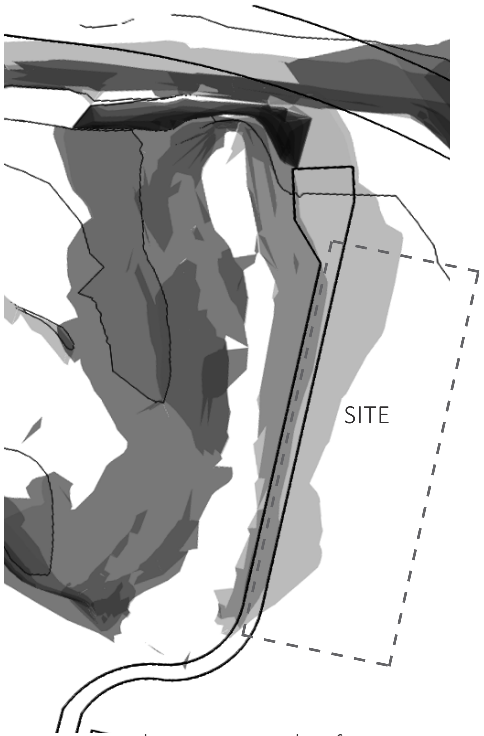


AIR TEMPERATURE /
Measured on a weekly basis
Max: 31.10 C^0
Average: 15.84 C^0
Min: -1.50 C^0

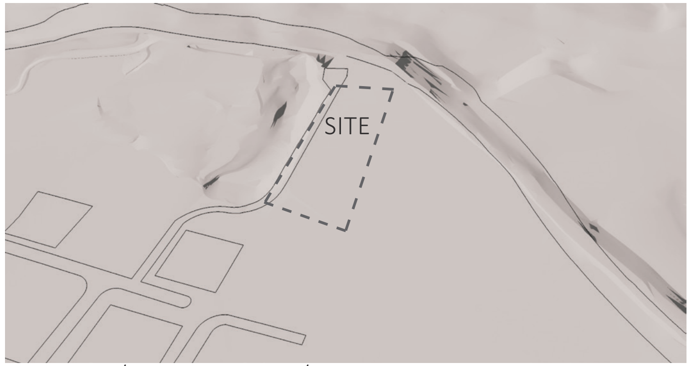
5.13_ Air temperature measurements for proposed site sourced from Archicad's Eco-design tool(Author, 2015).

5.2.2
SUN STUDY

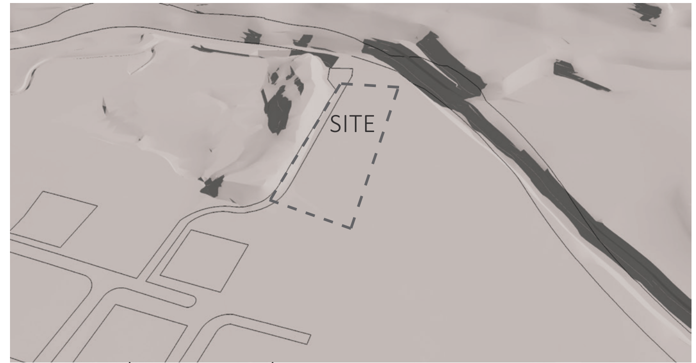
The sun's movement through the day and year is a crucial environmental factor to consider. When designing a building to be dependent on passive systems, it is critical to study the sun path. It can reveal where natural daylight can be utilized or where to place the PV panels. The proposed site's sun path was studied in summer, autumn, winter and spring.



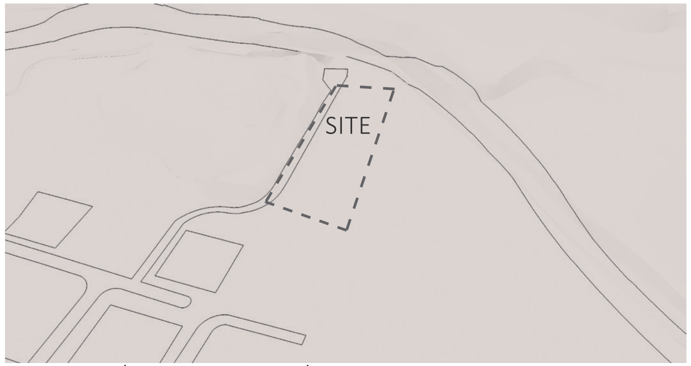
5.15_ Sun path on 21 December from 6:00 to 18:00 (Author, 2015).



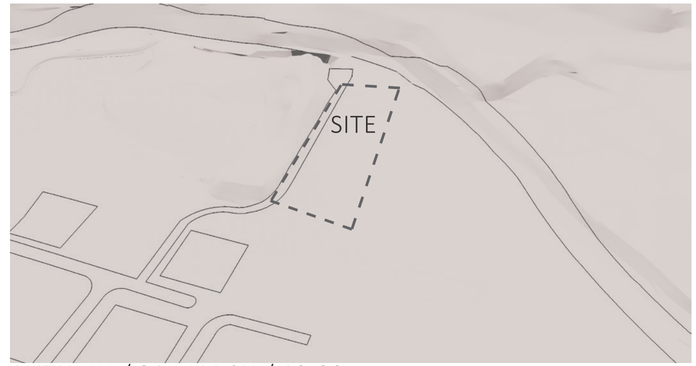
SUMMER / 22 DECEMBER / 8:00



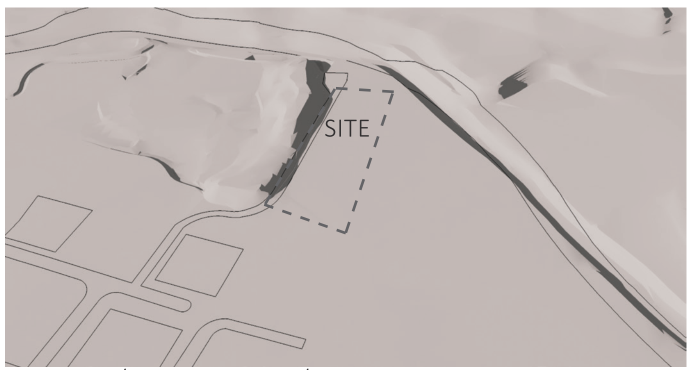
AUTUMN / 21 MARCH / 8:00



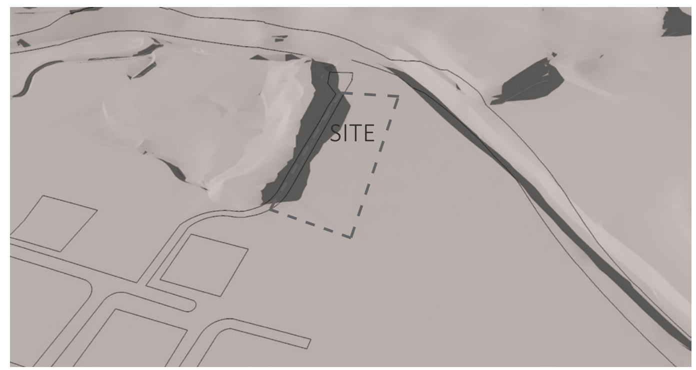
SUMMER / 22 DECEMBER / 12:00



AUTUMN / 21 MARCH / 12:00



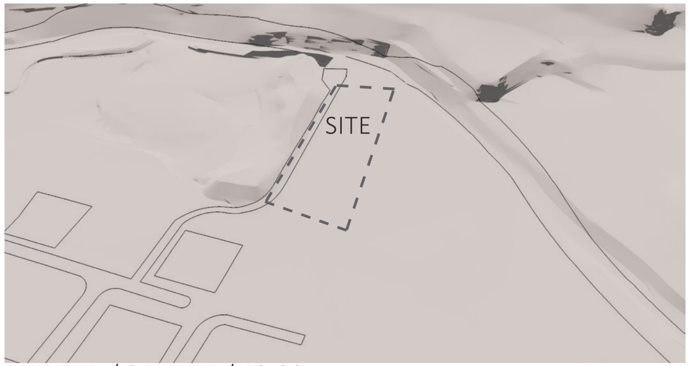
SUMMER / 22 DECEMBER / 17:00



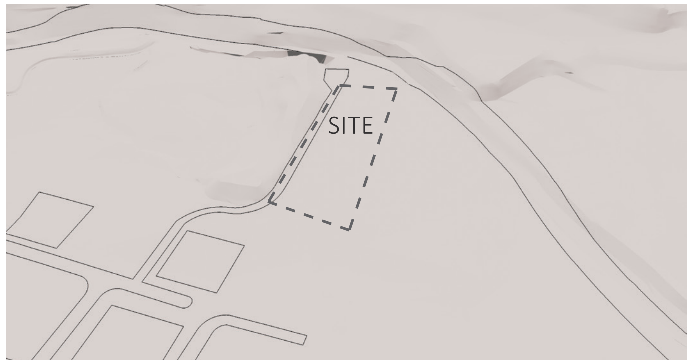
AUTUMN / 21 MARCH / 17:00

WINTER / 21 JUNE / 8:00

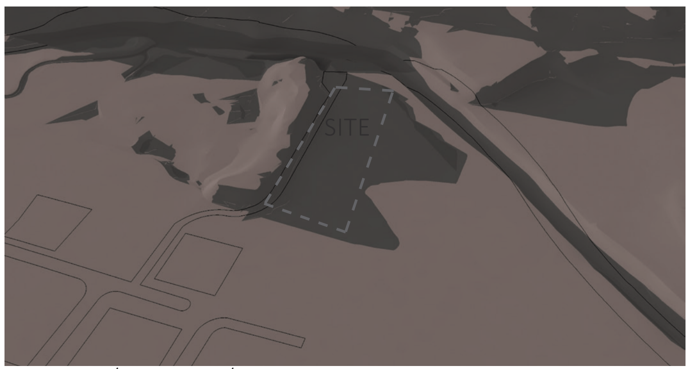
SPRING / 21 SEPTEMBER / 8:00



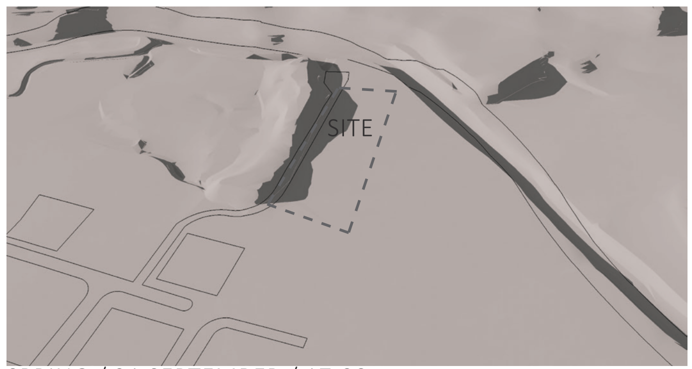
WINTER / 21 JUNE / 12:00



SPRING / 21 SEPTEMBER / 12:00



WINTER / 21 JUNE / 17:00



SPRING / 21 SEPTEMBER / 17:00

OUTCOME /

The outcome of the sun study reveals the site to be very exposed to the sun, with limited natural shading. The existing trees on the site do not provide sufficient shading. Therefore alternative means to create shading on the site are necessary. Planting trees, creating screens on the building and constructing objects to create shading for the building are options to consider.

5.16_ The sun study analyzed through the year focused between 8:00 the morning, 12:00 noon and 17:00 in the afternoon, and varied from summer on the 21st of December, Autumn 21 March, winter 21 June and spring 21 September (Author, 2015).

5.3 / ECO-MAPPING

Ecological mapping was done using the 'Ecomasterplanning' methods conceived by Ken Yeang[8] . Habitat mapping can increase insight into the character of that place[9] and enables the assessment of the ecological value and structures of the existing environment. It facilitates the restoration of destroyed habitats or the conservation of healthy habitats (Freeman, C. 2010: 100). Ecomasterplanning is the continuous integration of the environment and four infrastructures (Yeang, K. 2008: 128):

1- **Green infrastructure;** connecting greenways and habitats
2- **Gray infrastructure;** the engineering systems.
3- **Blue infrastructure;** sustainable urban drainage system
4- **Red infrastructure;** the human infrastructure consisting of built systems and hardscapes

The difference between ecomasterplanning and conventional master planning is the addition of the green infrastructure or 'eco-infrastructure'. The green infrastructure integrates the functionality of green spaces (that benefit from ecosystems) with the built infrastructure, resource management and land development (Yeang, K. 2008: 131). It is critical to have a green infrastructure in place in any master plan.

5.3.1
GREEN INFRASTRUCTURE

All natural areas are interconnected by green ways or wetlands that conserve the functions of natural ecosystems. The natural characteristics of the place are therefore preserved. The existing ecosystems are also enhanced, resulting in positive outcomes (Yeang, K. 2008: 128):

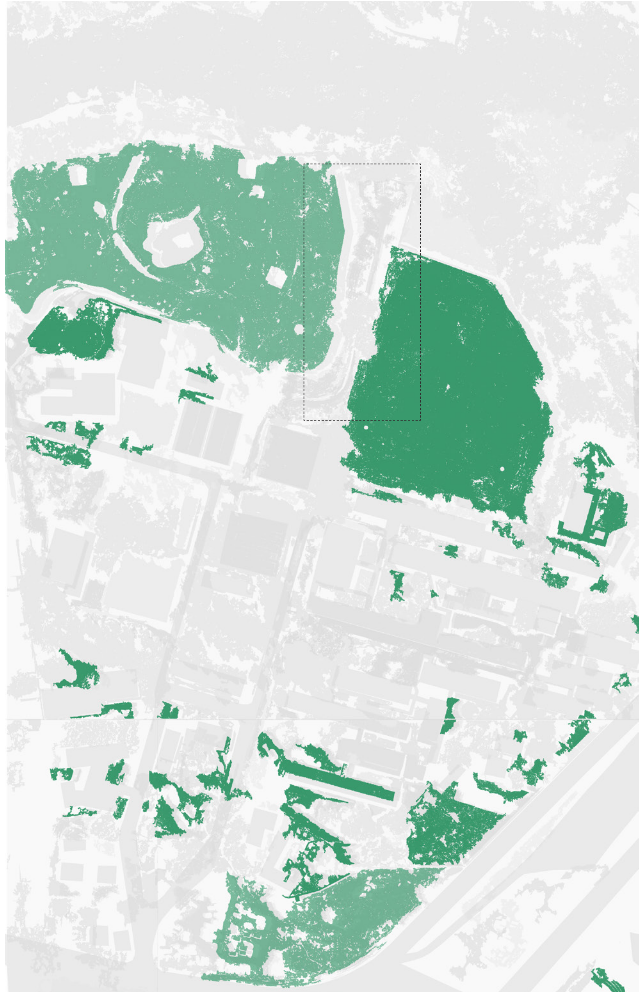
1- Cleaner water and enhanced water supply
2- Cleaner air
3- Reduction of the heat island effect
4- Moderation in the impact on climate change
5- Protection of sourced water.

The environmental benefits and positive values of green infrastructure are a critical framework for the functioning of natural systems. It is ecologically critical for the growth and care of plant and animal habitats, such as, healthy soil, water and air (Yeang, K. 2008: 128).

OUTCOME / The green infrastructure on site is to some extent overpowered by grasslands, formed by the school sports ground in the east and the zoo camps in the west. Bushes and trees form clusters of overgrown vegetation that create shade and habitat for some wild species. The site also consists of bare and patchy ground cover originating from human activities that negatively affected the site.

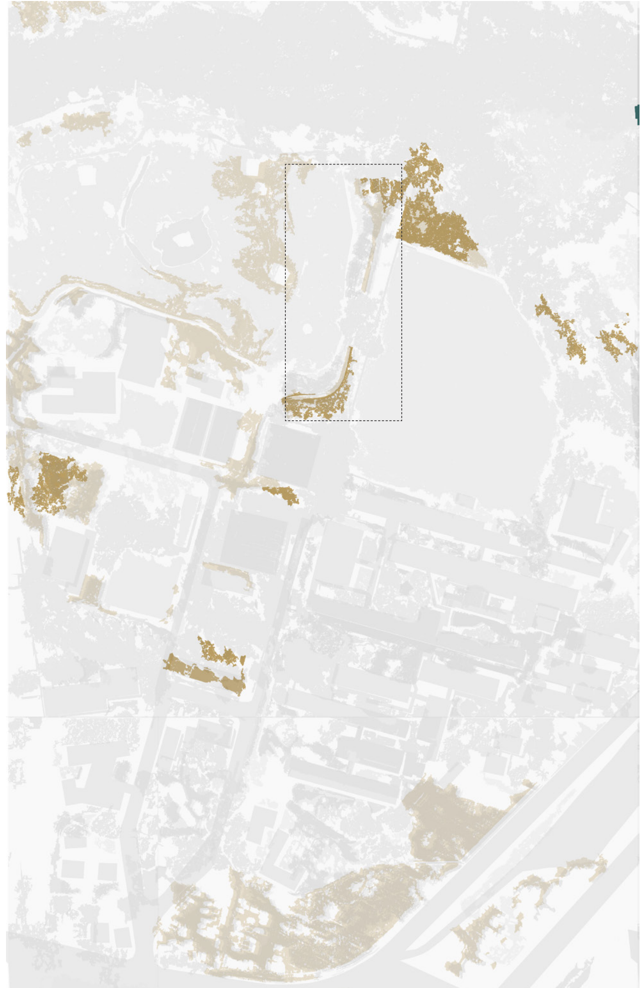
[8] Ken Yeang is a director of Llewelyn Davies Yeang in London and TR Hamzah & Yeang, Its sister company, in Kuala Lumpur, Malaysia. He is the author of many articles and books on sustainable design, including Ecodesign: A Manual for Ecological Design(Wiley-Academy 2006)
[9] As described in the theory chapter 3

GRASSLAND HABITATS /
- Open-space grass lands
- Rough Grassland irregular managed and grazed grassland



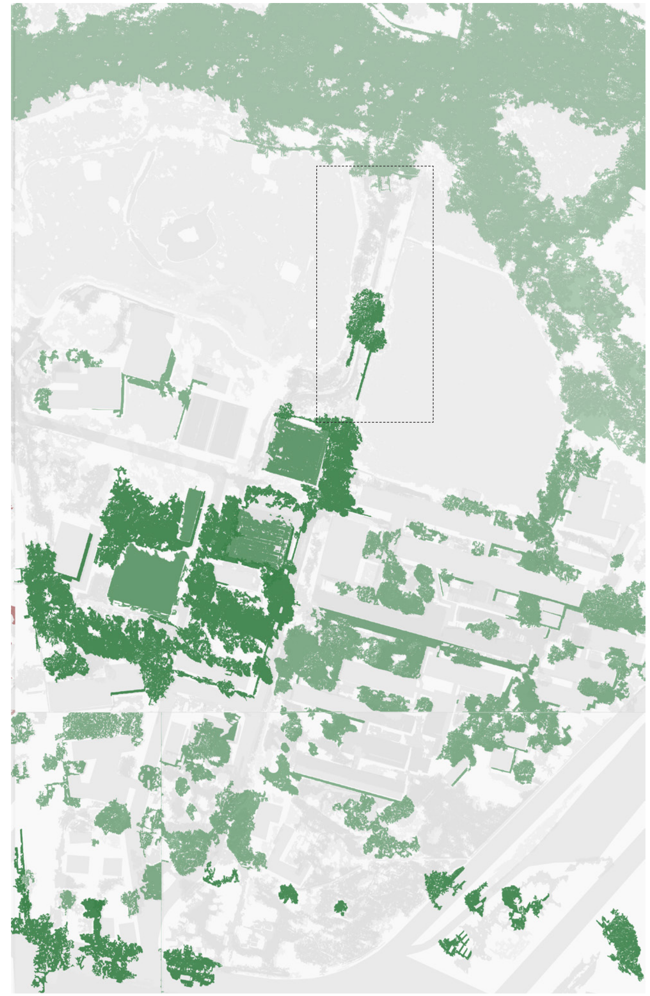
5.17_ Grassland habitat analysis of proposed site (Author, 2015).

BARE AND PATCHY HABITATS /
- Bare ground
- Dump / landfill



5.18_ Bare and patchy ground surfaces analysis of proposed site (Author, 2015).

BUSH AND TREE HABITATS /
- Bush and forest / close canopies
- Woodlands / scattered trees
- Plantation
- Tree groups / isolated group of trees.



5.19_ Bush and tree habitats analysis of proposed site (Author, 2015).

5.3.2
BLUE INFRASTRUCTURE /

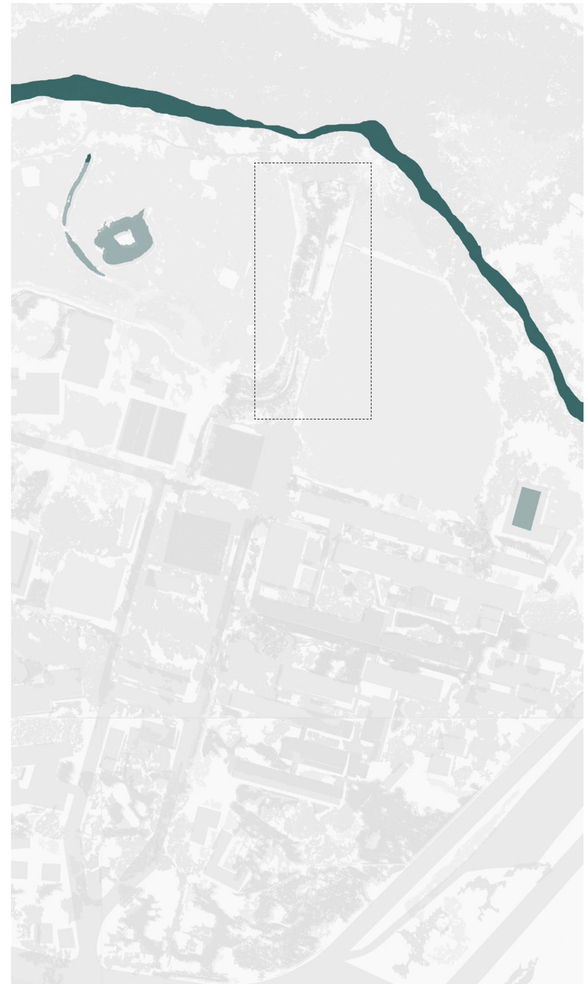
Blue infrastructure can be seen as surface water infrastructure. Through the use of filtration beds, built surfaces, retention ponds and bio-swales rainwater can be retained on the surface of the site and used to replenish the ground water (Yeang, K. 2008: 131). When identifying the character of a place in ecomasterplanning, the site's natural drainage patterns and contour slope play a part (Yeang, K. 2008: 131); as seen in Figure 5.20. After the water pattern has been considered, the surface water must be managed properly, so that surface water can be most beneficially utilized before it disappears through drainage or evaporation. The blue infrastructure in ecomasterplanning must conclude with the creation of a system that sustains urban drainage. It must be able to function as a wetland habitat and create a buffer strip that alleviates flooding and offers habitats for wildlife and other species (Yeang, K. 2008: 131).

OUTCOME / The site is significant because of its natural downward slope to the Apies River. The Apies River is the only natural water landmark on site and has been collecting run-off surface water from the surrounding area.

CONTOUR MAPPING /

5.20_ Contours sloping down to Apies River (Author, 2015).

AQUATIC HABITATS /
- River and stream
- Standing water



5.21_ Aquatic analysis of proposed site (Author, 2015).

RED INFRASTRUCTURE /
- Buildings
- Tarred Roads
- Gravel roads

5.22_ Built up infrastructure analysis of proposed site (Author, 2015).

5.3.3
RED INFRASTRUCTURE /

Red infrastructure can be seen as the human community; the buildings from the built environment (Yeang, K. 2008: 131).

OUTCOME / The buildings in the surrounding area are situated on the southern side of the site. These consist of school buildings and restaurant buildings in the Zoo area.

5.4 / PRETORIA ZOO

Dr J.W.B. Gunning established the National Zoological Gardens (NZG) of South Africa as a branch of the Staatsmuseum der Zuid-Afrikaansche Republiek (Engelbrecht, 2014: 63). The small collection of animals was moved to the site Rus in Urbe, which is the current site for the NZG, in 1899 when Dr Gunning received permission. This was followed by the construction of Lion House in 1902 and the main entrance in 1903 (Engelbrecht, 2014: 63).

Additional land was granted to the northern side of the Apies River in 1909 and in 1935 funding was received to enlarge the zoo by the addition of Prinshof farm No. 628. The NZG is the largest zoo with national status in the country. It currently occupies 85 hectares and houses over 8000 animals; which include reptiles, fish and birds (Engelbrecht, 2014: 67).

Today, the Zoo's arrangement of enclosures and exhibits is according to various rationales based on the animals' environment, region and climatological characteristics. Awareness is increasingly focused on the role of environment (Engelbrecht, 2014: 57). As a result, enclosures are grouped in terms of conservation, with an emphasis on habitats; thus conveying their importance to the public. The intention is to raise the public's understanding of the importance of biodiversity preservation through imitating the species' habitats.


5.23_ Existing plantation area in the Zoo (Author, 2015).


5.24_ Abandoned buildings in the zoo used for storage (Author, 2015).


5.25_ Dump sites in the Zoo area (Author, 2015).


5.26_ Aerial view of the site area (https://www.google.com/earth/ edited by author, 2015).

5.27_ Photos framed in the Prinshof school about the inauguration of the school, Mev. Betsie Verwoerd revealing the plaque of the school in 1967(Author, 2015).

5.28_ Photos framed in the Prinshof school about the inauguration of the school, the new building being introduced (Author, 2015).

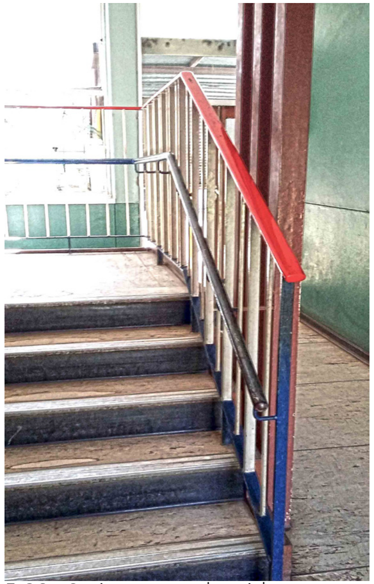
5.5 / PRINSHOF SCHOOL

HISTORICAL HIGHLIGHTS

In 1954 the parents of Pretoria requested that the Department of Education found a school for visually handicapped pupils of the Arts and Science. A committee was nominated to investigate educational facilities for the partially sighted in South Africa, and in 1962 the Department approved the establishment of such a school.

A year later the Prinshof School for the partially sighted was established. It was officially opened by Mrs. Betsie Verwoerd on 23 November 1963.

5.29_ Photos framed in the Prinshof school about the inauguration of the school, northern aerial photo of the school building in 1970 (Author, 2015).



5.30_ Stairs are made with extra handrail for the visually impaired school children (Author, 2015).

5.30_ The yellow columns is said to be visually stimulating for the visually impaired (Author, 2015).

5.6 / OUTCOME OF SITE ANALYSIS

The position of the building was identified based on conclusions drawn through eco-mapping (refer to Figure 5.31). The following conclusions were drawn: The existing ecosystems on site hold potential but are limited by the activities of man and the positioning of red infrastructure. The placement of roads and buildings disconnects the city from the Apies River. The water flow towards the river is interrupted by buildings and cannot flow naturally.

Areas that hold the most potential to enhance the natural ecosystems were identified. Areas that had already been disturbed by human activities were identified as potentially well-suited foundation sites for the building. The main purpose of this study was to better understand the character of the place, in order to allow its ecosystems to continue naturally. Although minimum excavation will take place to insert a building, the building should be designed to enhance the natural ecosystems and aid in the longevity of the ecosystem services.

To fashion a resilient and regenerative city, urban greening must seek a more integrated balanced solution that incorporates ecosystems. It must go beyond the minor introduction of soft gardens in and around buildings and rather create an urban area that incorporates living habitats with functioning ecosystems (Wells et al, 2010: 130).

5.31_ The conclusion gathered from the site analysis, reveals the best area to place the building. (Author, 2015).

6 / ENTOMOLOGY

7 / INSECT RESEARCH FACILITY

PROGRAM

6 / ENTEMOLOGY

6.1 / INSECT SERVICES

Insects outnumber humans 200 million to one, yet they are the most underestimated and disregarded organisms of the animal kingdom (Joffe, 2001: 10). Insects provide crucial services to humans and are critical to our biosphere. Humans, however, regard insects as pests and want to dispose of them without any regard for the consequences. Herbivores, predators, decomposers, pollinators and parasites are some of the key roles insects play; without them the terrestrial ecosystem cannot function (Joffe, 2001: 11).

Although cereal grains, like maize and wheat, are wind pollinated and do not require a living organism for the movement of pollen grain, most fruit and vegetables are dependent on the presence of pollinators (Mayes, 2013: 6). An insect pollinator is a living organism that fertilizes a fruit-bearing flower. It does so by moving pollen grains, which attach to its hairy body when it gathers nectar, to the stigma of a flower. Basically, this is what allows the plant to produce fruit. This movement of pollen can take place within one flower or among separate flowers in a given locality (Mayes, 2013: 7).

Pollination is one of the most significant services provided by insects in nature. It is a requirement for the seed and fruit generation that produces more than 35% of our daily food for consumption (Holzschuh, et al, 2012: 101). It is the continuous flow of pollen grains from the anthers to the stigma (male to female) that occurs when insect or animals forage for food. In the process of foraging they are instrumental to this flow of pollen grains and therefore provide a free service on which we are dependent (Mayes, 2013: 5). The destruction of these organisms affects our health regarding nutrition and food security.

6.1_ Bee collecting pollen from a sunflower; Photograph by Michael Kooren (http://www.theguardian.com/environment/2013/feb/28/wild-bees-pollinators-crop-yields

6.2_ Variety of colorful flowers is main source of pollinator nutrition (http://www.ourhabitatgarden.org/creatures/c-images/nectar-plants-large.jpg)

LEPIDOPTERA

6.3.2

Butterflies and Moths

DESCRIPTION /

Lepidoptera means "scale wings" and are the second largest insect order in the world (Hadley, 2015). The 2 pairs of wings are usually very colorful. Most are herbivores and the adults have long sucking tubes for mouthparts which is used to drink nectar (Culin, 2015).

HABITATS /

Variety of land habitats, and is dependant on their food sources (Hadley, 2015). When ready to pupate caterpillars usually find vegetation, soil, leaf litter or wood they have been tunneling for shelter to spin their cocoons.

LIFE CYCLE /

Consists of 4 stages; egg, caterpillar (larvae), chrysalis (pupa)and adult (Culin, 2015). The eggs are usually laid on or close to the caterpillars food plants.

HYMENOPTERA

6.3.1

Bees, wasps and ants

DESCRIPTION /

Hymenoptera means "membrane wings" (Hadley, 2015), they are also classified as insects with narrow waists between thorax and abdomen. They are the third largest insect group, but the most beneficial to humans.

HABITATS /

The live anywhere in the world, but their distribution is limited to their dependance on food supplies (Hadley, 2015). They are found in almost all terrestrial habitats; soil, leaf litter, range of vegetation, mud to construct nests or cells in man made environments (Lindauer, 2015)

LIFE CYCLE /

Most species will lay their eggs on appropriate host plants. Consists 4 stages; egg, larva, pupa, and adult.

COLEOPTERA

6.3.3

Flower Beetles

DESCRIPTION /

Coleoptera means "sheath wings", it describes the hardened forewings which forms a protective cover for the body. (Hadley, 2015)

Usually flattend or dish-shaped, with pollen easily accessible.

HABITATS /

Coleptera exists in nearly all climates (Gressitt, 2015). Beetles are found in nearly all terrestrial and aquatic habitats on earth (Hadley, 2015). Soil, humus, leaf litter, under the bark of living and dead trees, under stones and logs.

LIFE CYCLE /

The eggs are commonly laid near the food sources, such as in soil or on host plants depending on the species.

DIPTERA

6.3.4

Bee Flies

Hover Flies

DESCRIPTION /

Diptera means "two wings" (Hadley, 2015). Flower flies mimics ants,bees and wasps.

HABITATS /

Live in abundance world wide, their larvae usually requires a moist environment (Hadley, 2015). Larvae are found in many habitats; water, plant tissue, beneath bark or stone, decaying plant or animal matter (Gressitt, 2015). Adult flies are seen resting or hovering over blossoms or bare ground patches in a sunny location. Adult bee flies feed on nectar from a wide variety of flowers.

LIFE CYCLE /

Consists of 4 stages; egg, larvae, pupa and adult. Eggs are usually laid close to food sources.

6.3_ The insect order classifies 4 different insect groups (Author, 2015).

6.3 / INSECT HABITATS

When a large variety of insect habitats are conserved, ecosystem services automatically improve (Holzschuh, et al, 2012: 101). Insect habitats vary from species to species, depending on nutritional requirements; safety from predators; and shelter from the elements. A common characteristic of pollinating insects is the fact that they will create and populate their own habitat in an area that provides sufficient nutrition and shelter. Natural areas that are untouched by human activities are essential for the protection of pollinators. Establishing such areas will ensure that other ecosystem services also continue (Mayes, 2013: 21). Most insect pollinators rely on these natural areas and inhabit soil, dead trees and abandoned holes to complete their life cycle. Refer to Figure 00, as seen on the site:

- Carpenter bees rely on logs for their nests
- Leaf Cutter bees use leaves
- Honeybees build their nests in the cavities of trees (Mayes, 2013: 21).

If communities are to be more considerate of the protection of pollinators, they need to provide environments that include pollen, nectar, water, nesting sites and materials required by insect pollinators to complete their life cycle. Mayes (2013: 13) explains simple methods for people to provide habitats for pollinators (refer to Figure 6.4):

1. Supplying a constant source of nectar and pollen in all seasons.
2. Leaving undisturbed areas untouched for nesting.
3. Creating pesticide-free gardens that allow predatory insects to control pests in a natural way.
4. Creating healthy and diverse gardens that beautify the environment and serve as a food source for insects.

6.3.1
BUTTERFLY HABITATS

Successful butterfly habitats consider the following factors (Joffe, 2001: 35):

1. The butterfly habitat requires 5 – 6 hours of daily exposure to sun.
2. Butterflies can get their necessary nutrients and minerals from water puddles.
3. Nectar plants, varying in color, are favored by both caterpillars and butterflies and should be included.
4. Plants and flowers should bloom during the entire summer; therefore, a wide variety of flowers that bloom at different times is required.
5. Butterflies rest/ sleep underneath leaves or in between cracks of rock.
6. Butterflies cannot survive the winter season, therefore they lay eggs in selected grasses, called ‘the host’, that can withstand the cold.

6.4_ Example of a diver’s garden that serves as a food source, (Mayes, 2013: 13)

6.5_ Monarch butterflies gathering between branches (https://goodmorninggloucester.files.wordpress.com/2013/09/monarch-butterflies-daybreak-willow-tree-c2a9kim-smith-2012.jpg) edited by (Author, 2015)

Every butterfly chooses its own plant on which to lay eggs. This is called the 'host' plant, and is specific to each species of butterfly (Joffe, 2001: 34). Host plants are usually grasses, such as, Ehrharta Erecta (Shade Ehrharta) and Hyparrhenia Hirta (Common Thatching Grass). The host plant is also the caterpillars' source of nutrition after they hatch (Joffe, 2001: 34). Butterflies are therefore very sensitive to environmental change; they need to be protected and conserved to prevent extinction. Fortunately, butterflies are very loyal and will develop a preference for a certain area (with sufficient plants and flowers); they will return to this area year after year (Joffe, 2001: 34).

6.3.2
BEE HABITATS

Honey bees /
Honey bees are also called "cavity dwellers". They can create heat of up to 35 °C inside their nests. As heat makes the bees aggressive, it is vital to keep nests shaded. Nests should face east, and it must be noted that due to topography nesting sites are scarce. Except for naturally occurring sites, nests can also be built in man-made structures, such as, hollow spaces in walls, ceilings, and under the floor boards of buildings. The size and shape of nests may vary according to the size of the cavity; how long the colony has been established; and the abundance of forage available.

Trapping Bees /
When trapping bees, create an elevated decoy hive that is safe from vermin and vandals. Corrugated plastic and wax treated cardboard can be used in hive construction.

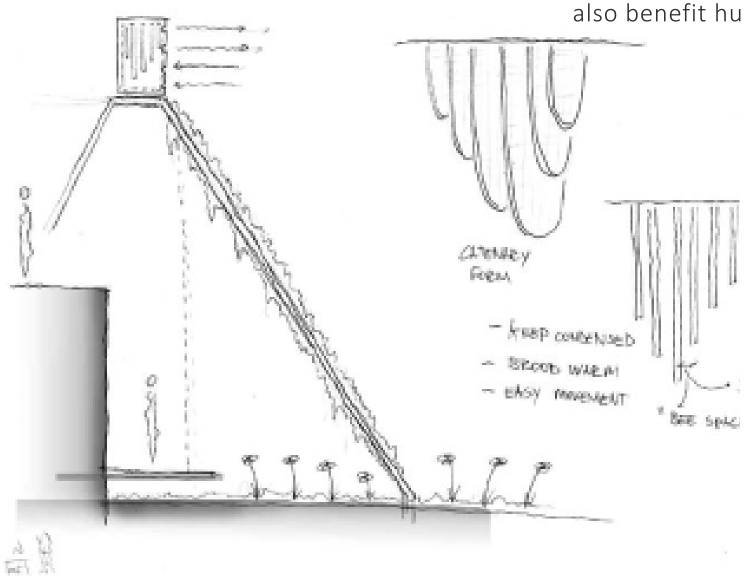
6.6_ Bees creating their hive inside a man made structure (http://s3-wp.lyleprintingandp.netdna-cdn.com/wp-content/uploads/2014/11/14110005/bees1.jpg)

6.7_ Insect hotesl created for insects to populate and create habitats (https://s-media-cache-ak0.pinimg.com/736x/c8/db/ed/c8dbedaa8be924b4a9e8440a12036d3a.jpg)

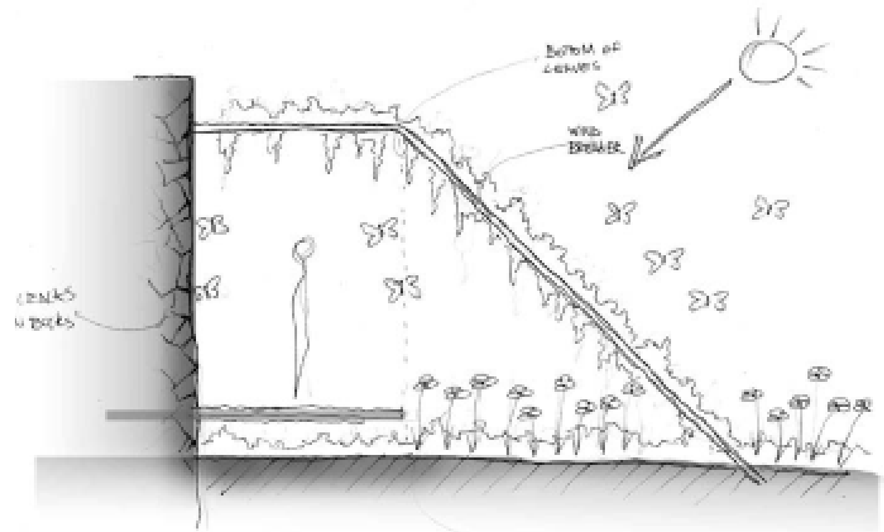
6.4 / HOW THE HABITATS CAN BECOME ARCHITECTURE

Creating a shelter for the insects is vital for their protection and conservation. The regenerative theory prescribes the creation of a mutually beneficial relationship between nature and humans. In parallel, how can sheltering insects become beneficial to humanity? Conversely, how can human shelter become beneficial to insects? The answer lies in using nature as part of the building layers, which play a vital part in the functioning of the building.

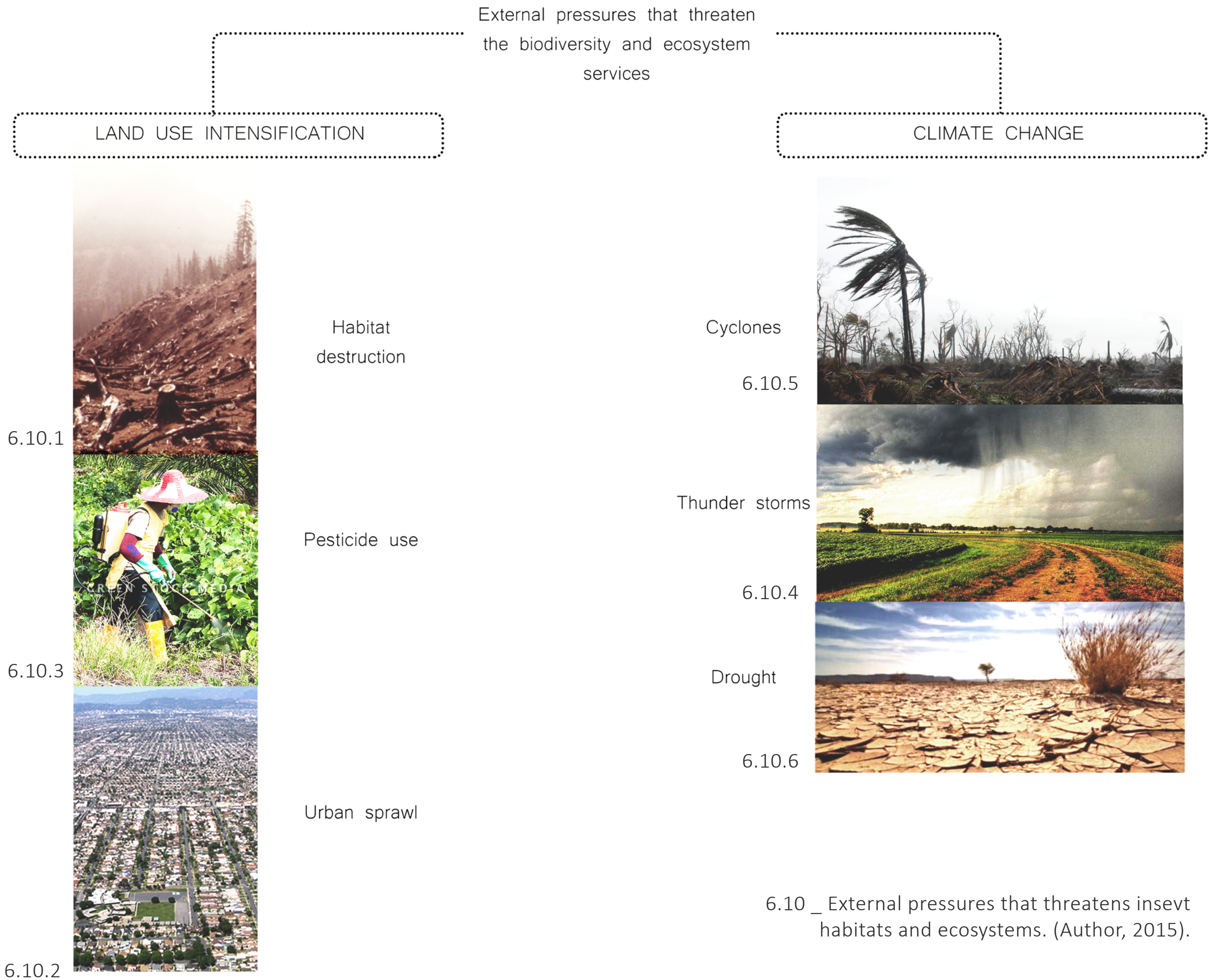
As the regenerative theory demands a mutual relationship between nature and humans, application of this theory requires that the building become a reciprocal element. The habitats of insects become a shade component that can control the temperature inside a building. Thus a structure is created as insect habitat that also shapes a livable space where people are protected from the sun and wind. Structural elements can, in a controlled way, become home to insects and also benefit humans.



6.8 _ Example of Insect habitats creating and defining spaces (Author, 2015)..



6.9 _ Example of Butterfly habitats creating space and becomeing beneficial for hmans. (Author, 2015).



6.10 _ External pressures that threatens insevt habitats and ecosystems. (Author, 2015).

6.4 / THREATS TO INSECT HABITATS

Insect habitats are (much like human habitats) also threatened by climate change and environmental destruction. The difference is that insect loss far outweighs human loss. These threats, in conjunction with human activities, such as, excavation, deforestation, the misuse of pesticides, and urban sprawl, are the main contributors to the loss of insect habitats. To curb these habitat losses, the search for carbon neutrality must be combined with a more sensible way of dealing with the environment.

The key to a sustainable future lies with these small creatures and there is still much to learn of insects and their services (Mayes, 2013: 3). Pollinators contribute not only to our food security but also to the survival of plants. It is on this survival that other wildlife depends, and on which biological diversity and the economy pivot.

The future of pollinators is uncertain due to the combined threats of climate change, environmental destruction and human activities. These effect the loss of insect habitats (Mayes, 2013: 11). If no pollinators remain to facilitate the production of fruit and seeds, our diets will be severely affected.

7 / INSECT RESEARCH FACILITY

7.1 / THE IMPORTANCE OF POLLINATORS

Human labor simply cannot achieve the same outcome as the free service provided by ecosystems. Insect pollinators are a crucial part of human survival and as such need to be respected and maintained. The conservation of pollinators can be achieved through the protection of both their habitats and nutrition providers. We know very little about the potential of these insects and the services they can provide us. It is thus necessary to study them without destroying their existence or damaging their natural habitats. The information gathered must be made available to the public and interested stakeholders.

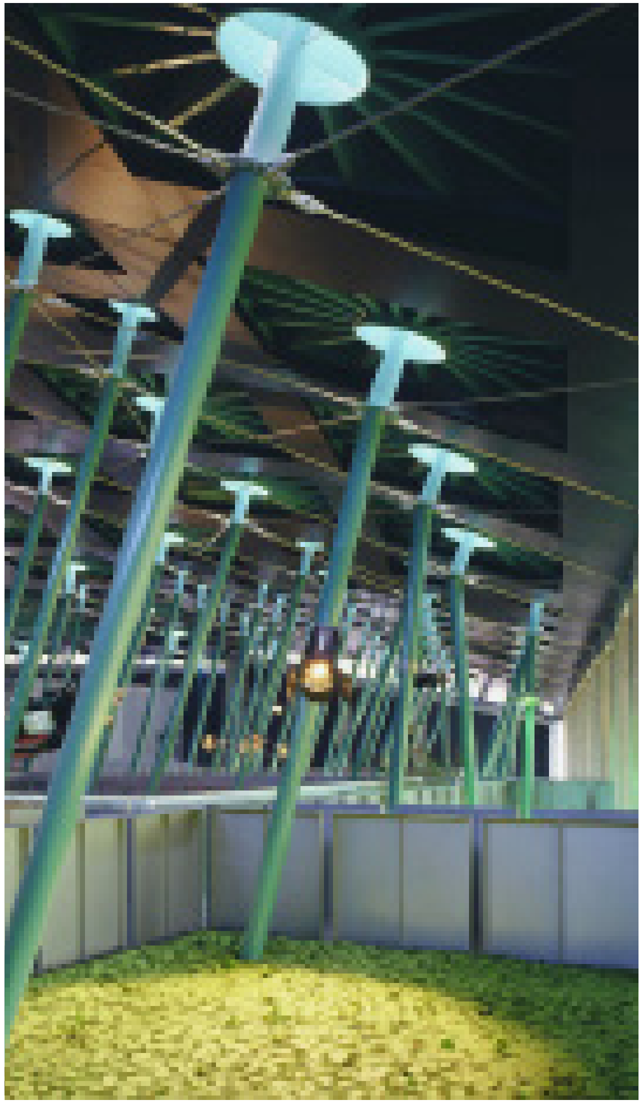
7.1_ Entrance to the museum (http://www.opus5.fr/ST-LEON-EN-LEVEZOU-Micropolis-Musee-des-insectes)

7.2 / CASE STUDY

MICROPOLIS; CITY OF INSECTS / A museum of the insect in the hills of Lévézou

Architect: Bruno Decaris
Area: 2 600m2
Location: Saint Léons in Levézou
Designation: An international center for insect research.

Micropolis superimposes the world of man, represented by an orthogonal path, on that of insect abundance, represented as slanted columns that form undergrowth. Visitors walk from the bowels of the hill to the light above, analogous to the insect in its metamorphoses.
The main building has a façade of mineral 500 m2 in size and a huge stained glass window that reproduces colour sequences in the visual perception of insects. The relevance of this project is as a link between human and insect. It is achieved through an architectural design that allows visitors to move from their human size to the size of insects; while the marked wall of soil strata rises, men's and insects' footprints change dimensions.



7.2_ Interior view of insect museum, columns used for roof is also light shelves (http://www.opus5.fr/ST-LEON-EN-LEVEZOU-Micropolis-Musee-des-insectes)

7.3 _ Movement route of the Micropolis Insect City (http://www.micropolis-aveyron.com/fr/outils/documents/micropolis-plan-de-la-visite-2015.pdf)

The 15 exhibition rooms spread over 2400 m2 show the lives of insects in general. Some of the 15 explained topics include:

- Awakening to biodiversity
- The discovery of the five senses
- The breeding room
- The butterfly house
- Insects on the surface, in the soil, and in the water
- The social life of insects
- The menus of insects

7.3 / THE PROGRAM

The insect research facility approaches insect rearing in a natural way by following the principles of regenerative design. The project under investigation is to house a research facility that broadens the study of entomology through the collection of helpful information to educate society on a regenerative and ecologically friendly future. The entomology research facility houses various programs: research, educational, recreational and habitats.

The supporting programs in the research facility strengthens the framework on which the facility supports on, and it is listed as follows:

1- Support buildings:
- Clerical staff offices
- Maintenance
- Utility rooms
- Workshops
- Warehouse
- Cafeteria
- Locker rooms
- Restrooms

2- Waste disposal:
- SOLID - Human waste
- Processed solid waste
- Organic waste material

3- Work-flow consideration:
Separation of irradiated and non-irradiated pupae:
- Separate entrance and exits required
- No staff movement between the two facilities.
- Radiation levels indicator
- Separate rooms with distinct temperature management.

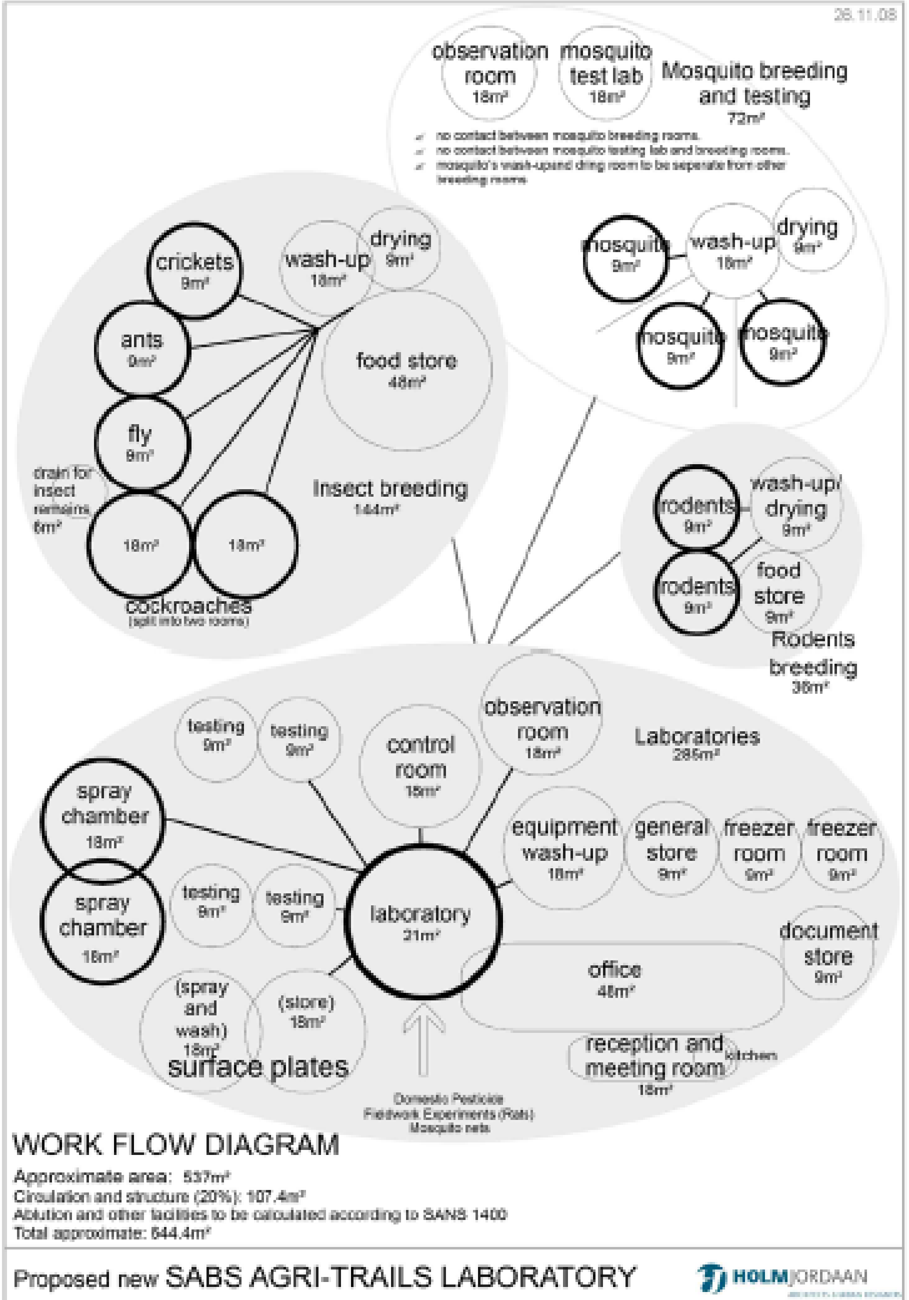
4 - Management of sanitation when operating the facility: control of pest and contaminant organisms. Treatment:
- Water-filled channels
- Vermin wire
- Depth of foundations
- Floor treatment
- Pre-building ground treatment.

5- Fire control, alarm system, and escape routes:
- Escape pathways
- Assembly areas
- Signage
- Placement of monitors
- Alarms
- Obedience to fire regulations

6- Record keeping:
Systems need to be employed for:
- Collection
- Storage
- Analysis of records.
- Backups of records should be stored in alternative locations.

7- Waste water treatment plant:
The options for use of waste water is either to discard or re-use. The re-use of waste water may require extra treatment. The degree of waste water treatment is dependent on the intended use of treated water.

8- Biosecurity areas for contamination control
Provision of showers, foot baths, changing rooms, airlocks, etc. The facility should be designed to maintain security that prevents insect escape; air locks, air curtains, and air tight doors are used.



7.4 _ A typical work flow diagram for a insect research facility (courtesy of Holm Jordaan Architects).

7.3.1
RESEARCH / Administration building, offices, laboratories, Insect habitats

The research facility is to consist of three separate buildings. Two of these buildings are laboratories and one is the administrative building. Each laboratory holds different classes of insect pollinators, thus preventing cross-contamination. The laboratories are formed by a series of lobbies and self-closing sealing doors; to prevent the escape of insects. Every laboratory is a sterile environment that is treated differently than the rest of the building. The administration block is the control point where people enter the research facility.

7.7 _ Display panels with insect information(Nel, 2015).

7.3.2

EDUCATIONAL / Entomology collection center, library, lecture rooms and exhibition spaces.

Information on the insects and their ecosystems is collected and showcased in the entomology collection center, which is an extension of the zoo. The information is to be revealed with the use of a gallery, exhibition space, lecture rooms and a library. As it is critical for the next generation to fully understand the importance of safeguarding the remainder of our planet's resources, this program facilitates school programs with organized field trips and lectures. Future generations must be made aware that it is necessary not only to restore ecosystems but also to enable the planet's resources to self-generate. This can be achieved by educating people on the characteristics of nature and the benefits it holds for society. The library and entomology collection, as well as a living wall and waste treatment facility, therefore play an important role in educating the people who visit the building. From figure 7.6 - 7.8 illustrates an interactive exhibition displaying the life of insects. This exhibition is held in the UK Nottingham Pavilion at the 2015 Milan Expo located in Italy.

7.8 _ A visitor viewing the information in one of the display boards (Nel, 2015)

7.6 _ A Display panel with viewing wholes inviting the visitors to peak inside and experience insect habitats (Nel, 2015)

7.3.3
RECREATIONAL / Public and workers, production, social condition

The facility is designed for a fully beneficial partnership between humans and nature. Nature should be respected and guarded in all aspects of our lives; it is also truly valuable for our livelihood to combine the human experience with nature. The building allows visitors to experience different habitats and the benefits they provide. It also holds social value for the people of Pretoria by providing green spaces, walkways, gathering places, sun shades and seating. The products produced on site can be sold at the taxi rank on Bloed Street; where a new informal social node can develop. The water on the site is of benefit to the production of plants and agriculture, which form the main habitat and nutrition required by the insects. As a regenerative facility it also requires multi-functional programs to produce zero waste.

The economic value, generated through the production of fruit and plants, benefits the social condition. Although the production is on a small scale, as this is not a production facility, it is advantageous to the closed-loop-cycle of the regenerative theory. The facility produces the following:

1. Indigenous plants and flowers: the facility houses a variety of flowers and plants for the pollinators. The plants that play an important role in luring pollinators act as a nursery, creating potential economic value. List of the flowers grown and their descriptions:
2. Fruit and other foods that require pollination from insects: these are also cultivated and can be sold in shops in the city. This benefits shop owners in the city for there will be no need for long-distance deliveries.
3. Organic waste produced in the laboratory: the waste that has not been irradiated can be mixed with grass to produce feed for the zoo animals.
4. Insects: the insects can also be used for culinary purposes.
5. Clean potable water: the facility also focuses on producing clean potable water.

7.3.4
INSECT HABITATS / insects relationship with the environment.

Creating a habitat for the insects is one of the critical aspects of this research facility. The biological parameters need a thorough investigation to provide the insects with enough shelter and nutrition to attract the right kind of insects. The following table indicates the specific indigenous plant and flower types that attracts pollinator insects:

Insect attractive indigenous plants	Size in mm	Insect order				Sun			water			Annual											
		Hymenoptera (Bees)	Lepidoptera (Butterflies)	Diptera (Flies)	Coleoptera (Beetles)	full sun	half sun	no sun	Lots	moderate	Little	summer Jan	Feb	Autumn Mrt	Apr	May	Winter June	July	Aug	Spring Sept	Okt	Nov	summer Des
Small Shrubs																							
Forest Spurflower (Plectranthus Fruiticosı	1000 x 1000		o				o	o		o		o	o										o
Bush Violet (Barleria obtusa)	750 x 10		o			o	o			o				o	o								
Yellow Seed (Eriosema psoraleoides)	20 x 750		o			o				o		o	o	o	o	o					o	o	o
Sun Hibiscus (Hibiscus calyphyllus)	1500 x 1500		o			o				o		o	o	o	o								
Rose-scented Pelargonium (Pelargonium	1300 x 1000	o	o	o	o		o			o		o							o	o	o	o	o
Geelblombos (Phymaspermum acerosum	1000 x 1000	o	o	o	o		o			o		o	o	o	o	o	o	o	o	o	o	o	o
Medium Shrubs																							
Velvet Brandybush (Grewia Flava)	2500 x 2500		o			o				o		o	o	o							o	o	o
Small-leaved plane (Ochna Serrulata)	2500 x 2500		o			o				o										o	o		
Christmas Bride's bush (Pavetta gardeniifo	3000 x 2000	o	o	o	o	o	o			o		o										o	o
Cape Leadwort (Plumbago Auriculata)	3000-5000 x 3000		o			o				o		o	o										o
Purple Broom (Polygala virgata)	2000 x 1000	o				o				o								o	o	o			
Jelly Beans (Senecio Barbertonicus)	1500 x 1500	o	o		o	o					o		o	o	o								
Large Shrubs																							
False Olive (Buddleja Saligna)	4000 x 3000	o	o		o	o				o		o	o	o	o						o	o	o
Sagewood (Buddleja salviifolia)	5000 x 4000	o	o	o	o	o				o									o	o			
Cat's whiskers (Clerodendrum Glabrum)	5000 x 6000	o	o		o	o				o		o								o	o	o	o
Bluebush (Diospyros Lycioides)	4000 x 4000	o				o				o										o	o	o	o
Puzzle Bush (Ehretia rigida)	4000 x 4000	o	o	o	o	o				o										o	o	o	
Crossberry (Grewia occidentalis)	5000 x 3000		o			o				o		o	o									o	o
Silver Sugerbush (Protea roupelliae)	5000 x 4000		o			o				o			o	o	o								
Dogwood (Rhamnus prinoides)	4000 x 4000	o				o				o											o	o	o
*Champhor Bush (Tarchonanthus Camph	5000 x 5000	o	o	o	o	o				o					o	o	o						
Groundcovers and bulbs																							
Veld Aloe (Aloe greatheadii var. davyana)	200 x 400	o	o	o	o	o					o						o	o					
Pig's ear (Cotyledon orbiculata)	300 x 450		o			o					o								o	o			
Baberton Daisy (Gerbera jamesonii)	400 x 300	o	o	o	o	o				o										o	o	o	
Scented Grass Bulbine (Bulbine capitata)	450 x 350	o	o	o	o	o				o									o	o	o	o	
Stalked Bulbine (Bulbine frutescenes)	300 x 400	o	o	o	o	o					o	o	o	o	o	o	o			o	o	o	o
Pineapple Flower (Eucomis autumnails)	500 x 500	o	o	o	o	o	o			o		o	o										o
Trailing Gazania (Gazania rigens)	200 x 400	o			o	o				o		o	o							o	o	o	o
Star Flower (Hypoxis hemerocallidea)	400 x 500	o	o	o	o	o				o		o								o	o	o	o
Dwarf Agapanthus (Agapanthus africanus	350 x 350	o	o	o	o	o	o			o		o	o	o									o
Water Garden																							
Orange river Lilly (Crinum bulbispermum)	400 x 950	o	o	o	o	o			o											o	o		
River Lily (Crinum Macowanii)	400 x 800	o	o	o	o	o				o		o	o								o	o	o
River Stars (Gomphostigma virgatum)	1500 x 1500	o	o	o	o	o			o			o	o	o								o	o
Blue water lily (Nymphaea nouchali)	100 x 800	o	o	o	o	o			o			o	o	o	o					o	o	o	o
Small Yellow water lily (Nymphoides thun	80 x 800	o	o	o	o	o			o			o	o	o	o	o					o	o	o
White Arum Lily (Zantedeschia aethiopica	950 x 500	o	o	o	o	o	o		o			o								o	o	o	o
Annuals																							
Wild foxglove (Ceratotheca triloba)	1200 x 400	o				o				o		o	o	o	o	o						o	o
Climbers																							
Traveller's Joy (Clematis brachiata)	4000 x 2000	o	o	o	o	o				o		o	o										o

* The root system is aggressive and this species can successfully be used to control soil erosion

7.5 _ Table (Left) of indigenous plants to Gauteng area that attracts pollinator insects and displays requirements (Joffe, 2003 edited by author, 2015)

8 / CONCEPT

9 / DESIGN

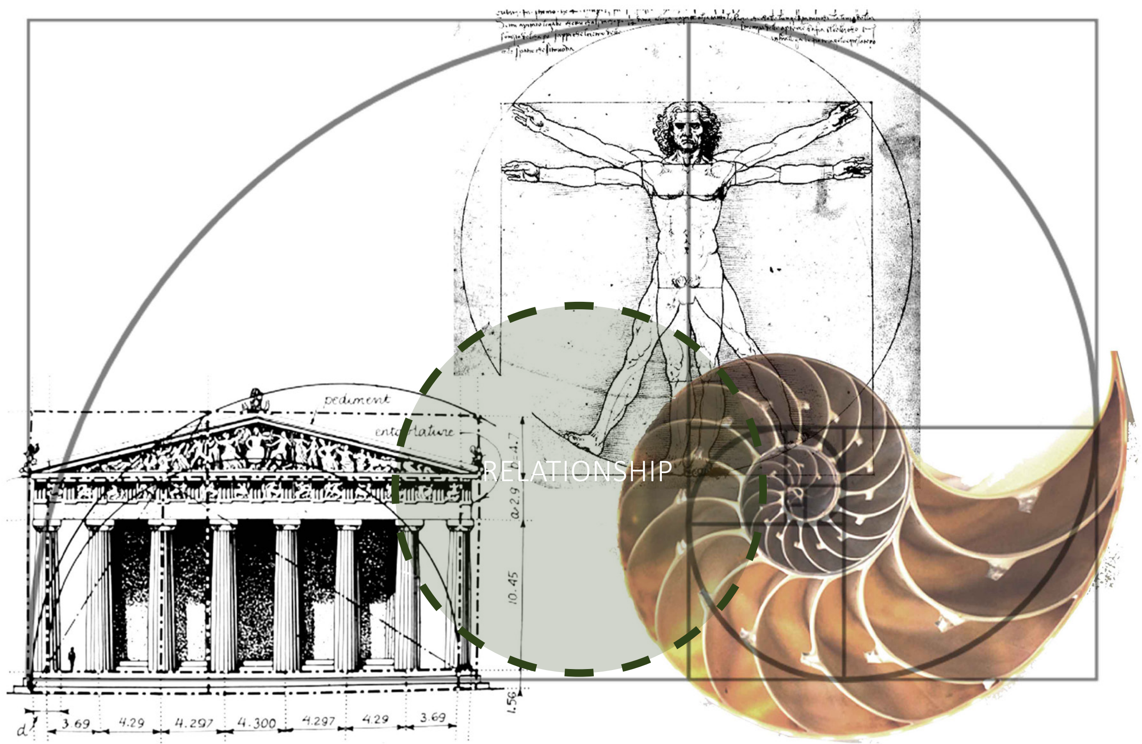
DESIGN DEVELOPMENT

8 / CONCEPT

8.1 / INFORMANTS

The design of the building was informed by aspects of the **urban vision, environmental strategies, regenerative theory, and programmatic factors**. The shift from conventional thinking to a co-partnered relationship between buildings and nature became a strong concept in the design development.

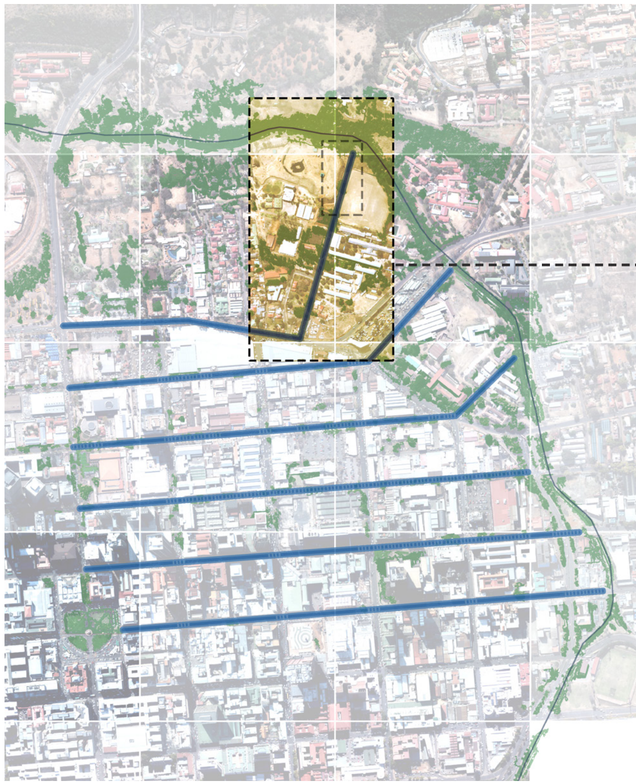
MAN / MEDIATOR



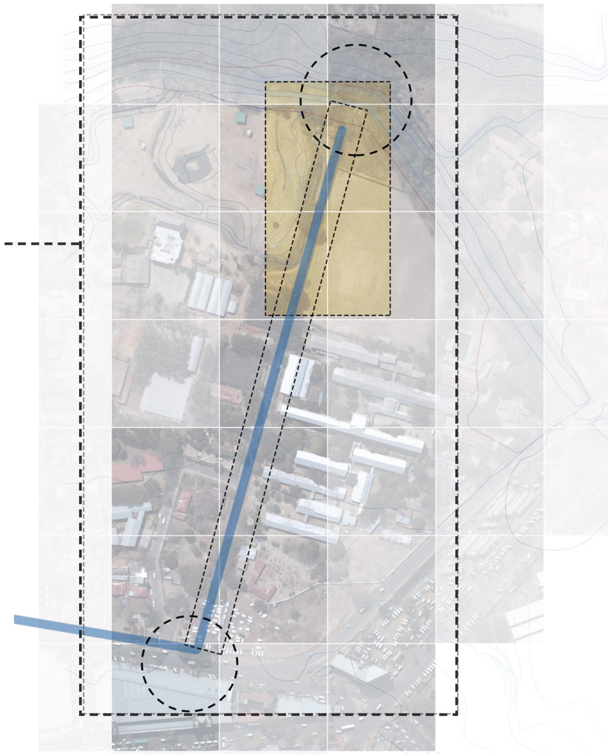
BUILDING / RECIPRICOL ELEMENT

NATURE / RESTORATIVE AGENT

8.1_ The relationship between man, building and nature (http://www.soulsofdistortion.nl/images/vitruvia1.jpg, http://miguelmartindesign.com/blog/wp-content/uploads/2011/01/figure7.jpg, edited by author, 2015)



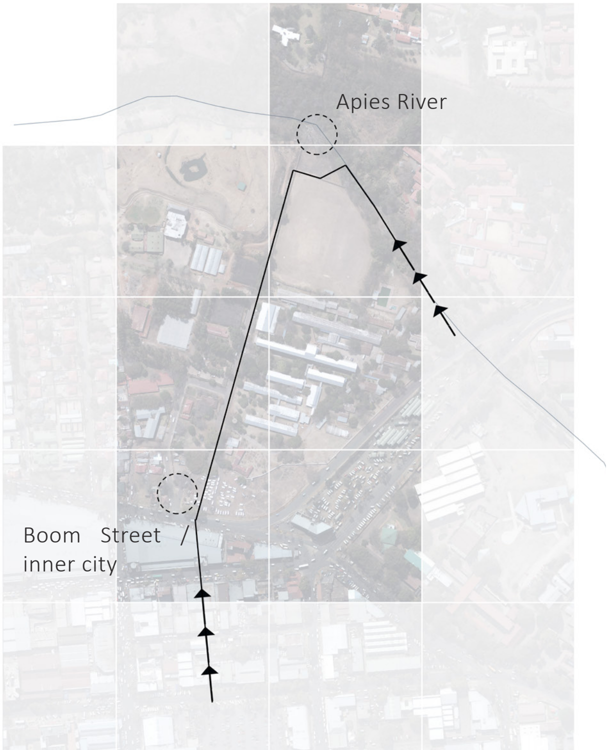
8.2 _ Diagram of Water channels leading to proposed site from group framework as an important informant (Author, 2015)



8.3 _ Prosed site, showing proposed water axis cutting through the site (Author, 2015)

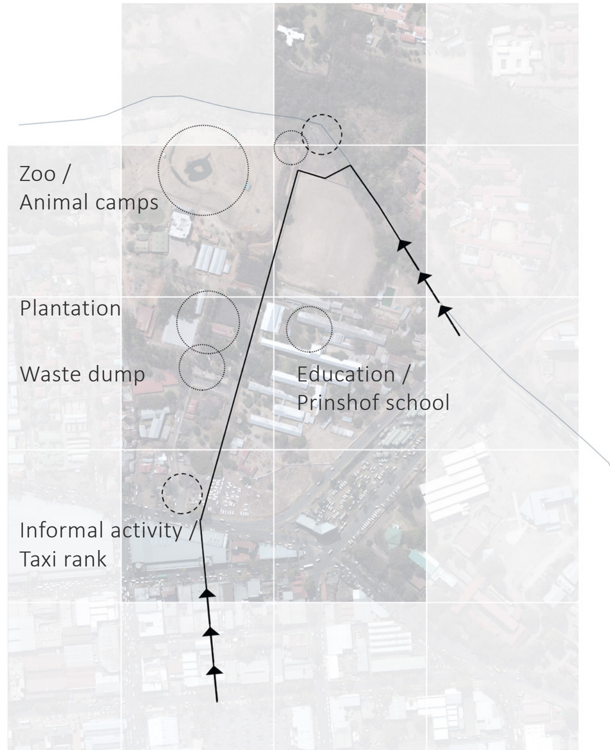
8.1.1
URBAN VISION /

The larger impact of the urban vision is the water channels, which collect and clean water from the city's hard surfaces, so that water runs into the Apies River in a cleaner state than its existing condition. The concept of "giving life back to the Apies River" is utilized. It also serves as an introduction to the proposed project site, where one of these water channels runs through the site to get to the Apies River. A strong axis line between the city and the Apies River is created, from which the building can develop.



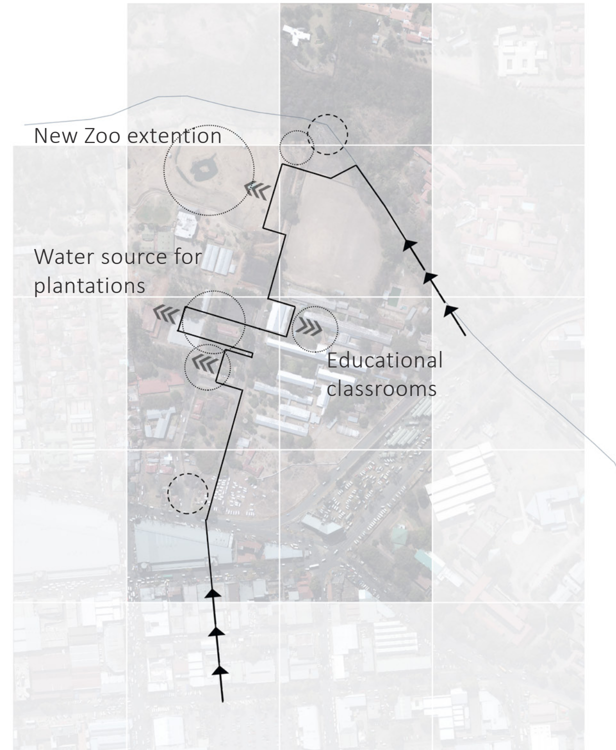
8.4 _ Diagram, connection axis between Apies River and city (Author, 2015)

This diagram illustrates the connection between the city and the Apies River. This connection forms a strong axis line from which the building can be formulated.



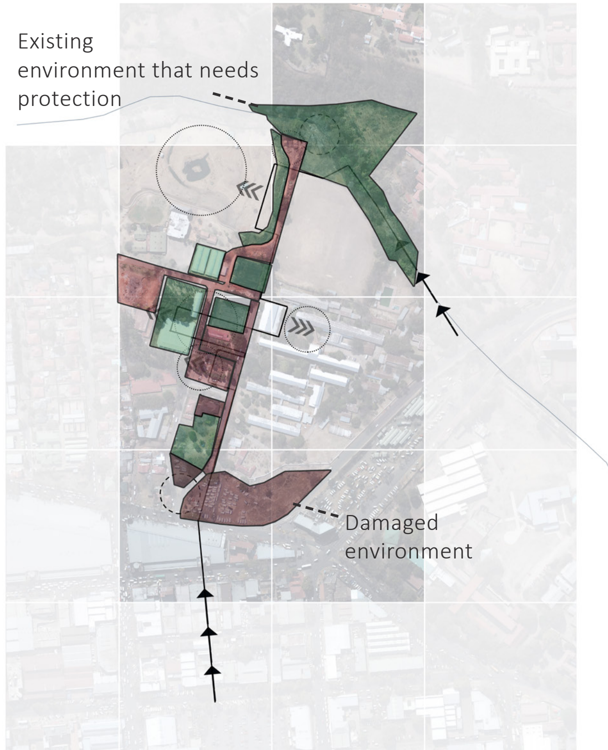
8.5_ Diagram, Existing site informants (Author, 2015)

The strong axis line runs through existing programs and functions. These existing programs influence the project in its functionality, as well as the way the new building responds to the surrounding environment. The response from the building needs to influence existing programs in a positive way.



8.6 _ Diagram, Existing informants implications (Author, 2015)

The response of the new water axis to existing programs must enhance that which is pre-existing. The existing functions must benefit from this new insertion of the project.

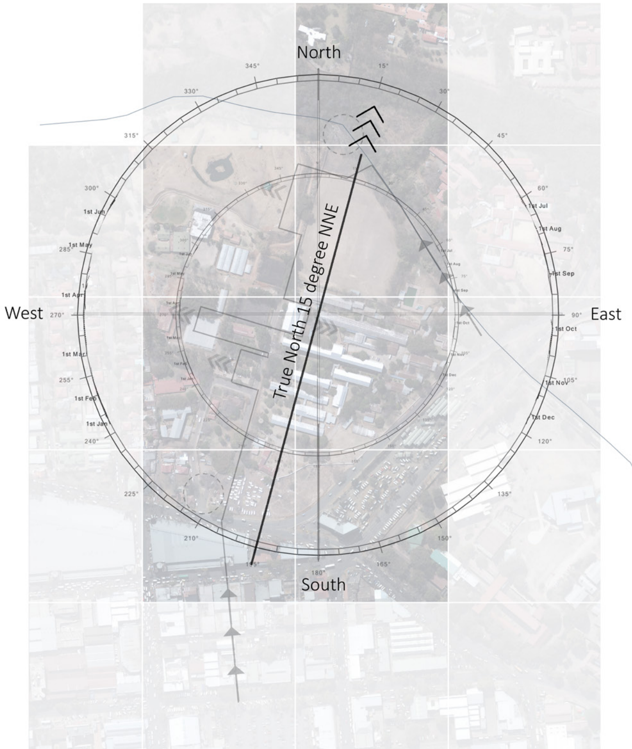


8.7 _ Diagram, conclusion of Eco-Mapping, condition of existing habitats (Author, 2015)

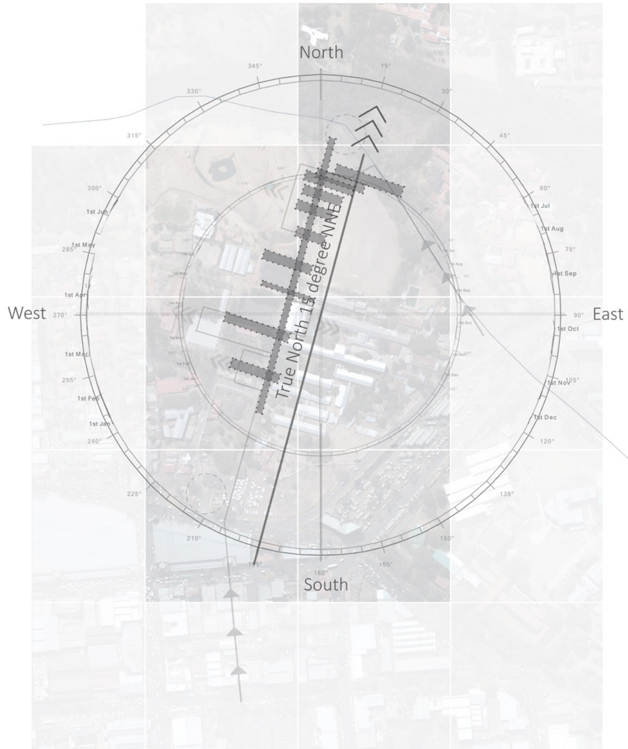
The conclusion drawn from the Eco-mapping in the previous chapters shows the environmental response on this axis line. It clearly indicates destroyed habitats and habitats that need to be conserved.

8.1.2
ENVIRONMENTAL FACTORS /

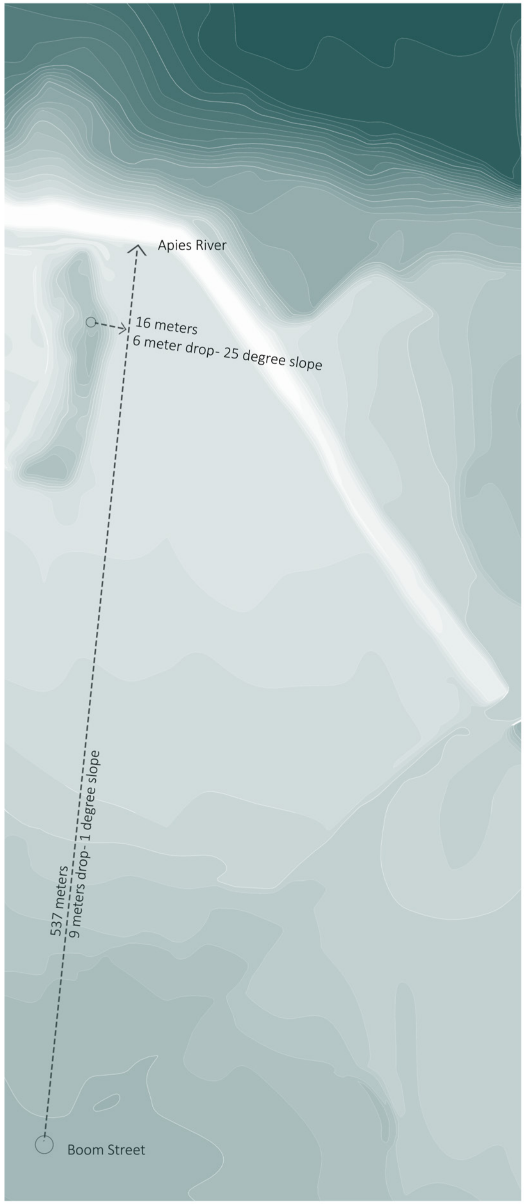
The placement of the new building resulted from the characteristics of the site (revealed in Chapter 5) and the conclusion of the Eco-mapping (showing the more sensitive environments and already destroyed habitat environments). The sun factor influenced the orientation of the building, with the larger façade designed for maximum sun exposure. The slope of the site towards the Apies River influenced the organization of water channels, water storage and roof angles. The site also requires a zone that is left undisturbed by human activities to allow nature the opportunity for continuous growth and expansion of the natural ecosystems that insects and other species inhabit. This zone is located at the northern edge of the site; where the site converges with the Apies River. The building is designed to gradually merge with nature.



8.8 _ Diagram showing true north (Author, 2015)

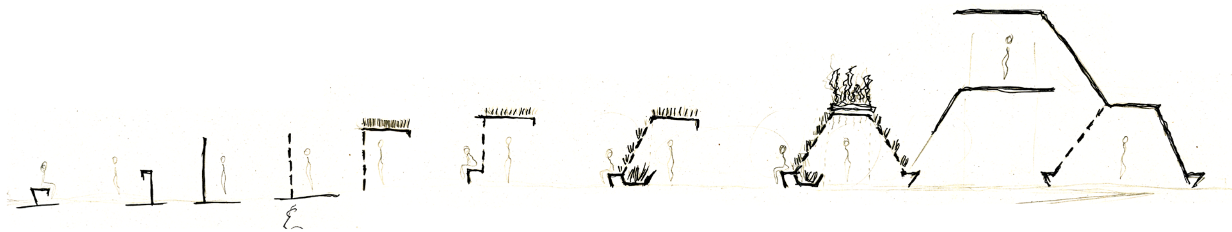


8.9_ Intuitive placement of building orientated to true north (Author, 2015)

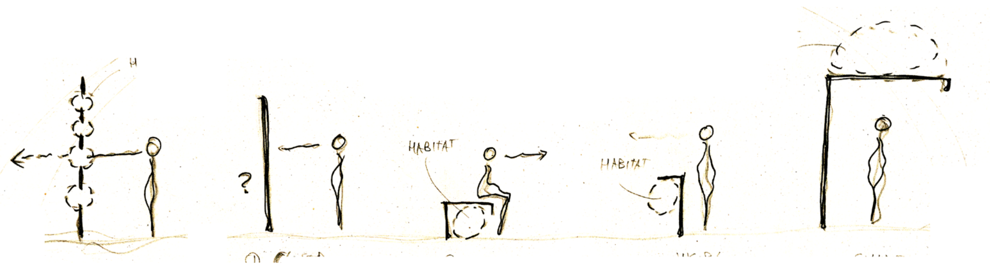


A principal environmental aspect considered of the building was the response to the environment in terms of placement and orientation.

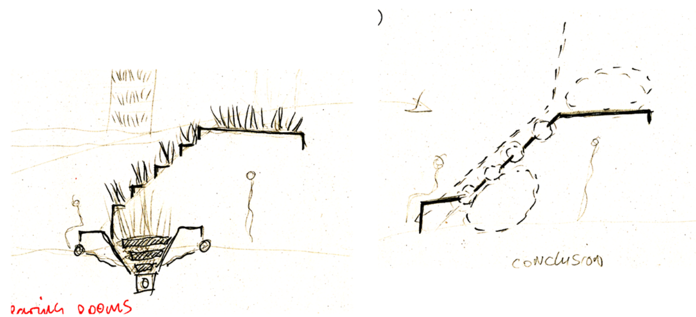
8.10_ Contour sloping from Bloed Street to the Apies River (Author, 2015)



8.11_ The different wall progression possibilities to create spaces with walkways and seating (Author, 2015)



8.12_ Different possibilities of a "wall" (Author, 2015)



8.13 _ Potential habitat spaces, with water channel and growing plants (Author, 2015).

The "Living-wall": waterways should not be limited to gutters or pipes, but should rather be explored in the introduction of wetlands and buffer strips that hold ecologically functioning habitats (Yeang, 2008: 131). The water channel that intersects the site becomes part of a 'living-wall' or a 'bio-wall'. Here water is cycled through a wall or supporting structure with the assistance of photovoltaic panels. It accommodates a growing medium that allows plants to grow on the wall, either using creepers or normal plant boxes. The purpose of this wall is to create both an awareness of the possibilities of water and habitats for bird life or insects. The wall structure can then become usable for the people in the area, through the creation of walkways, viewpoints or seating, depending on what is required. This wall conceptually becomes part of the proposed building, where it changes to adapt to the building's program requirements. Waste water from the buildings is also collected 'in' the wall where filtering and cleaning takes place using John Todd's Eco-Machine.

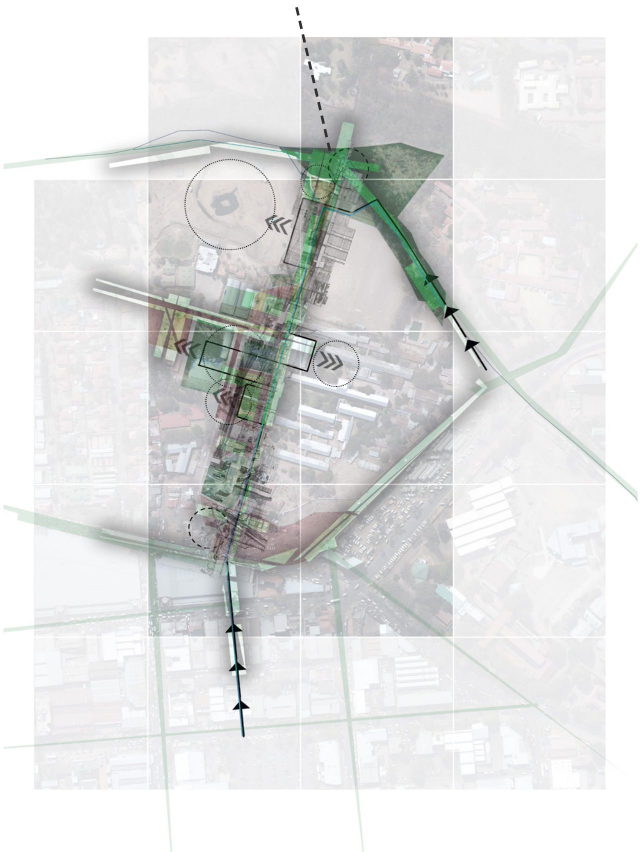
8.1.3 **REGENERATIVE THEORY /**

Regenerative Theory is defined as the relationship between humans and nature that creates a mutually beneficial environment in which to co-exist. Architecture should have a reciprocal relationship with nature.

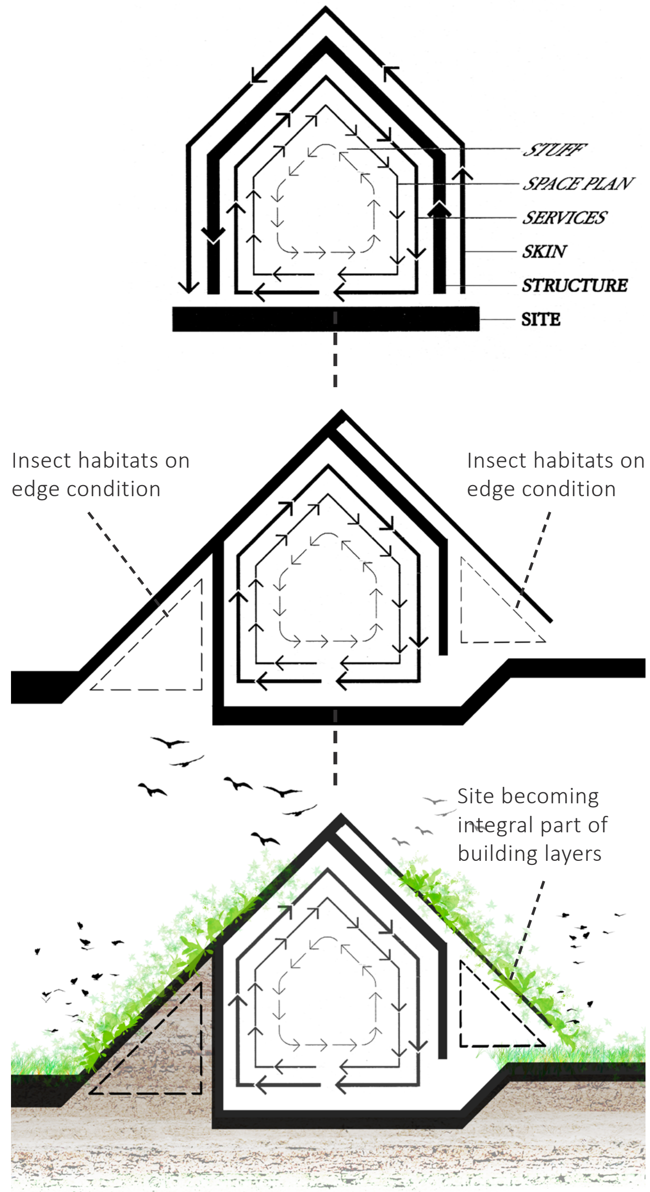
Image 00; The regenerative approach to design on the site is the identification of damaged and non-damaged habitats. The response is to restore the damaged ecosystems by creating new ones and to enhance the already existing ecosystems.

Steward Brand's 6 'S' approach can be utilized to create new habitats or enhance existing ones. It can be adapted to combine the 'site', 'skin', 'structure' and 'services' into one element. Thus, the building's skin becomes the reciprocal element between humans and nature. The form, shape and slope of the building skin/ roof are crucial elements in creating this relationship with nature. A few questions arose: how does the roof use rainwater? How can the skin adapt to natural elements? How can it become a habitable space for both humans and insects?[1]

Vegetation on the building; the green spaces between the buildings; and plant life for the surrounding habitat all form part of an interconnected ecological nexus, which is the principle of an eco-design (Wells et al, 2010: 13).

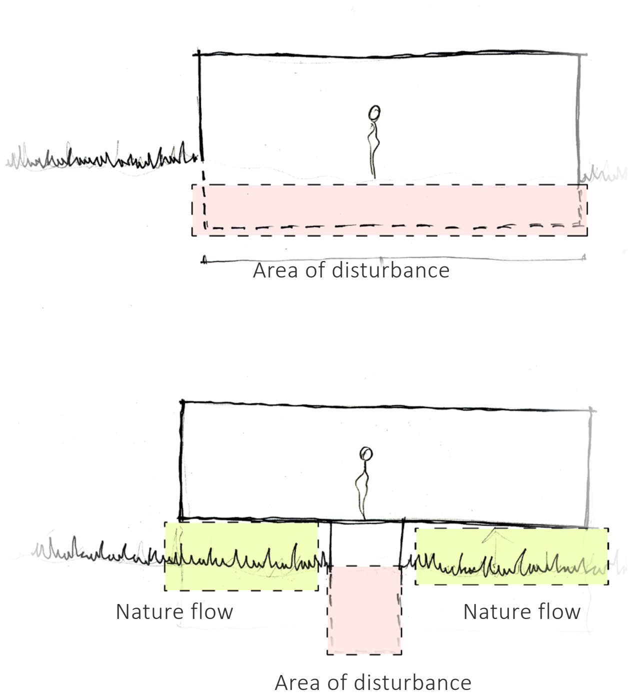


8.14_ Diagram illustrating the vision of the growing ecosystems (Author, 2015)

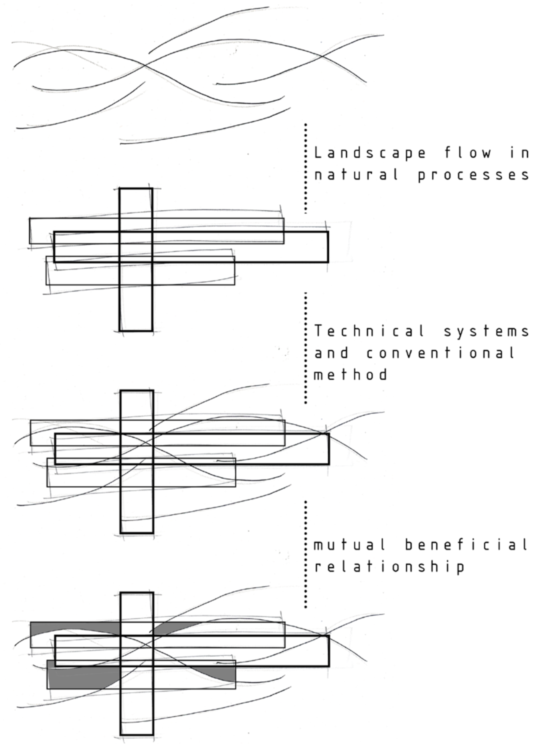


8.15 _ Steward Brand 6 "S" adaption to integrate site (Brand, 1994: 13 edited by author, 2015)

[1] These questions will be further developing in the design chapter



8.16 _ Building elevated from ground to allow ecosystem flow on the site (Author, 2015)



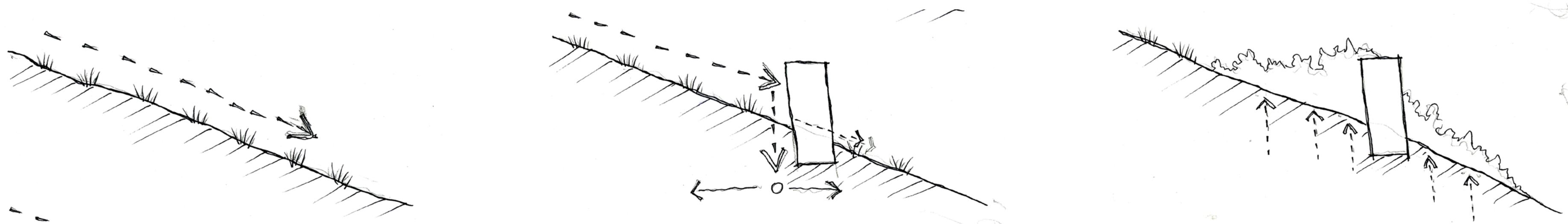
8.17 _ Diagram, finding a balance between structure and the natural flow of the environment (Author, 2015)

8.1.4 **ARCHITECTURE**

The study of Regenerative Theory led to the development of architecture where the relationship between buildings and site become very important.

The architectural approach would be to find the reciprocal element between the natural systems and the technical systems. This is done by creating an overlay of the two elements and finding a balance between them. Elevating the building allows the environment to continue naturally on the site as there is minimal disturbance on the ground. The slope of the skin that makes contact with the ground allows plants and creepers to grow, and expresses the notion of the building merging with nature; it conveys the idea that nature grows and becomes the building.

8.18_ From left to right; illustrating water flow from site creating a small ecosystem by adding structure (Author, 2015)



The site has a natural slope that permits water to flow over the surface, but does not allow it time to stop and seep down to create a water table.

By blocking the water flow on the surface of the slope, the water is given enough time to seep down and replenish the water table.

The stabilization of the water table provides vegetation enough time to grow.

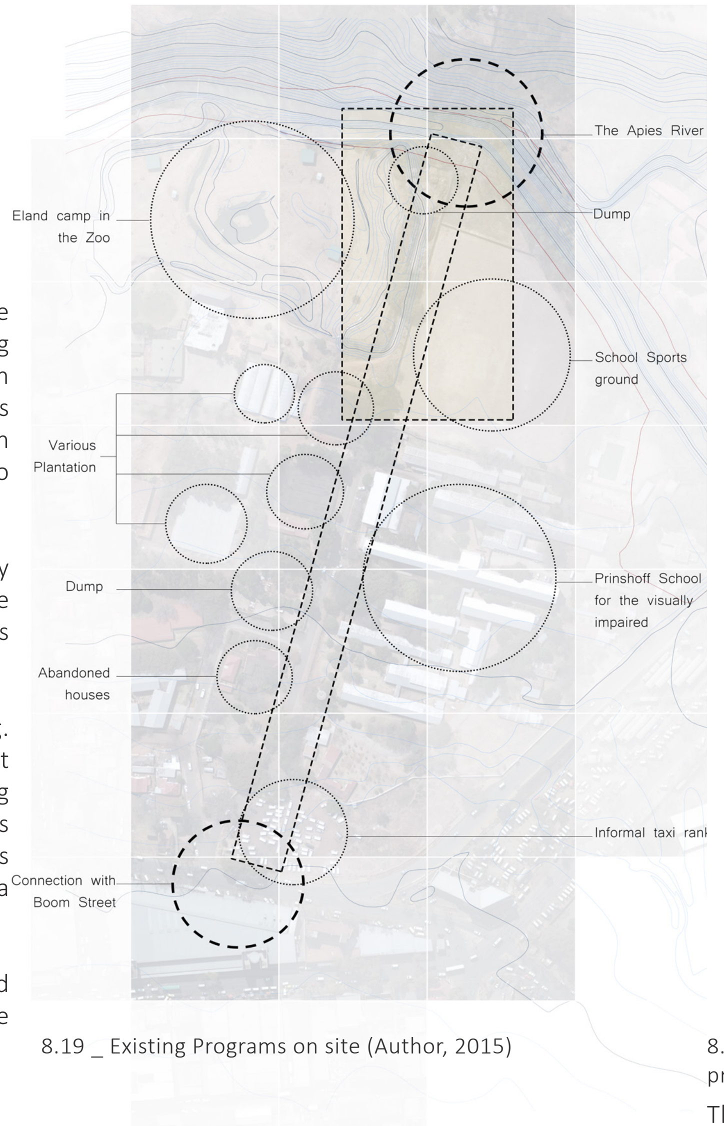
8.1.5
PROGRAM REQUIREMENTS

The program requirements became important in the layout of the building, which influenced the building design. The approach to the site requires an introduction to the function and program of the building. It is predominantly a public building because of its connection to the zoo. An administration building is thus required to control the access of people to the building.

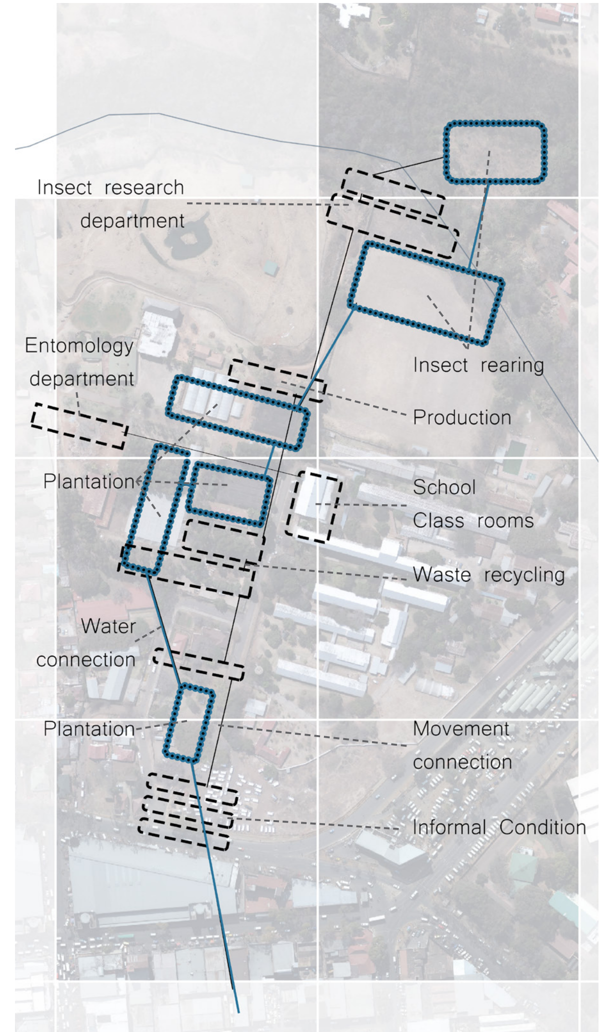
Therefore, the first building houses the entomology collection, a public library and a restaurant area. The information gathered from research in the laboratories is stored and viewed in the gallery and exhibition space.

The second building is the storage and deliveries building. No cars or delivery trucks are allowed beyond this point because of the natural zone. The purpose of this building is as repository of the facility's equipment and tools. As these are to be used often, there is a service route access to this building and deliveries to the restaurant area shares this route.

The third and last building is the main office and administration of the research facility. This is where the samples and insect species are gathered to be studied.

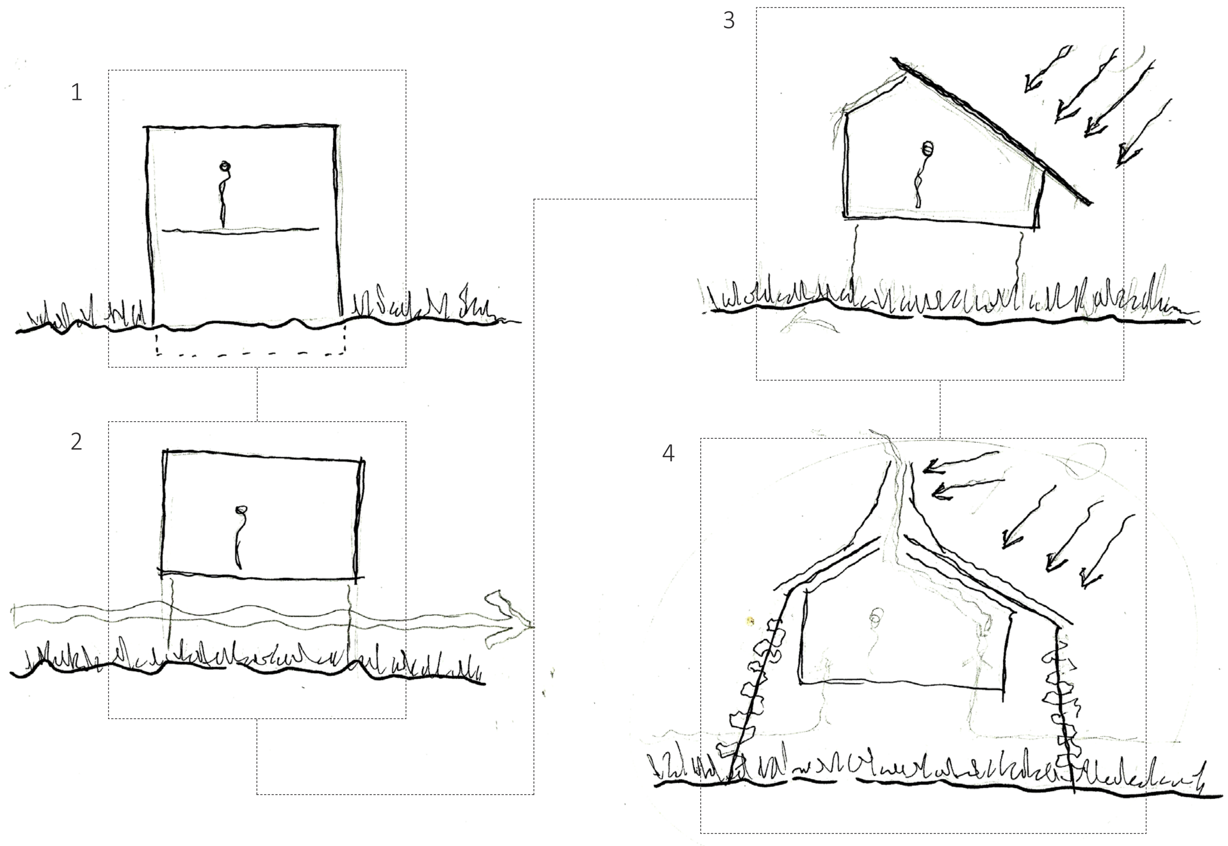


8.19 _ Existing Programs on site (Author, 2015)



8.20 _ Diagram, Water channel link influencing programs (Author, 2015)

This diagram reveals the implication of the new water axis and its functions and how it integrates with the existing programs; ensuring that a beneficial relationship is developed.



8.1.6
PASSIVE SYSTEMS

The basic shape of the building is informed by the climate. The pitch of the roof is angled for optimal sun exposure of the façade, enabling easy placement of photovoltaic panels for energy harvesting. It gradually slopes down onto the ground to maintain the concept of the building growing out of the site. To extract hot air from the building an outlet is requisite at the highest point in a building. The building is therefore shaped at an angle and the hot air flow rate is expedited by a solar chimney stack that extracts the hot air from the building. Rainwater is collected by gutters on the roof and delivered to the water channel axis route, which is situated on the western side of the building.

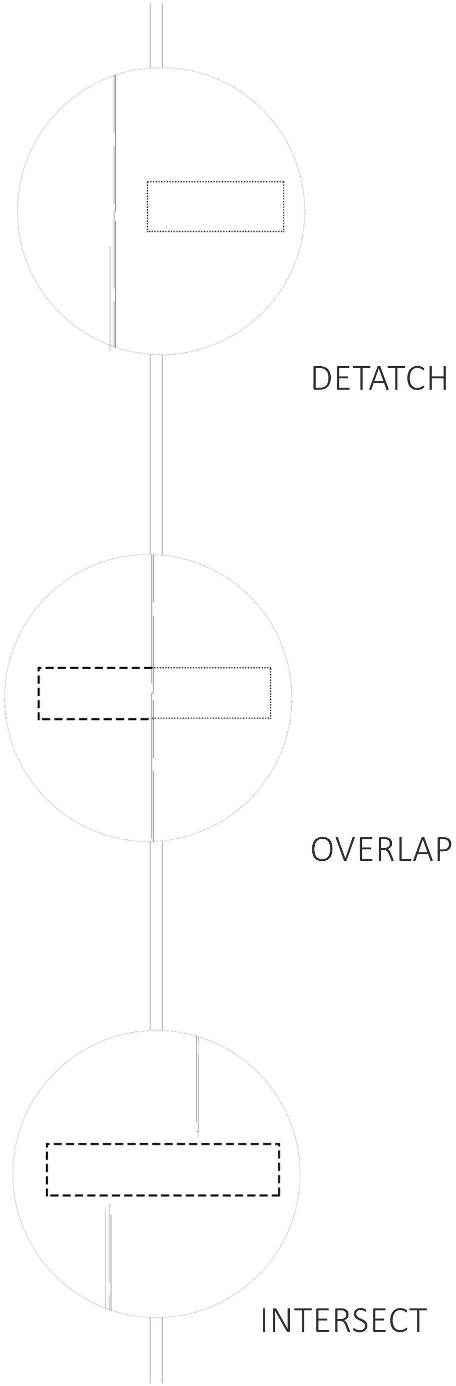
8.21_ Passive system informants; 1- Standerd building orientated north, 2- Lifting the building from the ground allowing nature to grow, 3- Northern facade of the building slopes perpendicular towards the optimal sun angle, 4- The roof slopes down into the ground allowing the water to flow down and nature to grow on the side of the facade (Author, 2015)

Creating habitable spaces for both humans and insects through the use of natural- and technical systems is the main focus of the building design. The use of plants on the building skin, operating as a sun shade to control the temperature inside the building, also functions as habitats for the insects. This development derived from the evolution of Steward Brand's 6 'S' layered principle to create an alternative building layer that is integrated with nature.

Transcending the simple way of just greening a building with a more biodiverse design calls for the use of diverse natural or semi-natural habitats in all aspects of the building design; nearby, on and within the building (Wells et al, 2010: 130).

The incorporation of the green infrastructure on the site with an artificial wetland, through the use of a water channel, allows the area to prosper as a natural habitat for a variety of wildlife and insects. It connects habitats across the landscape and permits animal and bird species to move freely (Yeang, 2008: 128). These continuous wildlife corridors connect larger areas with existing green spaces, creating new habitats.

8.22_ insect hotels, insect habitat architecture (http://assets.inhabitat.com/wp-content/blogs.dir/1/files/2014/01/Bug-hotel.jpg).



8.23_ Building responding to water channel axis (Author, 2015)

8.3 / CONCEPTUAL APPROACH / Shifting more into nature

The conceptual approach is an extension of the urban vision in that the water channel becomes the living wall that runs through the site. The buildings respond to the 'living-wall' and to the environment in three ways:

1. BUILDING INTERSECTING / The water channel that intersects the site represents the environment and ecosystems; the first building interrupts the ecosystems, thus illustrating the way humans perceive the ecosystems at first.

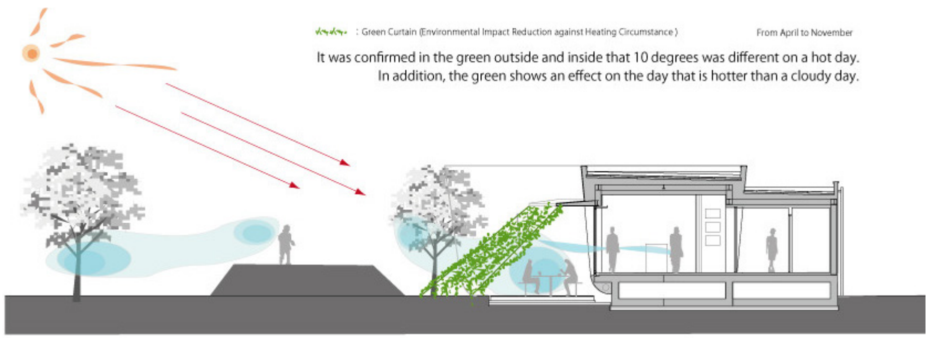
2. BUILDING OVERLAPPING / The second building still forms part of the water channel, but represents awareness that nature is a self-healing, self-regenerating entity; it therefore overlaps the natural flow of the environment.
3. BUILDING DETACHING / The last building is to the north of the site, which is zoned as the most natural area; it is released from the water channel and becomes integrated with nature.

8.4 / DESIGN PRECEDENT STUDY

8.4.1
GREEN SCREEN HOUSE/ Hideo Kumaki Architect Office

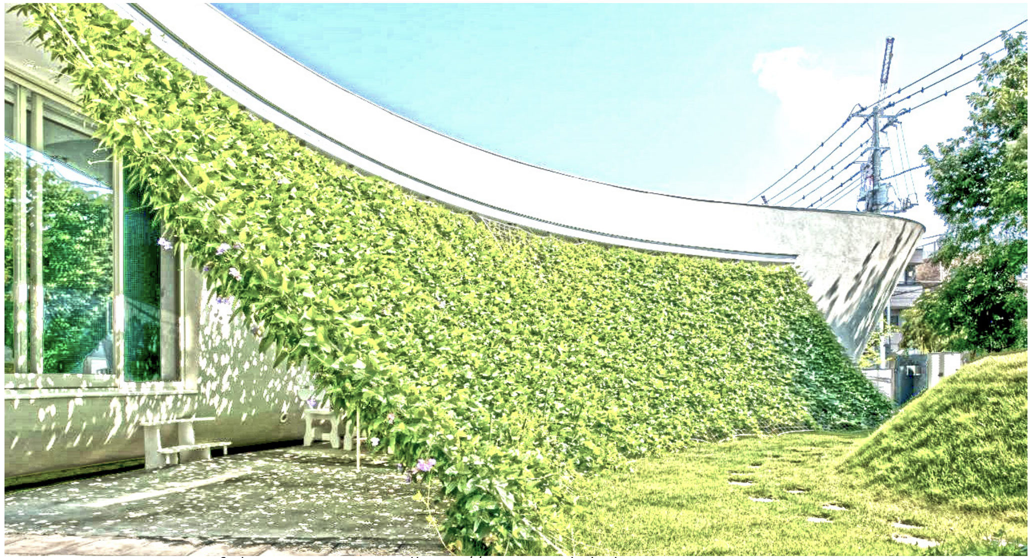
Location: Saitama, Japan
Area: 130m2
Project Year: 2012

It is a minimalist house that deploys a green screen to protect the interior spaces from direct sunlight. The green screen functions for thermal comfort and reduces the electricity cost of air conditioning. According to Hideo Kumaki (Director of Hideo Kumaki Architect Office) there is a 10 degree difference between the inside and the outside of the house (Chang, 2012: 1). The relevance of this project as a design precedent lies in the fact that Kumaki used nature as a service device to create a comfortable space underneath the green façade.



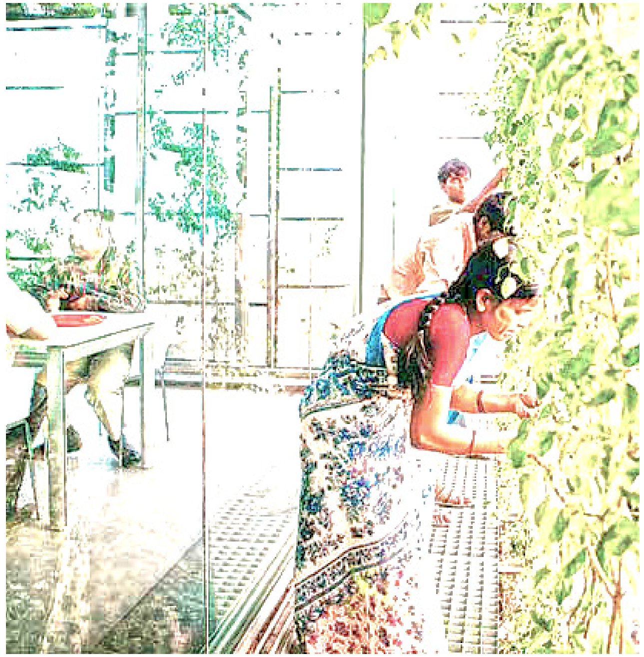
8.24_ Diagram illustrating the passive design (http://www.archdaily.com/421607/green-screen-house-hideo-kumaki-architect-office/521e4e27e8e44ed7fc00003a-green-screen-house-hideo-kumaki-architect-office-diagram edited by author, 2015)

8.25_ Interior view towards outside green screen (http://www.archdaily.com/421607/green-screen-house-hideo-kumaki-architect-office/521e4d5de8e44ef64000003d-green-screen-house-hideo-kumaki-architect-office-photo edited by author, 2015)



8.26_ Exterior view of the green screen (http://www.archdaily.com/421607/green-screen-house-hideo-kumaki-architect-office/521e4d8ce8e44ef64000003f-green-screen-house-hideo-kumaki-architect-office-photo edited by author, 2015)

8.27_ Exterior view of the outer skin green facade (http://rmaarchitects.com/architecture/kmc-corporate-office edited by author, 2015)



8.28_ View between the building and outer skin (http://rmaarchitects.com/architecture/kmc-corporate-office edited by author, 2015)

8.4.2
KMC CORPORATE OFFICE/ RMA Architect

Location: Cyber City, Hyderabad, India
Project Year: 2012

The architects adapted the use of a double skin for a corporate building to save energy and to be visually striking. The outer skin of the building contains a custom casted aluminum trellis with hydroponic trays that contain growing medium for a variety of plant species. The inner skin is reinforced concrete frames with typical aluminum windows (Archdaily, 2013). The façade of this building serves an aesthetic purpose as its abundant plant species bloom in the various seasons. The façade hence changes in color depending on which season it is.

8.29_ Elevations designed with plant palette patterns (http://rmaarchitects.com/architecture/kmc-corporate-office edited by author, 2015)

9 / DESIGN

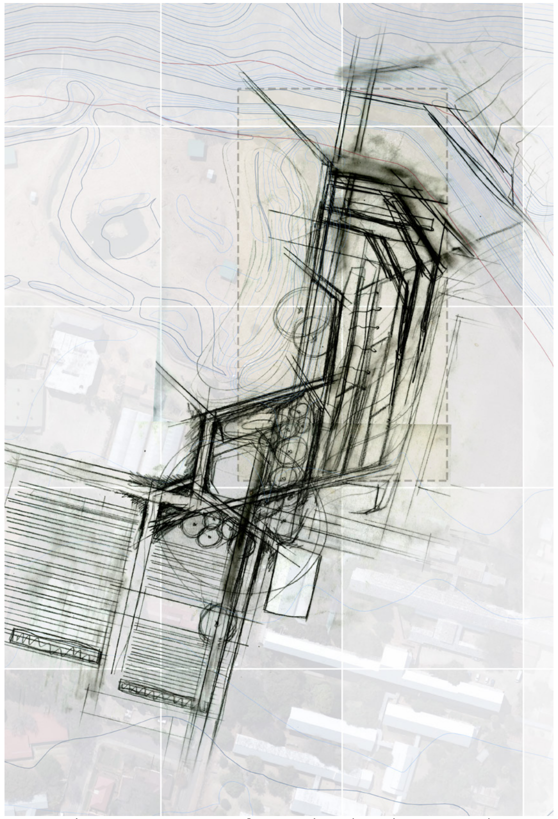
9.1 / DESIGN DEVELOPMENT /

Finding the relationship between man, nature and building

DESIGN 01 / The first design sketches delineate the boundaries of the project site. Connections to neighboring sites are shown and space is left for the school to use their sport fields. The development of as much vegetation and natural ecosystems as possible creates a natural barrier between the two sites. The water channel, as a strong axis, follows a straight path to the Apies River. The walkways and footprints of the building are carefully placed to not harm existing habitats, but to instead enhance the ecosystems in already damaged areas (refer to Section 8.1.2).

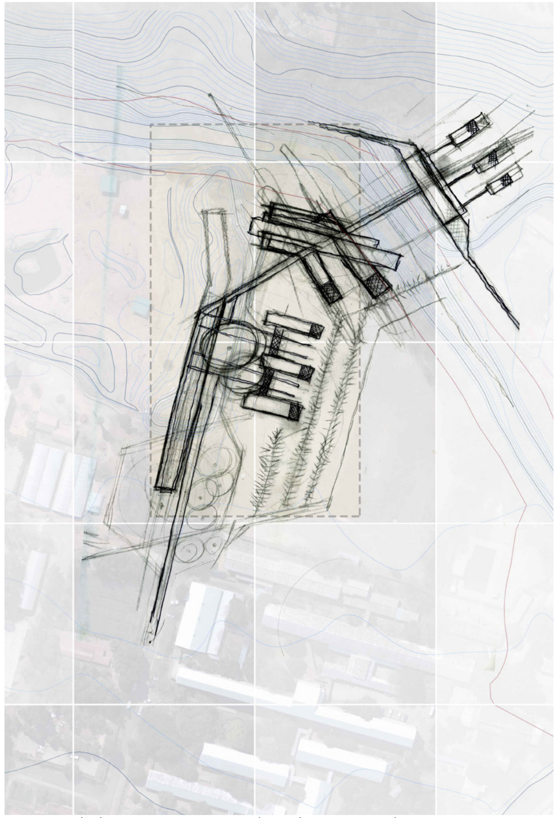
DESIGN 02 / The second design is intuitive and emphasizes the approach to the site in the form of building cantilevering from the hilltop on site. The existing Eland encampment border runs straight across the middle of the hilltop; therefore, the entire hill cannot be utilized. The second response is to place the research buildings facing north and in the middle of the natural created ecosystems, where insect species can be quickly captured for research. Different research buildings are placed further north to accommodate different insect species and the bee sanctuary is north of the Apies River, away from people.

DESIGN 01



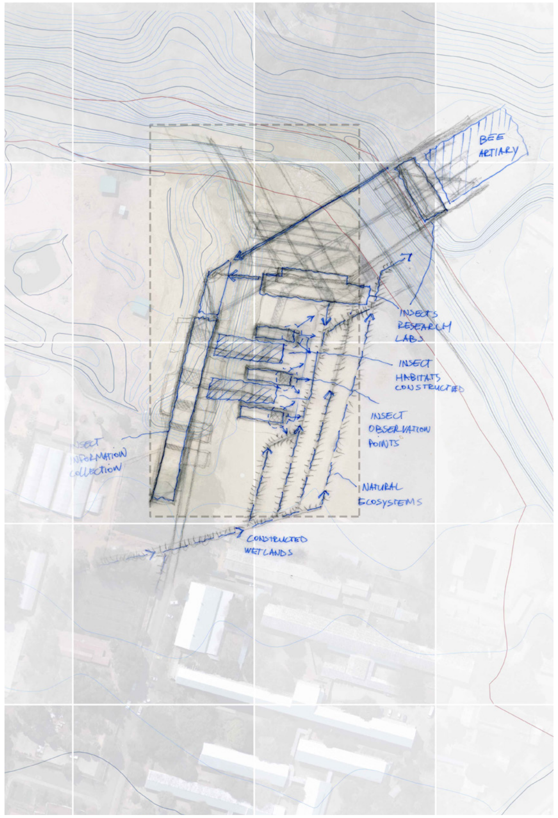
9.1_ First design iteration of site plan (Author, 2015)

DESIGN 02

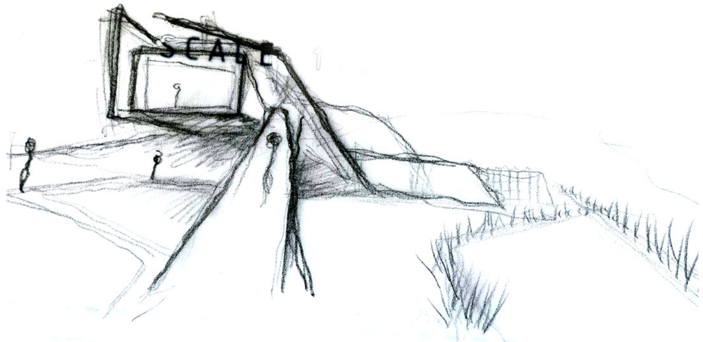


9.2_ Second design iteration (Author, 2015)

DESIGN 03

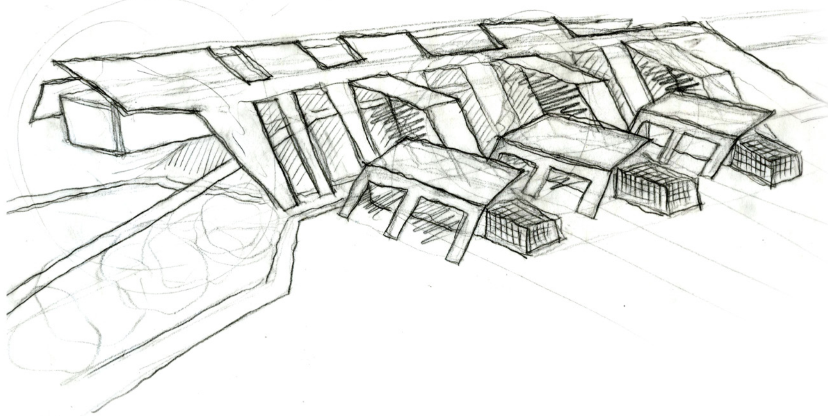


9.3_ Third design iteration that developed further (Author, 2015)

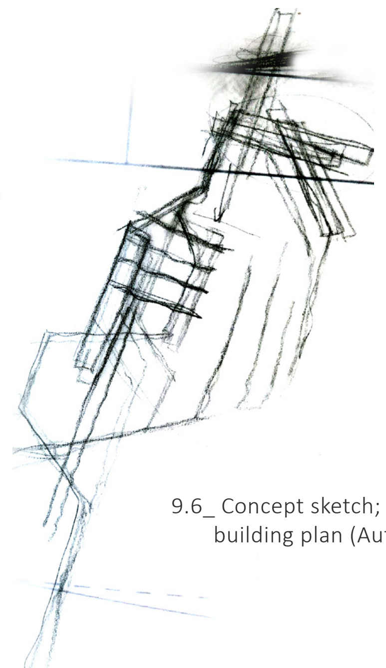


9.4_ Concept sketch of the extention of the zoo department with the wetland insect habitats on the left (Author, 2015)

DESIGN 03 / In the third iteration the architecture is simplified and specific programs are assigned to the buildings. The water channel is more defined where it becomes an artificial wetland and water route to enhance the insect habitats. The public route brings visitors up close and personal with the insect habitats. The proposed building, however, is disconnected from the public and does not define the entrance to the research building or define itself enough as a building belonging to the zoo. The strong water axis leading to the Apies River is also lost and does not serve a purpose for the research building.

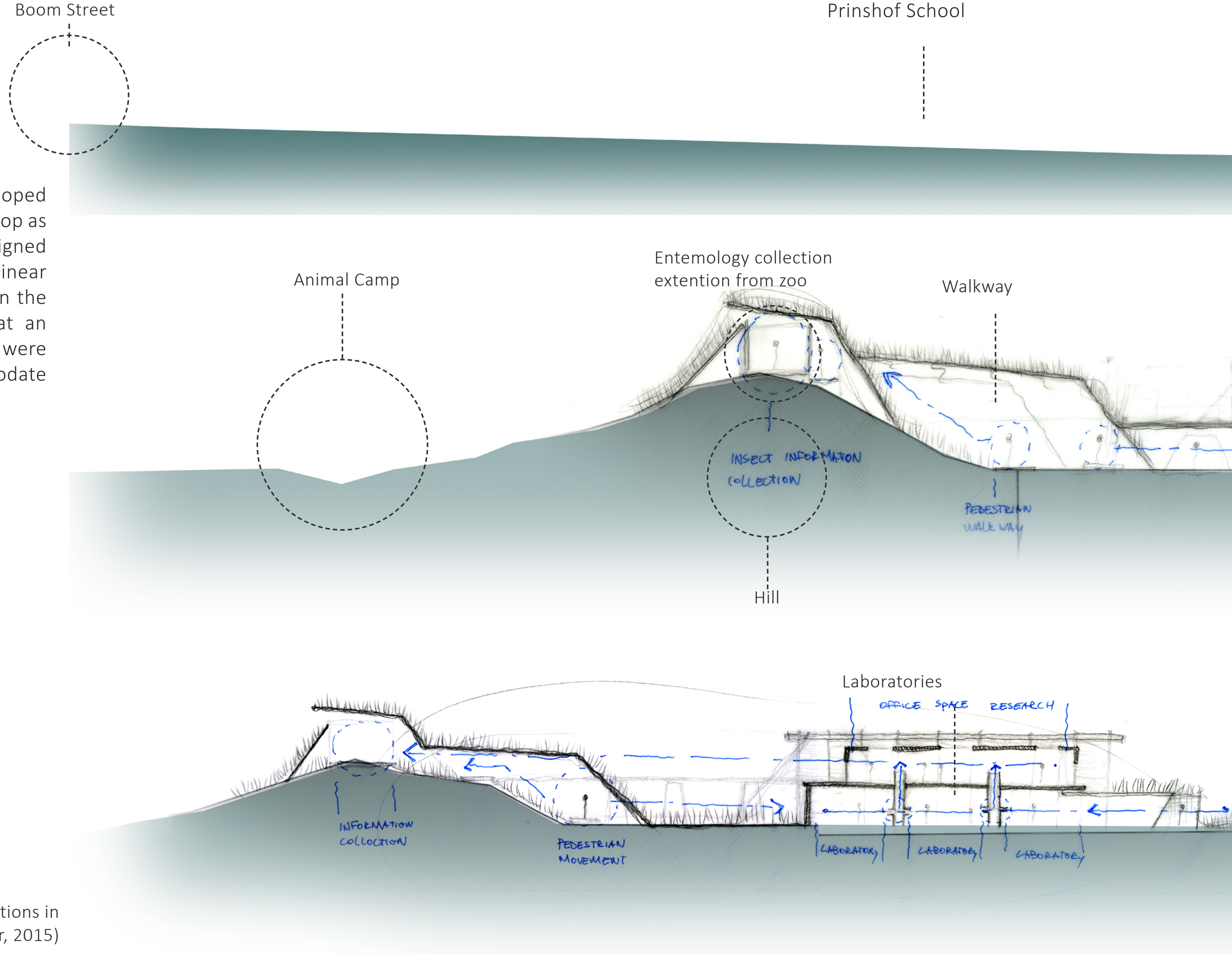


9.5_ Concept sketch; aerial view of the research facilities with the laboratories (Author, 2015)

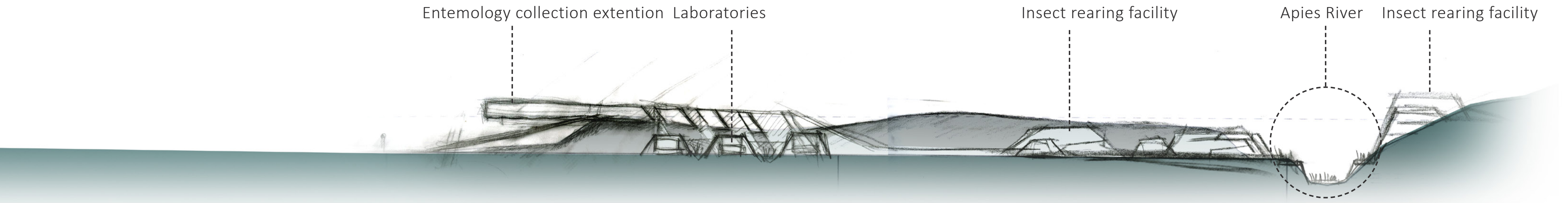


9.6_ Concept sketch; diagram of building plan (Author, 2015)

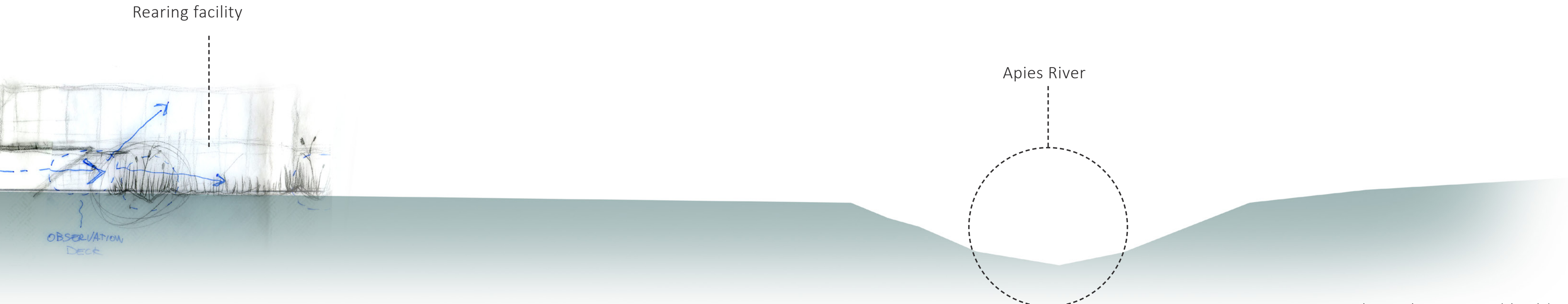
The following sections and elevations were developed from Design 03. Inspiration was drawn from the hilltop as the building started to form. The building was designed with the hilltop and site instead of against it; a linear building is created that defines the spaces between the structures. The roofs were intuitively designed at an early stage to form part of the site, sloped roofs were created to control water run-off and to accommodate the vegetation that grows on the building.



9.7_ Concept sketch; sections and elevations in relation to the site and hill (Author, 2015)



East elevation displaying the buildings relation to Boom Street and the Apies river



East- West section through proposed building

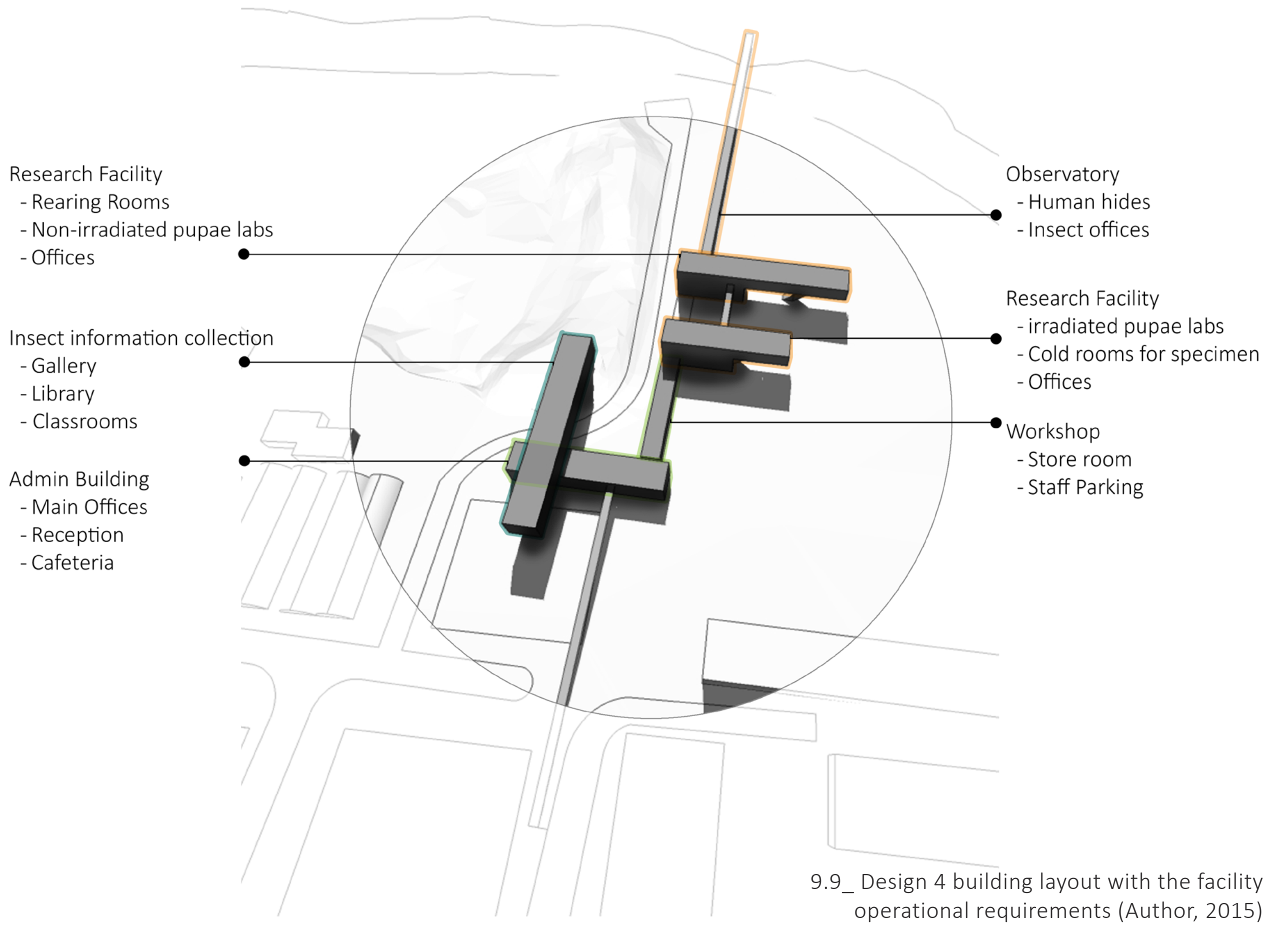
East- West section through proposed building

9.1.1
DESIGN 04 DEVELOPMENT

DESIGN 04 / This iteration of the layout moves the entomology collection building to the south of the site. An administrative building is included to define the entrance of and control access to the research facility. Pedestrian movement is defined between the public and people employed at the research facility and parking for employees' vehicles is separated from the delivery route into the site. The building defines the entrance space south of the site, whilst the north of the site is zoned to promote natural growth of vegetation and insect habitats. The public route is determined by the natural barriers that the constructed wetland creates between public and private. The building cantilevering from the hilltop defines the approach to the entrance and becomes part of the entomology department of the zoo; creating a connection between the zoo area and the research facility. The axis of the water channel towards the Apies River has a prominent effect on the layout of the building. This axis controls the water filtration and manages the waste water collection from the buildings. It gains educational value as part of the building program.

DESIGN 04

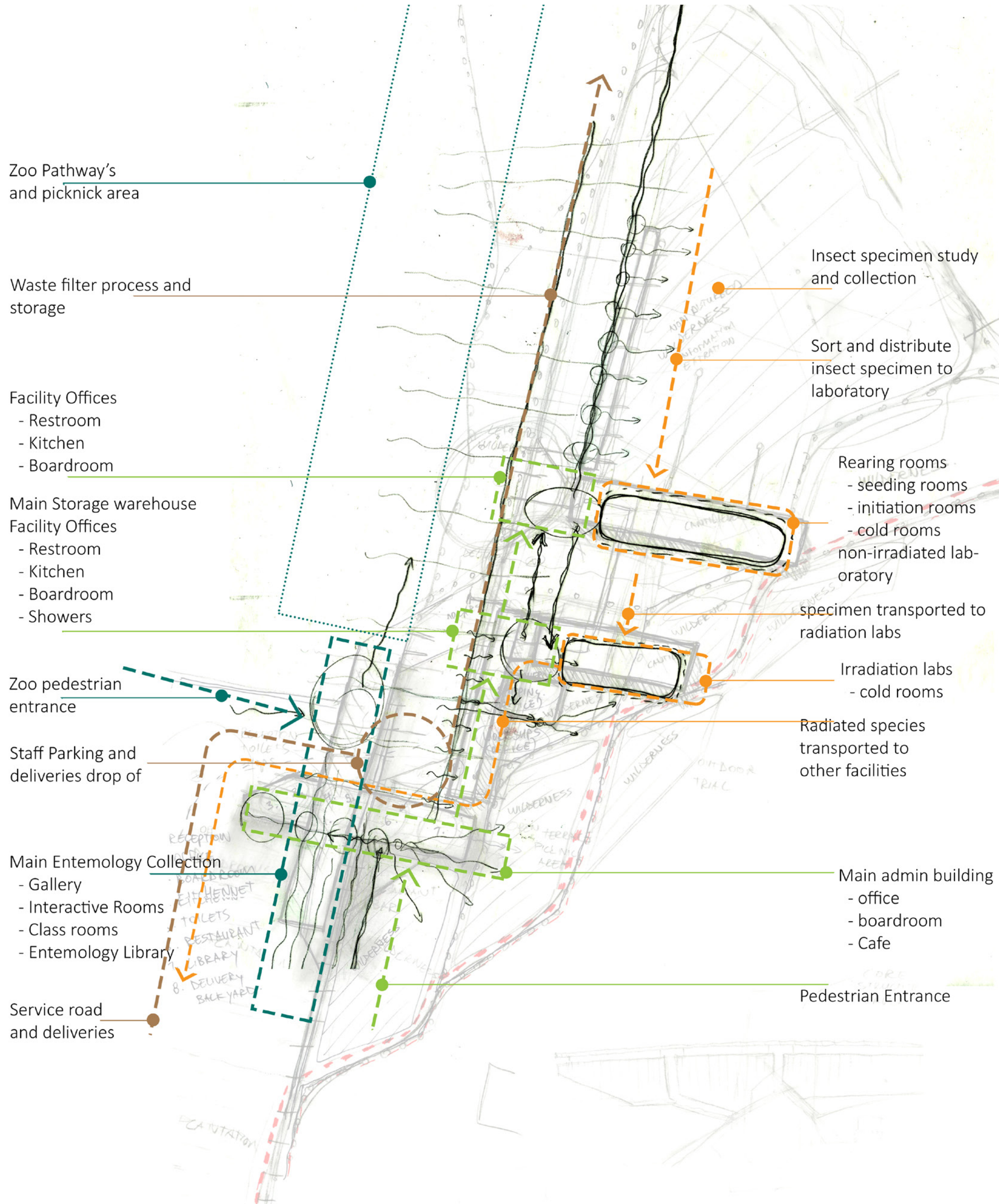
9.8_ Concept sketch; design 4 site layout and is the final layout that will be further developed (Author, 2015)



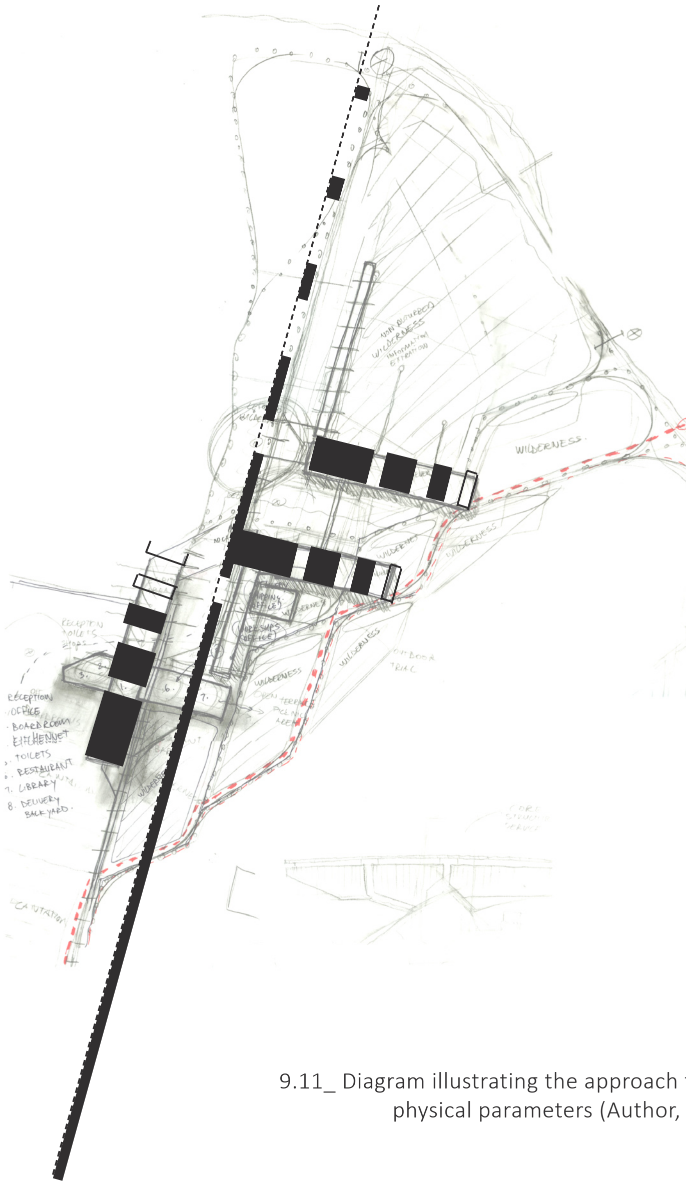
9.9_ Design 4 building layout with the facility operational requirements (Author, 2015)

DESIGN 04 / Program

The design layout is further explored in terms of movement, roof layout, physical parameters, biological parameters, facility operational requirements and environmental parameters. All these factors influence the final outcome of the design.



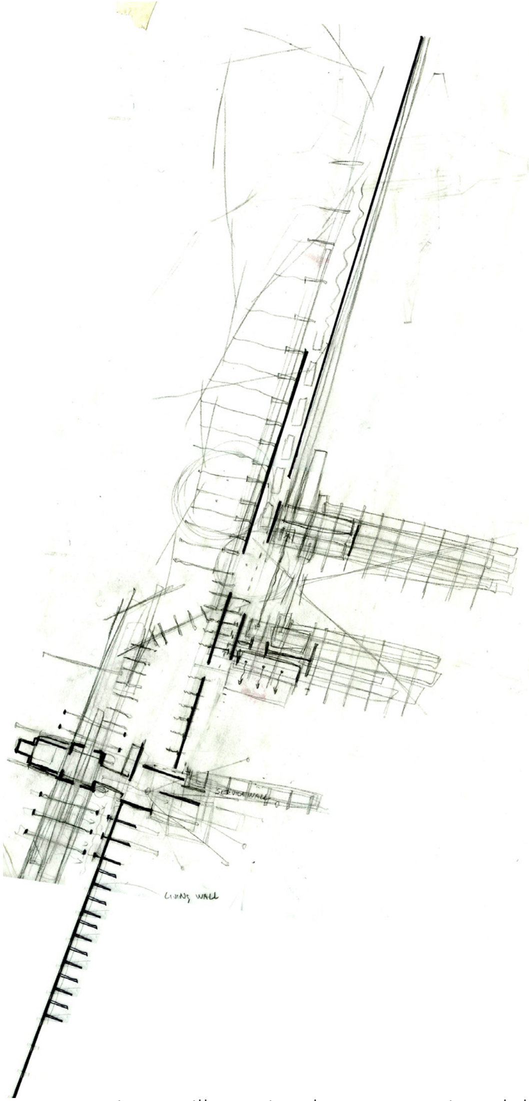
9.10_ Bubble diagram illustrating the program throughout the layout (Author, 2015)



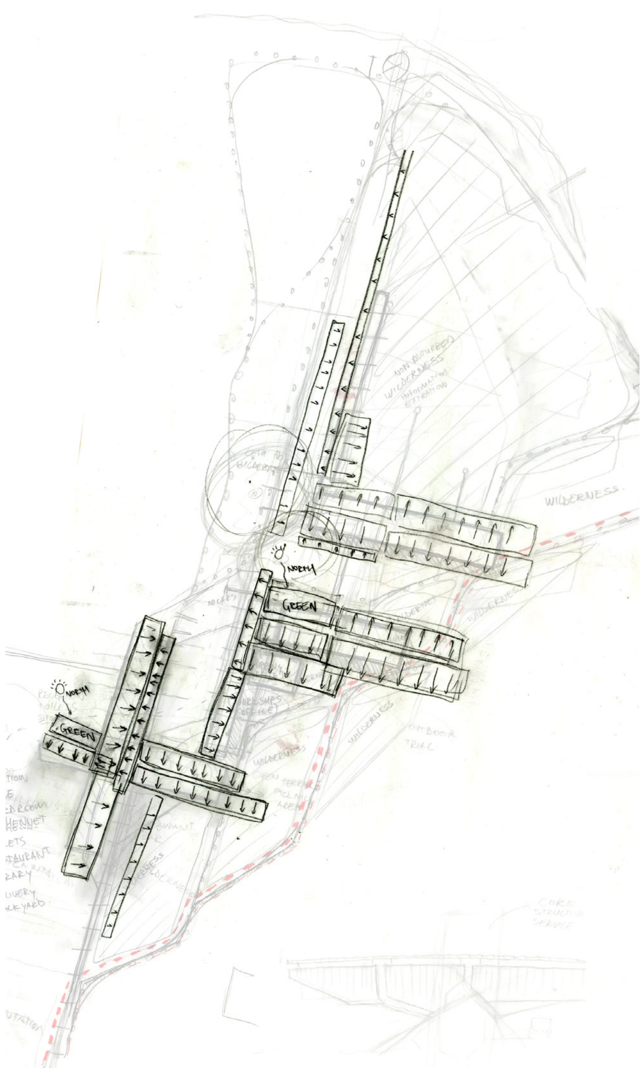
9.11_ Diagram illustrating the approach to the physical parameters (Author, 2015)

DESIGN 04 / physical parameters

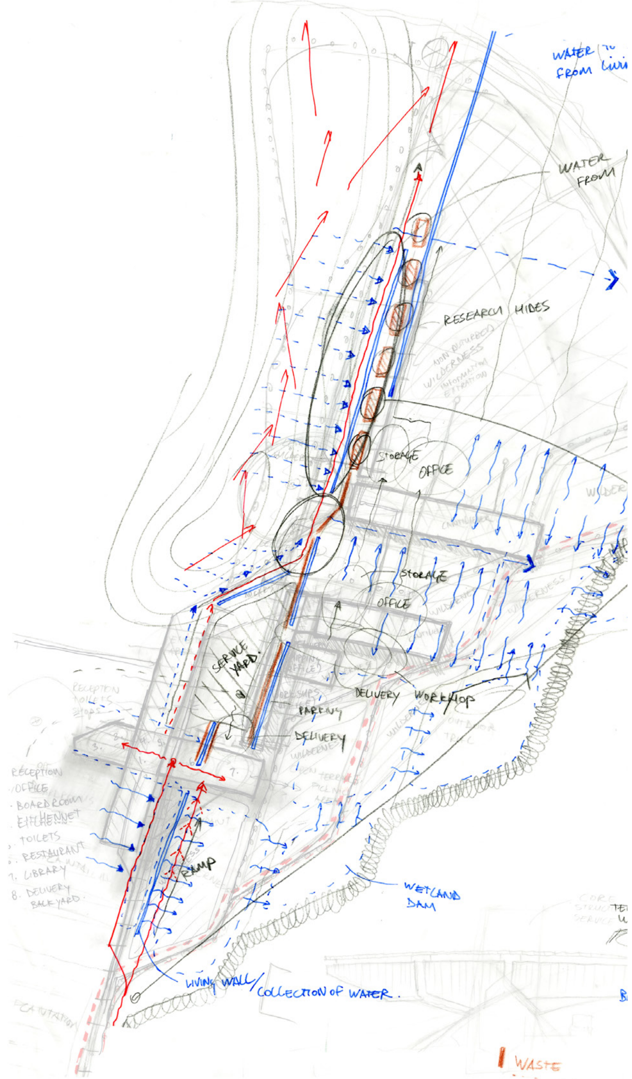
The physical parameters of the building correspond with the concept. They form an appropriate relationship with the environment. The building changes gradually as it nears the natural zone in the north; its mass changes to a more lightweight structure that illustrates the building's adaptation to form part of nature. The water channel axis, which is the living wall, reflects this concept by changing in size as it develops through the site and ultimately thinning out as it becomes part of nature.



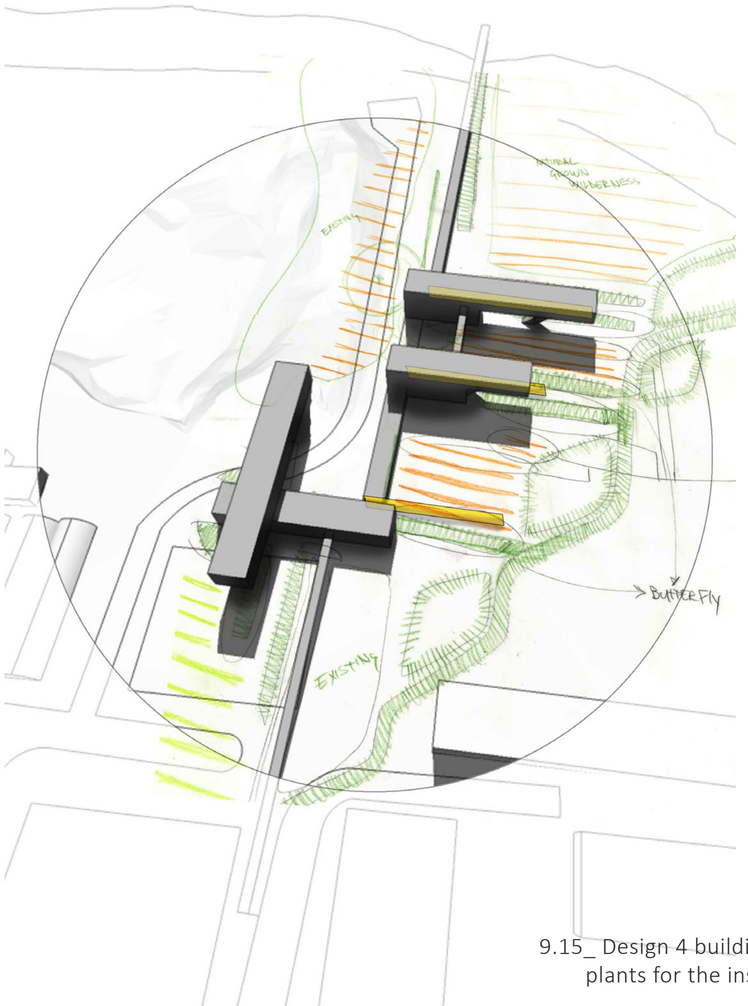
9.12_ Diagram illustrating the stereotomic and the tectonic of the structure (Author, 2015)



9.13_ Diagram illustrating the roofs slopes as they direct the water flow (Author, 2015).



9.14_ Diagram illustrating the movement between public and private (Author, 2015)



9.15_ Design 4 building layout with the different plants for the insect habitats (Author, 2015)

DESIGN 04 / Biological parameters

The biological parameters form an integral part of the building program and therefore must be properly designed for. As the purpose is to accommodate insect habitats on site, appropriate nutrition and shelter must be provided so that the insects populate the site in a more natural way. Indigenous plants and flowers that provide appropriate nectar and nutrition for these insects are listed in Table 8.27. The insects require plants and flowers to bloom throughout the year; if there is enough nutrition and appropriate shelter the insects will not need to migrate to other sites for food or shelter.

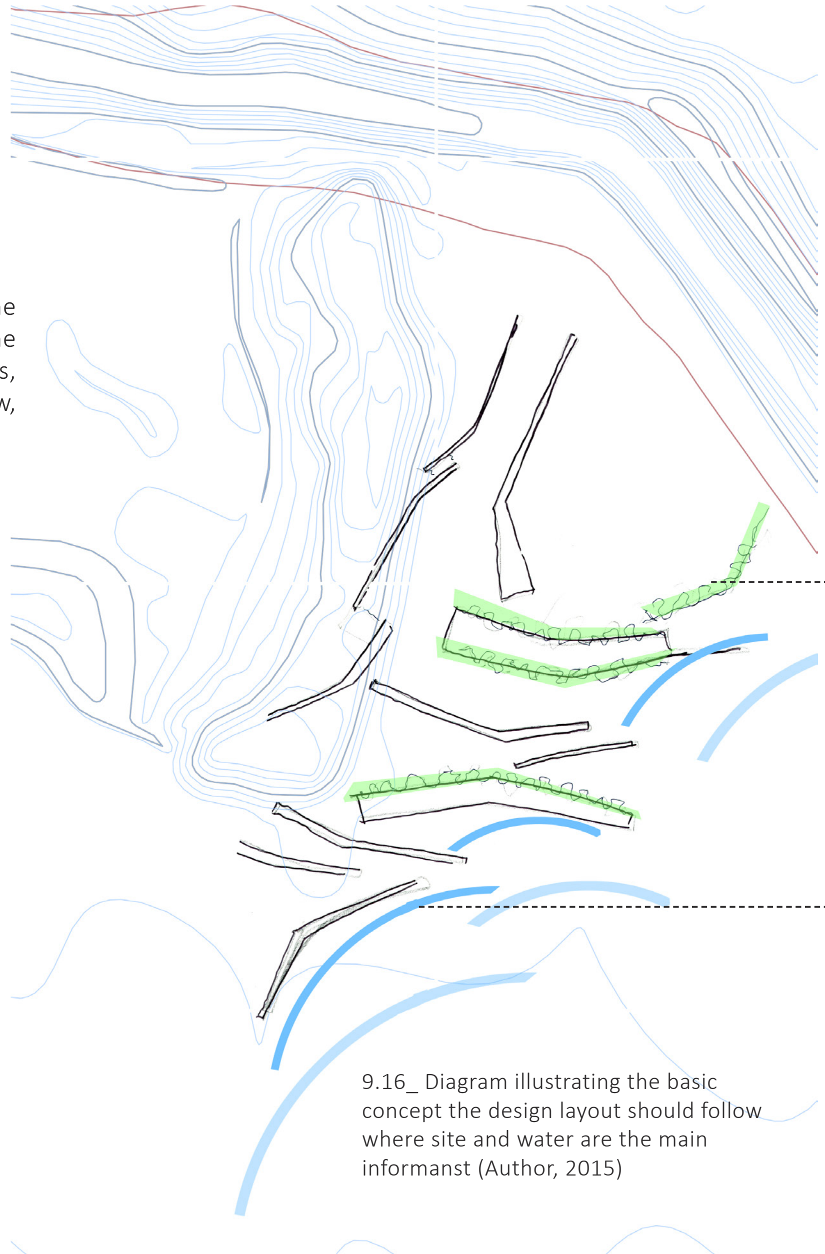
1. Target insect species: The insect group that uses flowers as a food source are classified as the 'order':

- Hymenoptera: Bees, wasps, and ants
- Lepidoptera: Butterflies and moths
- Diptera: Flies
- Coleoptera: Beetles

2. Number of species: Mass rearing of one or more species in one facility will impact on facility design.
3. Scale of production: Small scale research facility, laboratory.

9.2 / FLOOR PLAN ITERATION / Spatial exploration

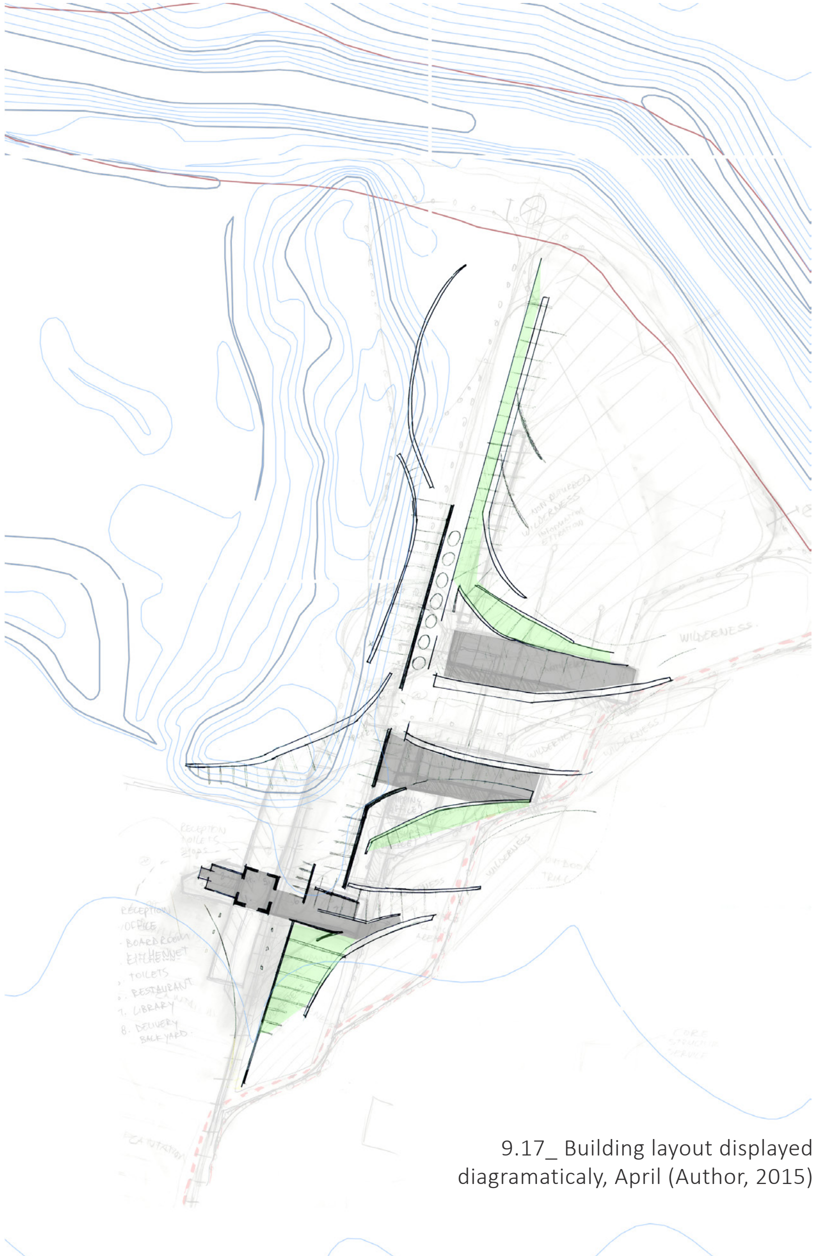
The basic shape of the design layout is to morph with the site rather than against it. The main informants of the building shape are the site and environmental conditions, where the building is shaped to direct the water flow, thus the building becomes part of the site.



The Green indicates the site becoming part of the building.

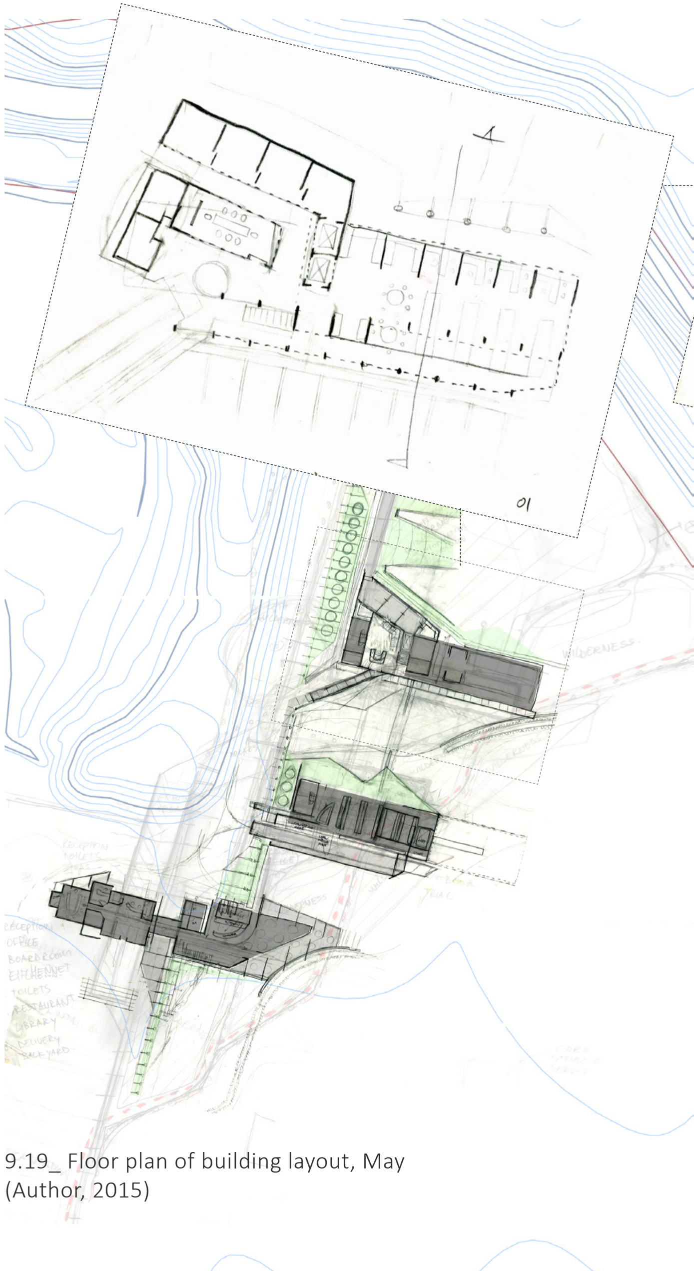
The Blue indicates the water flow through the site. It shows how the building can manipulate the direction of flow to direct the water where it needs to go.

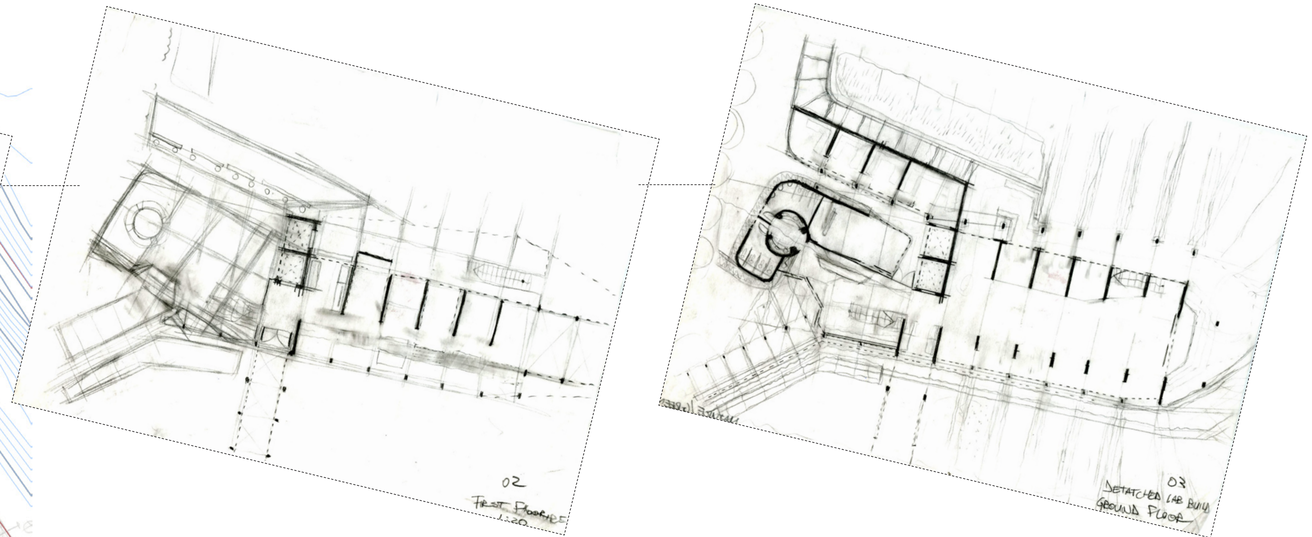
9.16_ Diagram illustrating the basic concept the design layout should follow where site and water are the main informanst (Author, 2015)



9.17_ Building layout displayed diagramaticaly, April (Author, 2015)

9.18_ Building layout displayed diagramaticaly, May (Author, 2015)

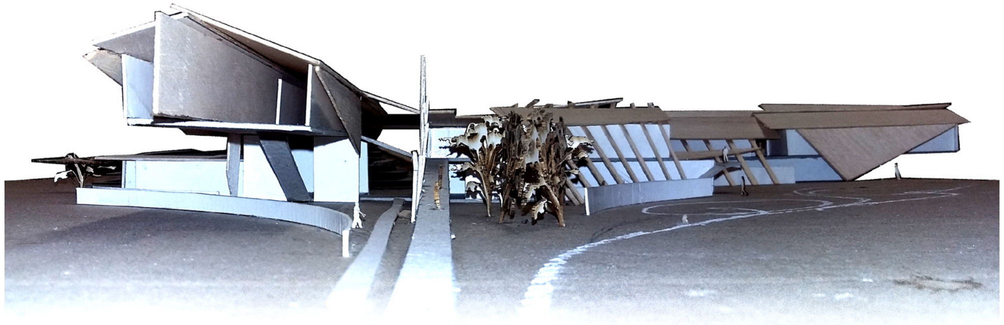




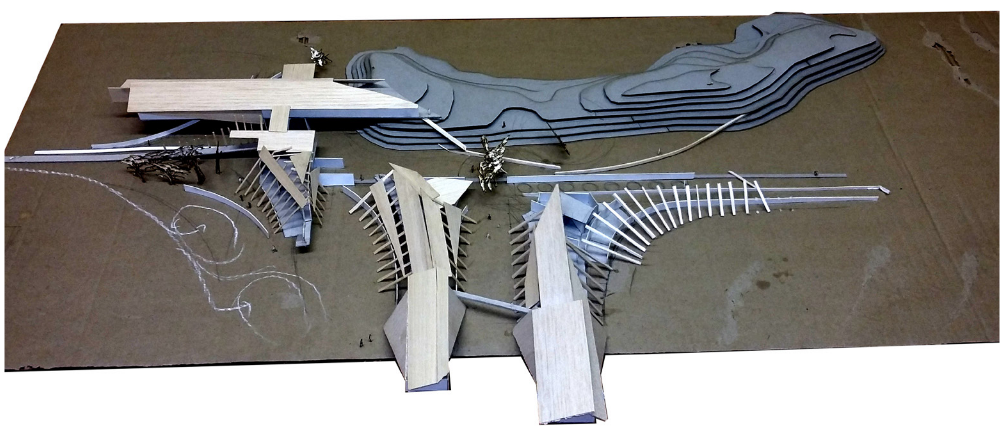
9.20_ (From left to right) Floor plan iterations, June / July (Author, 2015)

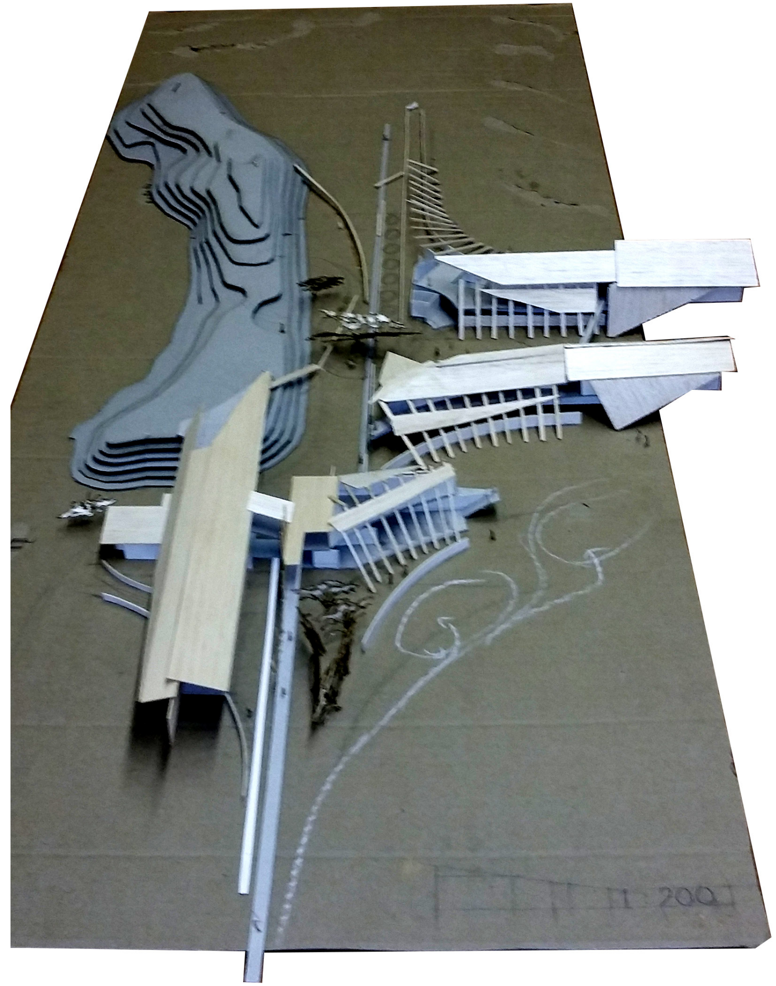
9.19_ Floor plan of building layout, May (Author, 2015)

9.2.1
MODEL



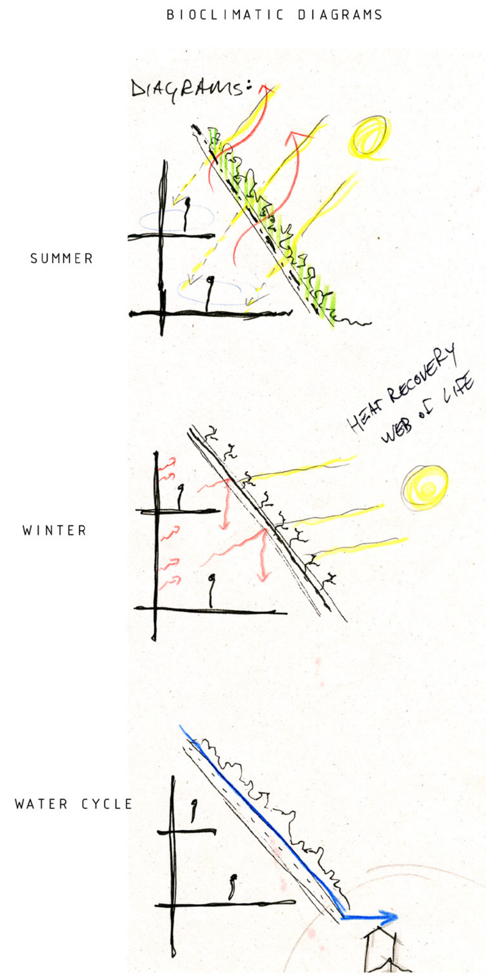
9.21_ Model built of design in June
(Author, 2015)



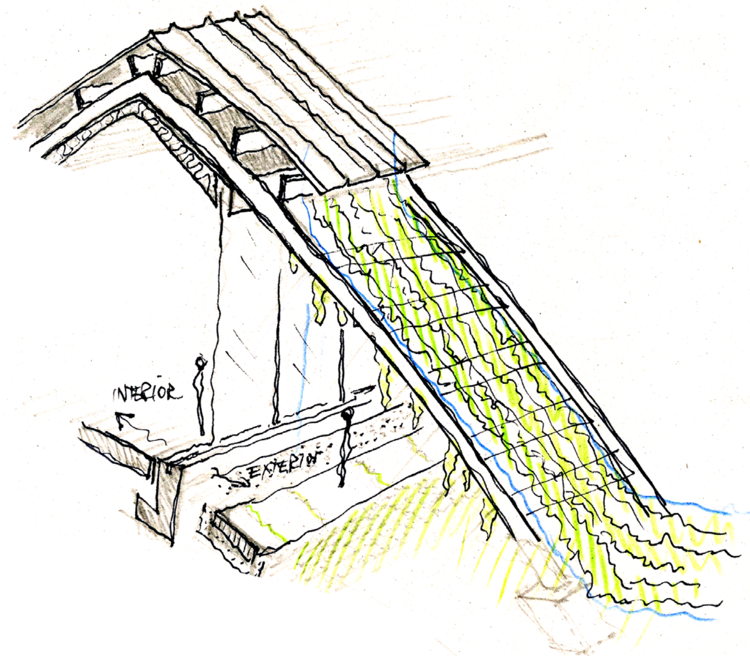


DESIGN 04 / Roof intention

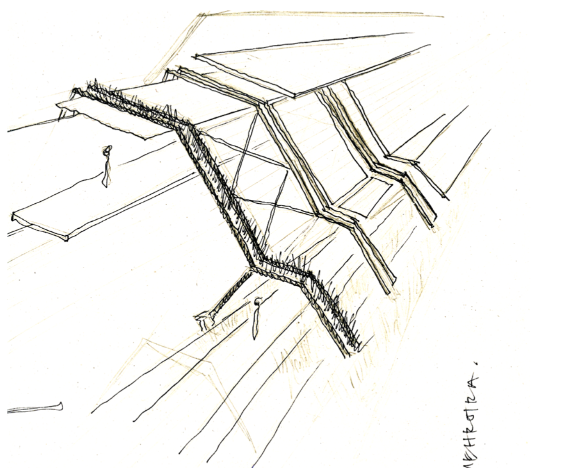
The roof is designed to fulfill different functions that relate to the design informants of regenerative theories. It plays the most important role in this design. The main function of the roof is to create the reciprocal relationship between man and his environment; this is where nature and man reach an equilibrium for co-existence. The roof ultimately becomes the façade of the building and the façade of the building becomes the ground, and vice versa. The envelope of the building is one element that hosts various functions; allowing plants to grow on the façade accomplishes these. The plants create habitats for the insects and provide a service for the inhabitants of the building. Humans create the structure that allows insect population and nature provides a free service for the humans. A mutually beneficial relationship is therefore achieved.



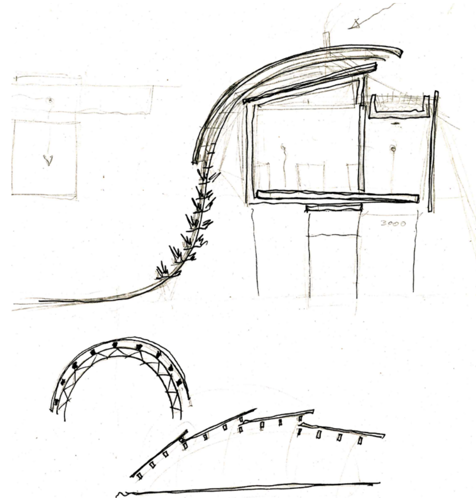
9.21_ Roof as a passive system (Author, 2015)



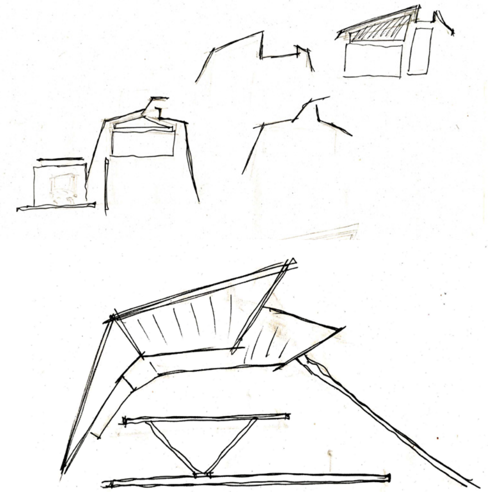
9.22_ Concept sketch of the roof as an important role in the building design (Author, 2015)



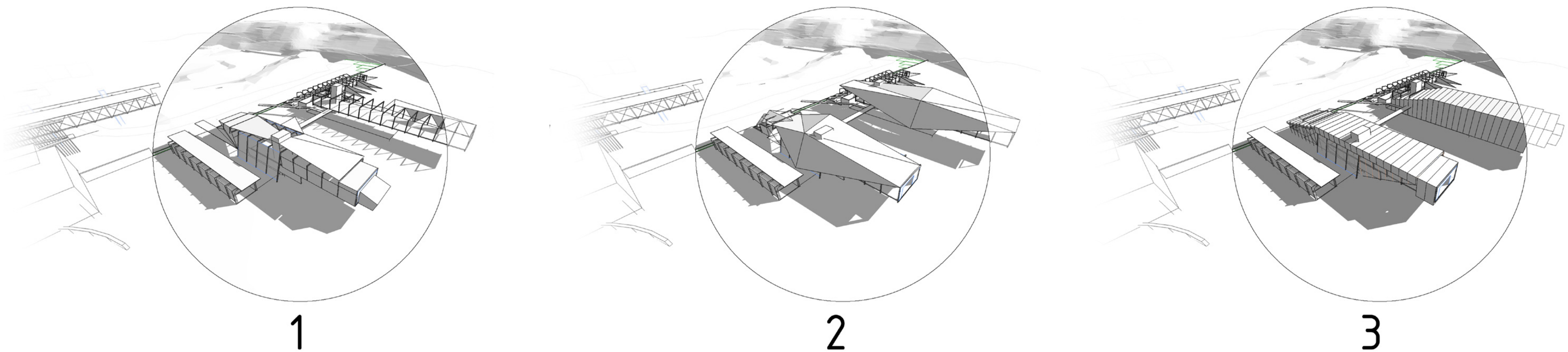
9.23_ Concept sketch of the roof integrated with the concept of the living wall (Author, 2015)



9.24_ Concept sketch of the roof with a more organic form to integrate more with the environment (Author, 2015)



9.25_ Exploring more ways the roof could be to accomodate more functions (Author, 2015)

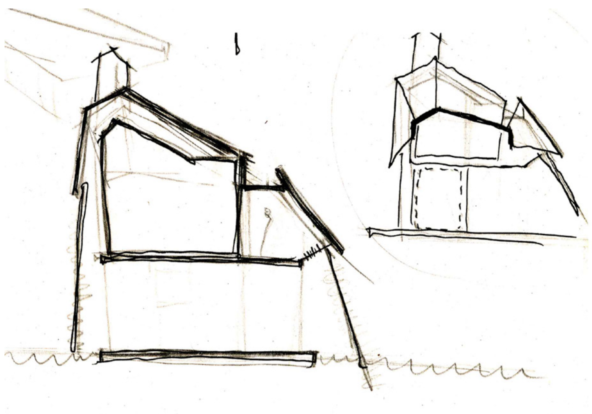


9.26_ (from left to right) 3D exploration of roof iterations (Author, 2015)

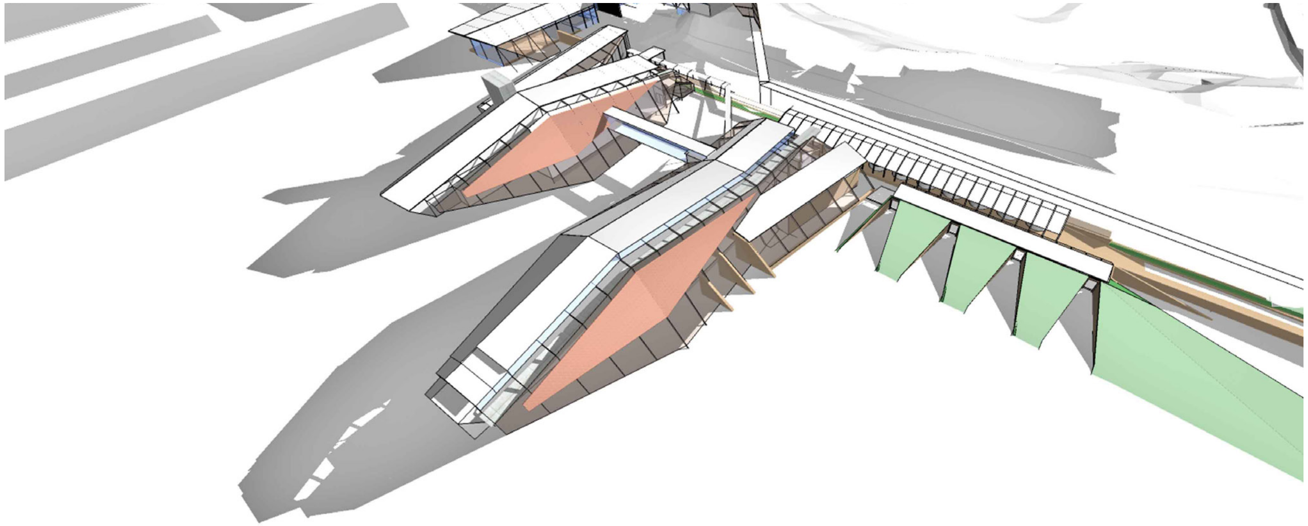
The following iterations pursue the concept of the roof adapting to the façade and integrating with the site. It evolved from the idea that the water flows from the sky to the soil.

The roof shape starts to form in an organic way, however, the construction would be problematic as the building should lift from the ground. A more structural solution is required.

Shaping the roof from a structural aspect, but still keeping in touch with the concept, results in more design iterations of the roof. The roof becomes the design aspect that binds the various elements together.

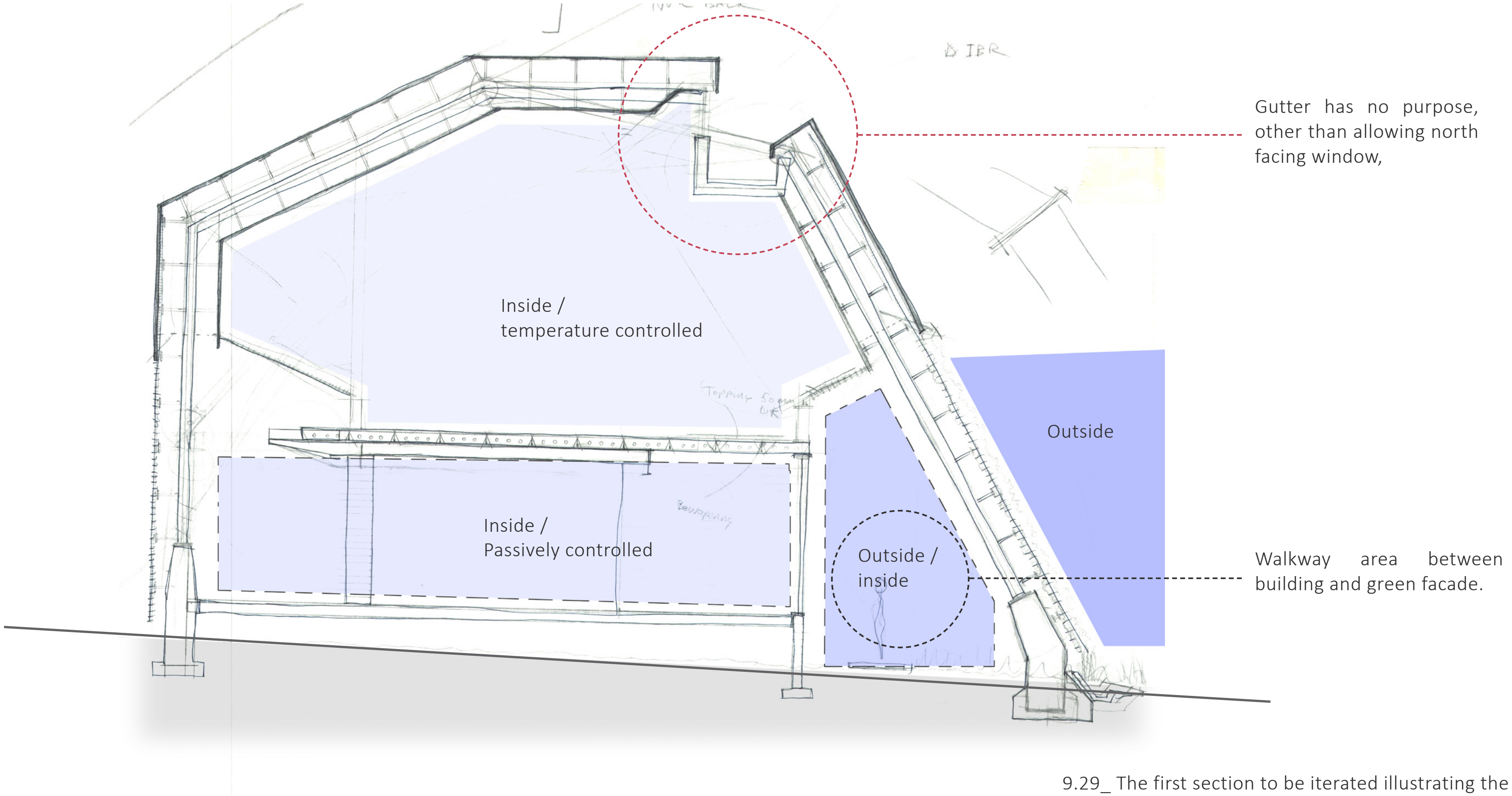


9.27_ Concept sketches that led to the final roof shape (Author, 2015)

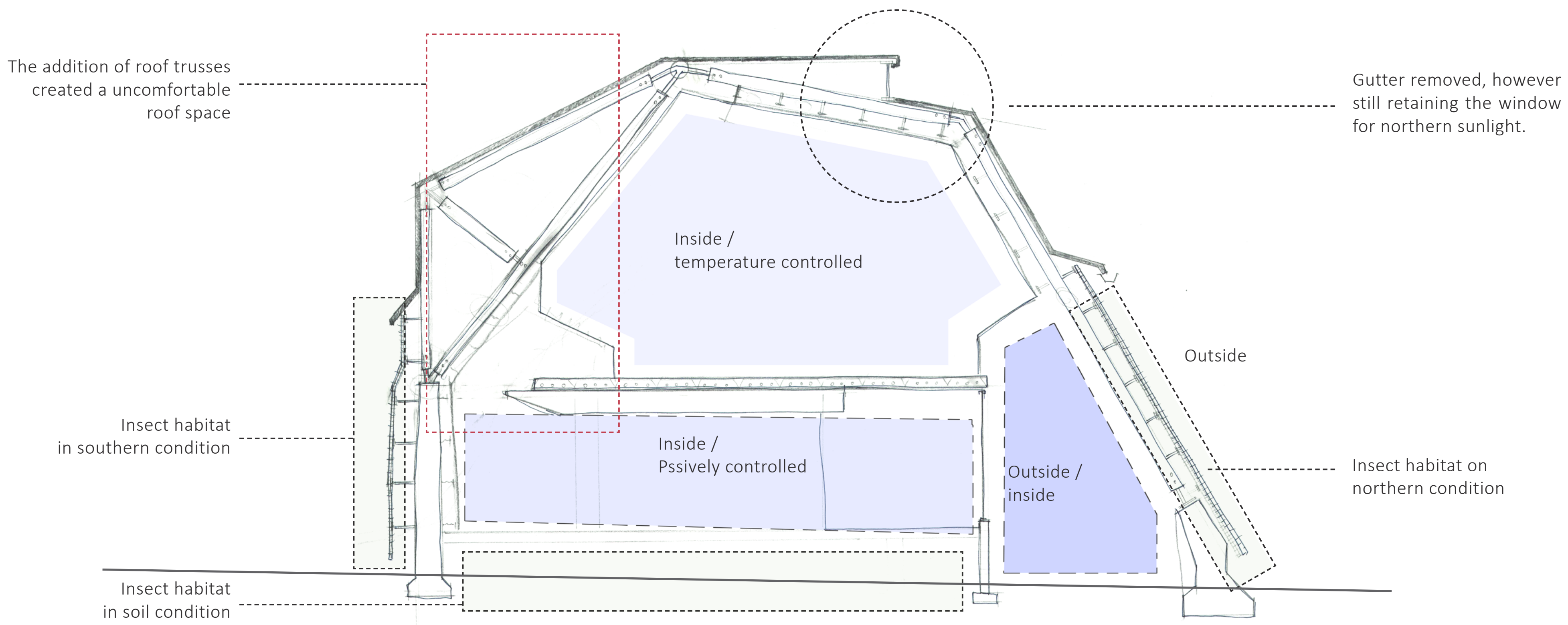


9.28_ 3D exploration of final roof shape (Author, 2015)

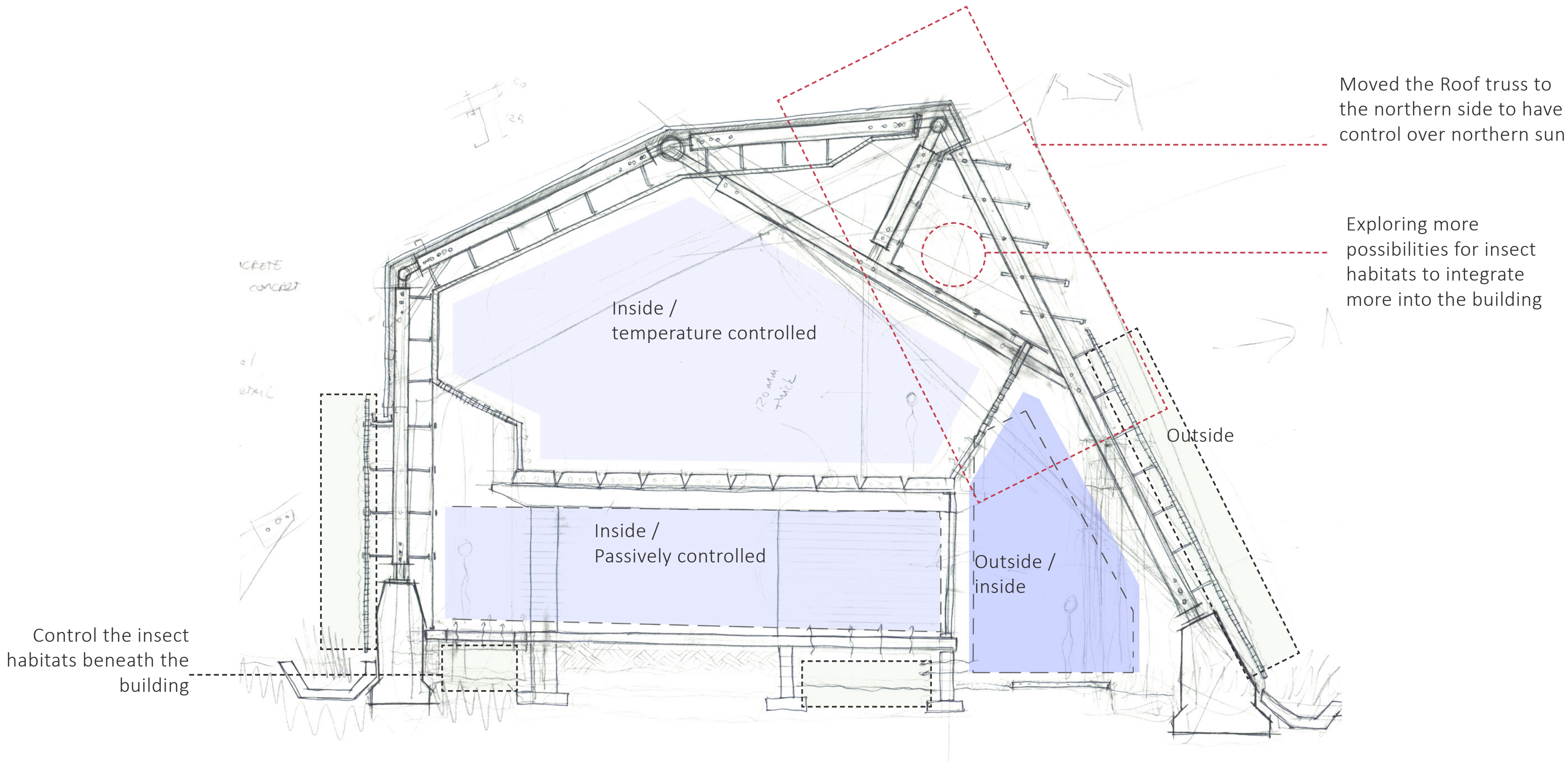
The final iteration of the roof concludes in a single line drawing that allows the building to be formed and shaped in many possible ways. This shape follows the concept and allows the design to become adaptable in its requirements.



9.29_ The first section to be iterated illustrating the different habitable spaces. (Author, 2015)

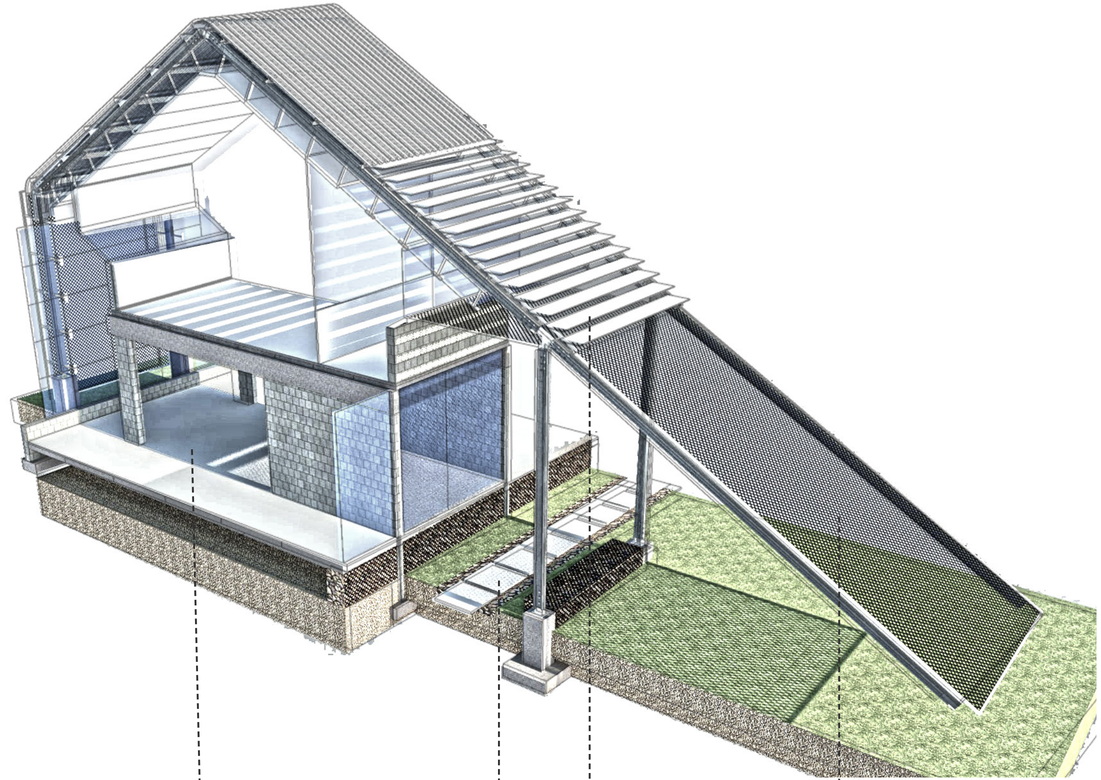


9.30_ Changes made to the section. (Author, 2015)

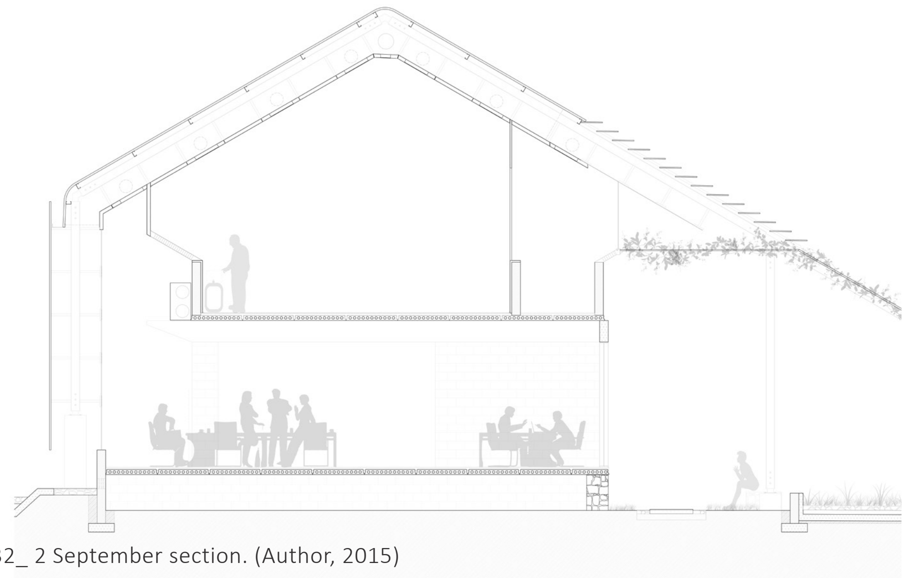


9.31_ Changes made to the section. (Author, 2015)

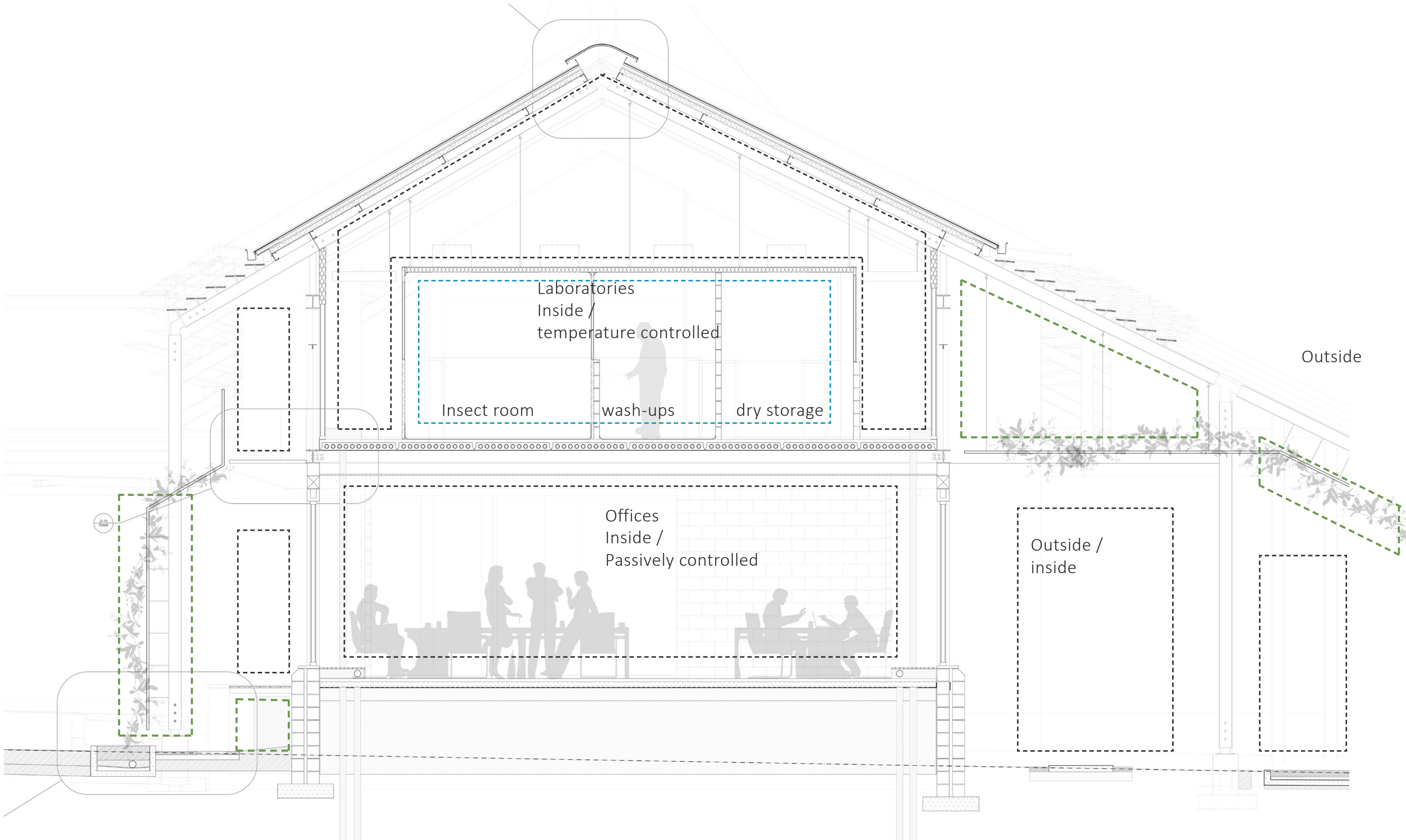
The shape of the laboratories followed the shape of the roof. Although it works diagrammatically, it was found to be problematic from a practical point of view. The insect rooms requires a certain temperature and need mechanical assistance. The current volume of the laboratories is too big to achieve a certain temperature quickly. As seen in figure 9.29, the laboratories shrunk to achieve an effective volume to cool down mechanically.



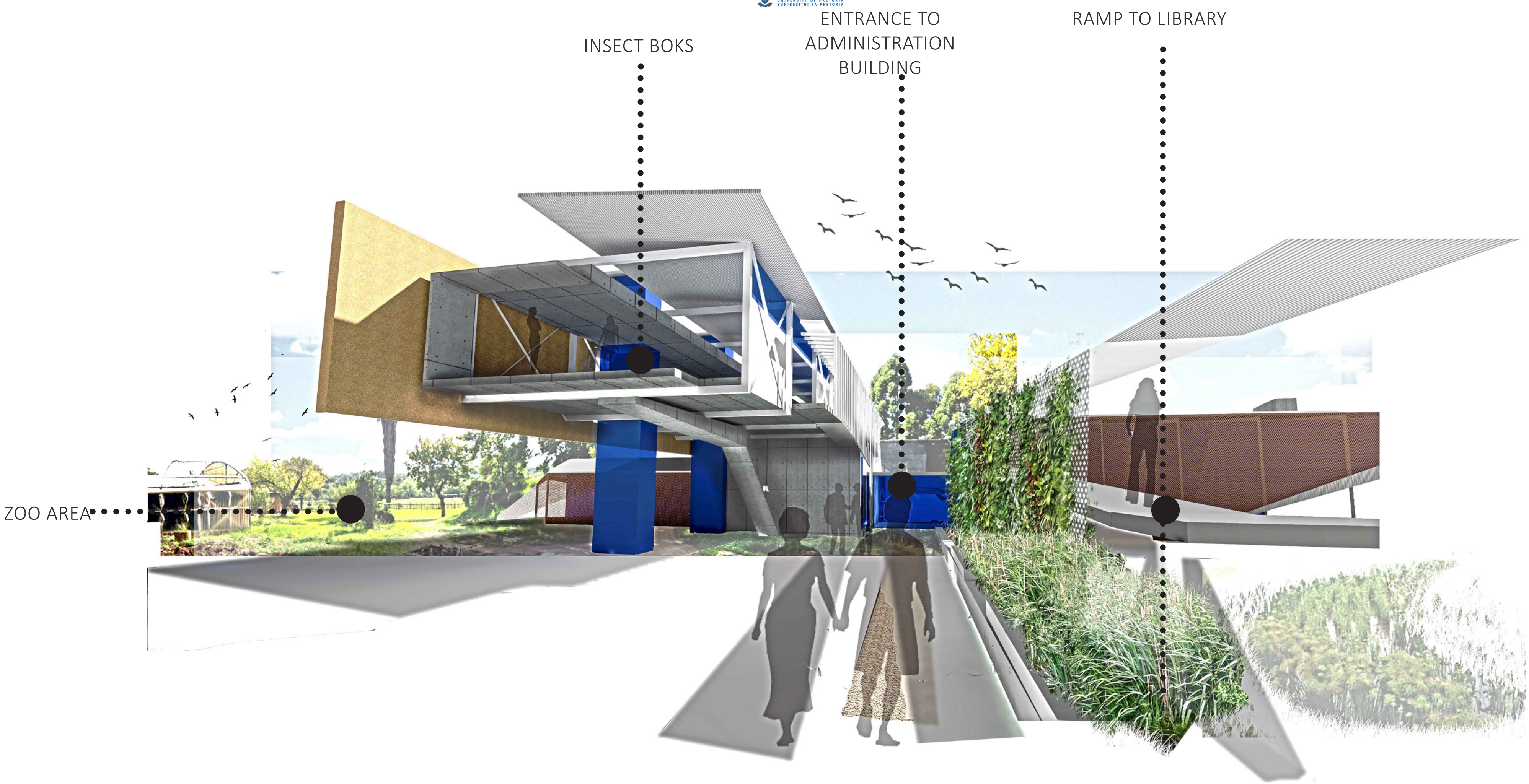
9.33_ 2 September section 3D model exploring spatial implications. (Author, 2015)



9.32_ 2 September section. (Author, 2015)

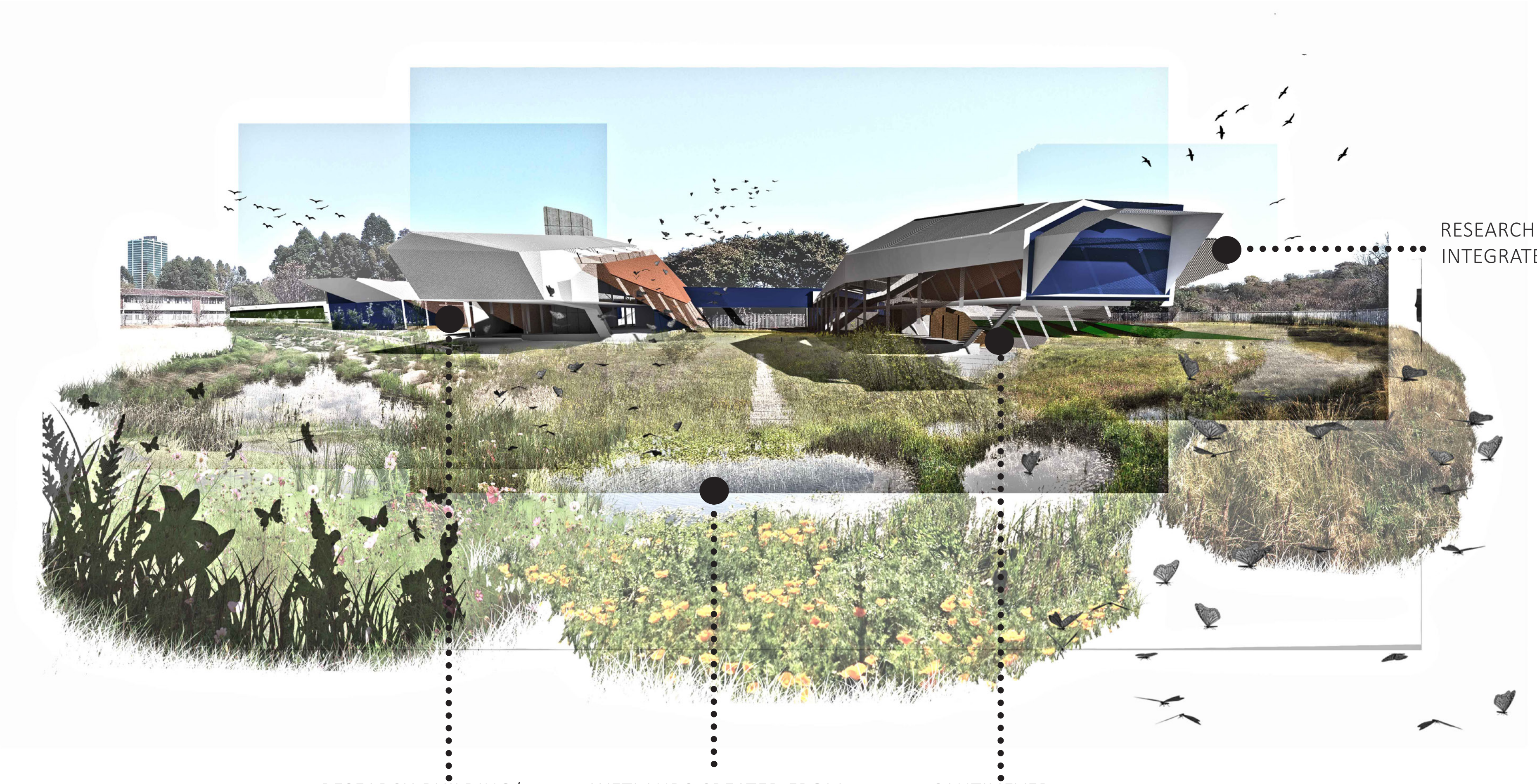


9.34_ 30 September section. (Author, 2015)



PERSPECTIVE VIEW / ENTEMOLOGY COLLECTION DEPARTMENT

9.35_ Final Design renders in July; Entrance to the Entomology collection department the extension from the zoo (Author, 2015)



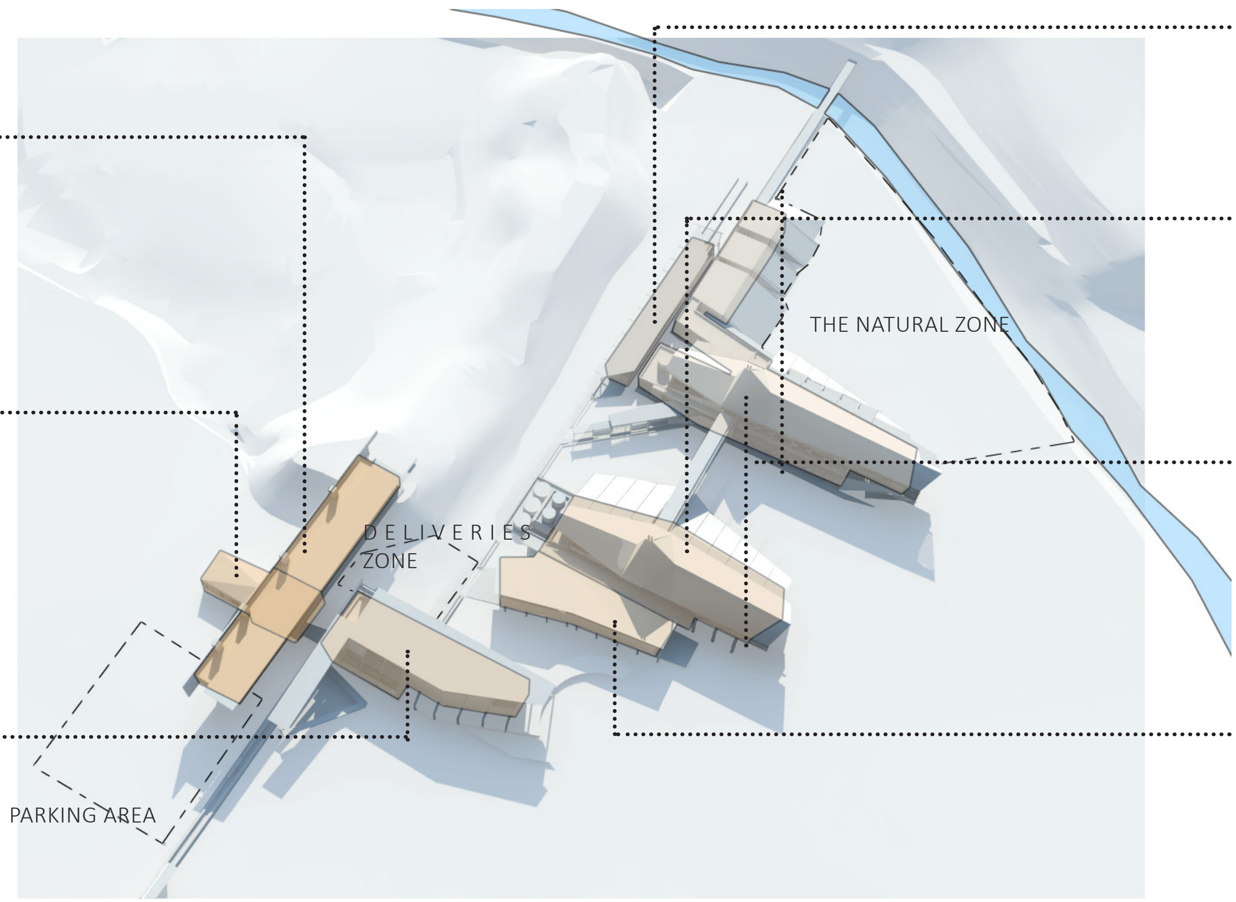
PERSPECTIVE VIEW / RESEARCH FACILITY

9.36_ Final Design renders in July; View of the two research facilities on site, view of ecosystems and insect habitats (Author, 2015)

ENTEMOLOGY COLLECTION /
All the insect and ecosystem information stored and viewed in this building, open to public, an extention of the Zoological gardens

ADMINISTRATION BUILDING /
Offices and boardroom where the administration of the building happens and the public not entering through the Zoo are controlled

Restaurant and library/
This area also open to public and school area where the insect and ecosystem information is also stored in book format.



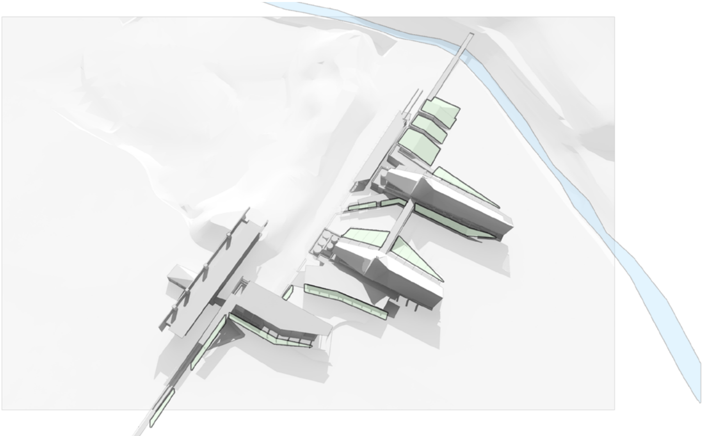
ECO-MACHINE /
This nursery is for the establishment of healthy growth for the plants that is required to clean the wast water from the facility

RESEARCH LABS/
The first floor rooms is allocated for the study of insects as part of the ecosystem services

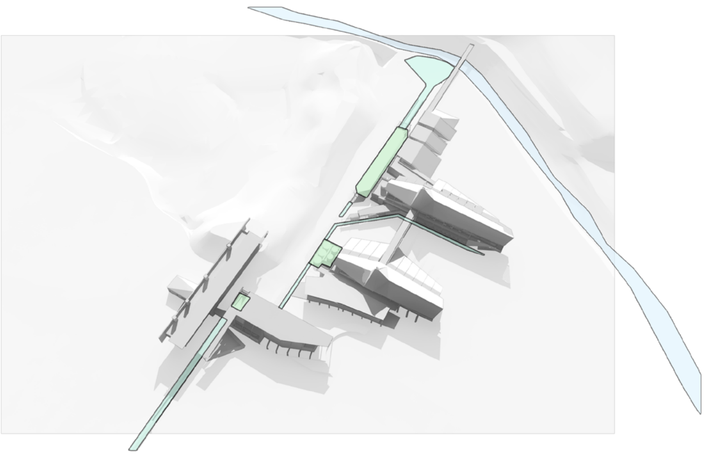
STORAGE WAREHOUSE/
This ground floor level is for the storage of all equipment used on site, special allocation for chemical storage.

WORKSHOP/
This area is allocated for unload and loading of deliveries. It also serves as a workshop for site equipment and fixing of facility equipment

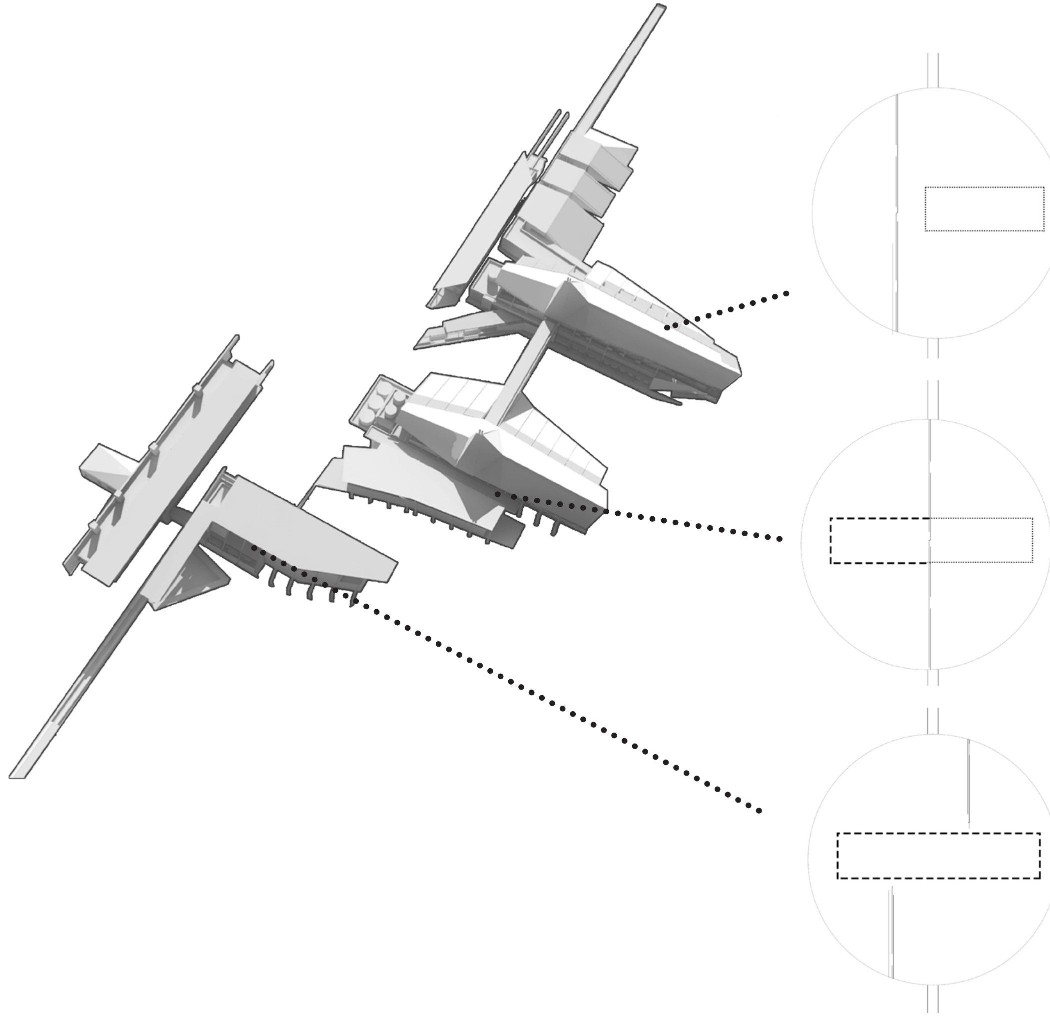
9.37_ Program Building zoning (Author, 2015)



3D EXPLORATION/ RECIPROCAL ELEMENTS



3D EXPLORATION/ WATER SYSTEM



9.38_ Program Building zoning (Author, 2015)

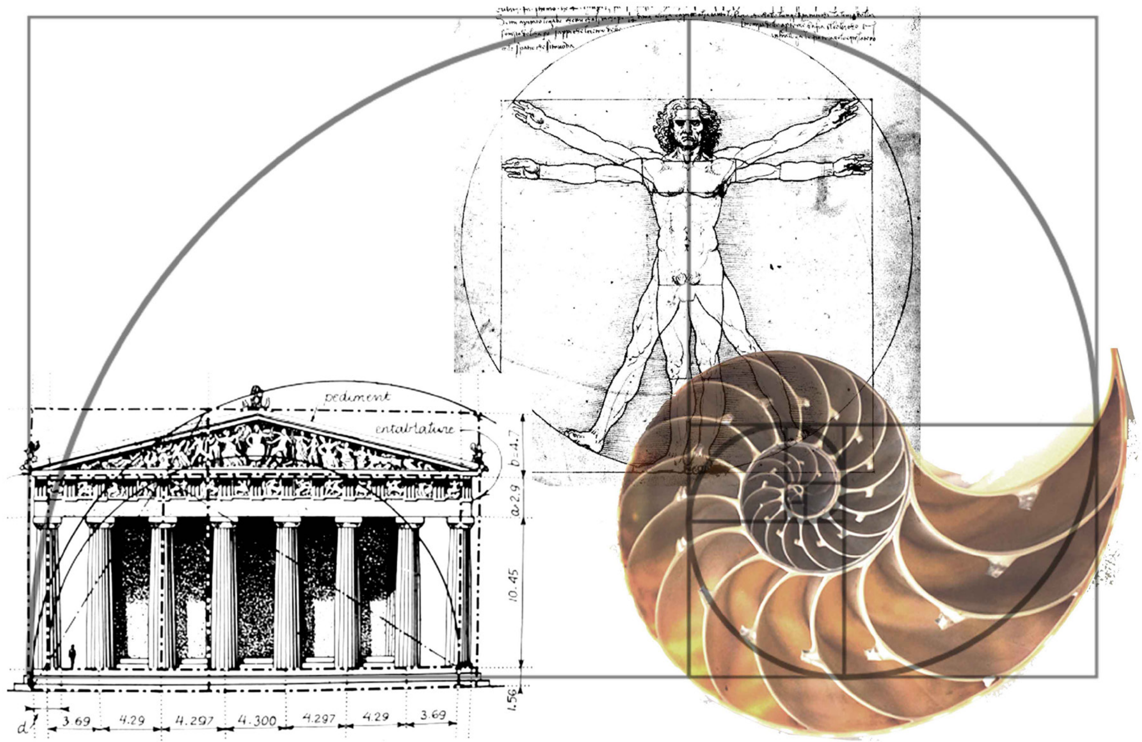
10/TECHNICAL DEVELOPMENT

TECHNICAL

10 / TECHNICAL DEVELOPMENT

10.1 / INTRODUCTION

The design of form; creation of space; and technical resolution are inseparable, accordingly the search for a relationship between man, nature and building is evident in the concept of this dissertation. This chapter is a continuation of the design process on a detailed level. The purpose of this chapter is not to produce contract documentation, but rather to communicate the development of tectonic ideas. Tectonic development explores the potential of creating new ways to deal with structure, materials, technology, and construction details in order to convey the concept and meaning.



10.1_ The relationship between man, building and nature can also be translated to a detailed level.
(http://www.soulsofdistortion.nl/images/vitruvia1.jpg, http://miguelmartindesign.com/blog/wp-content/uploads/2011/01/figure7.jpg, edited by author, 2015)

10.2_ Constructed insect habitats always provide holes or cracks that create shelter for the insects (http://www.inspirationgreen.com/insect-habitats.html, edited by author, 2015)

10.2 / INFORMANTS

10.2.1
THEORY /

Regenerative theory proposes that humans and nature co-exist in a mutually beneficial relationship. This theory can be adapted by applying Steward Brand's 6 'S' approach to building, thus not only creating materials and details that respond to the environment but also creating space in the building for nature to grow. This can be achieved in the technical resolution by developing multi-functional building elements; re-using the existing materials found on site; and enhancing the existing environment by adding new ecosystems.

10.2.2
NATURE /

The informants that influenced the design of the technical solution can be narrowed down to climatic factors; insects (pollinators and their habitats); flora (plants and flowers); the living wall as an extension of the urban vision; and the humans who inhabit the building

10.3_ Diagram illustrating the tectonic approach to the building, the building emerging from nature (Author, 2015)

10.2.3
THE LIVING WALL /

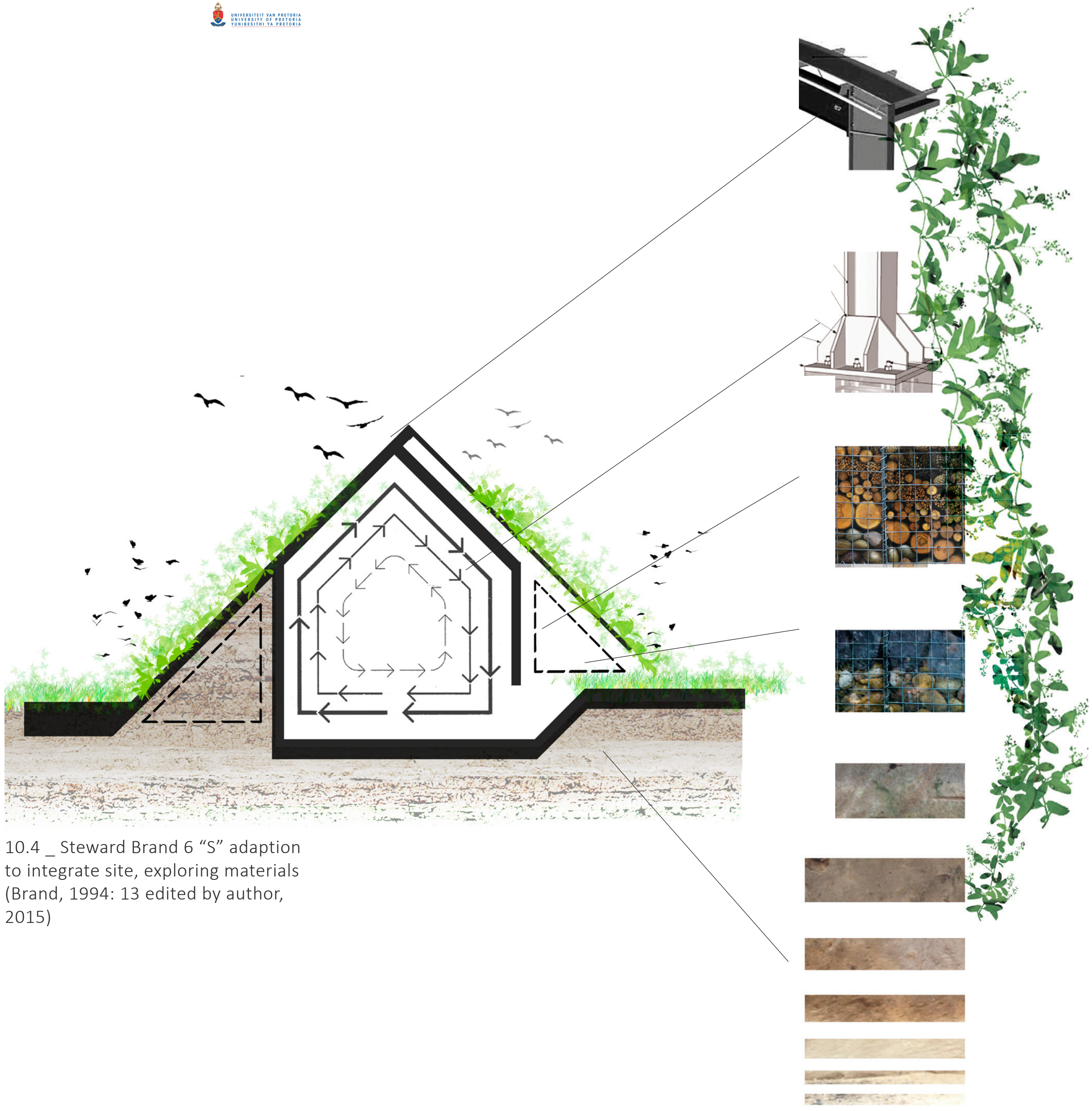
The Water channel that intersects the site forms a strong axis along which the buildings on site are organized; it informed the technical solution. One of the water channel's purposes is to filter the building's waste- and rain water, therefore qualifying it as an element separate from the rest of the buildings.

The living wall consists of recycled bricks and wood found on site. These materials were chosen for their reaction with water, seeing as the living wall represents the water collection and the filtration process.
The wall will eventually form part of the buildings along with a welded wire mesh to hold the creeper plants that grow on the façade. When the water channel reaches the end of the site, where it disgorges water into the river, the materials change to gabion walls to become more integrated with the environment and fade into the site.

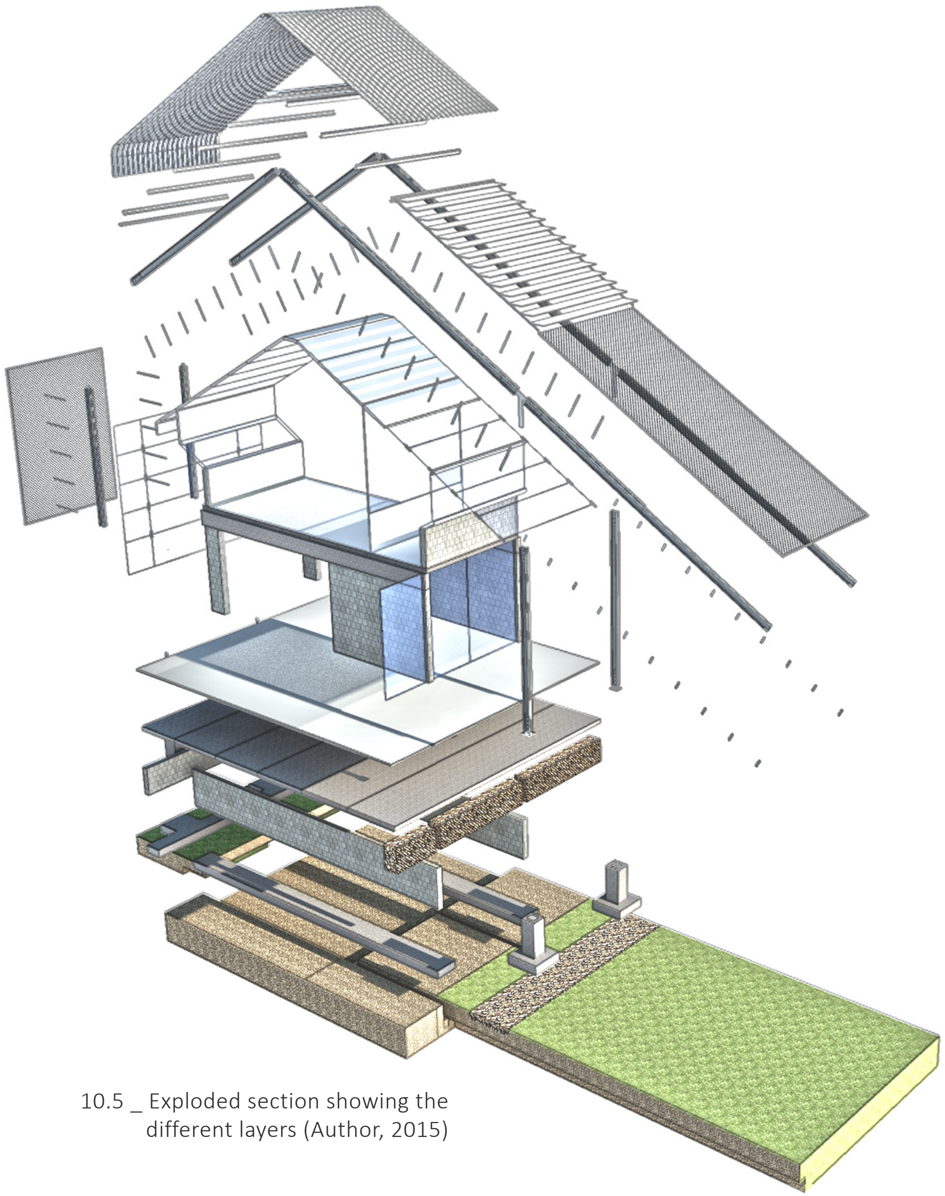
10.3 / CONCEPT

The change in building forms is based on the concept of progression into nature, which is reflected in the construction of the building. The construction highlights the transition between different materials by separating the materials with only a small link to connect them.

The concept formed by the informants, can be captured in one diagram, which is an adaption of Steward Brand's 6 'S' principles. Here 'site' is added to 'structure', which formulate the 'skin' and 'services'. They are combined in the single element of the building envelope, where the structure responds to the environment. The concept can thus be illustrated as a release into nature; the building becomes part of the environment. From the conclusion of the eco-mapping, it is clear that the site consists for the most part of grasslands with only the hill and trees to provide habitats for the insects. Therefore, insect habitats had to be created in the building envelope. The insect habitats become part of the building envelope and the theory is reflected that a relationship between man and nature must be established.



10.4 _ Steward Brand 6 "S" adaption to integrate site, exploring materials (Brand, 1994: 13 edited by author, 2015)



10.5 _ Exploded section showing the different layers (Author, 2015)

10.4 / MATERIALS

10.4.1
MATERIALS DECISIONS /

The materials generated for the material palette are based on the concept of progression into nature. The material palette is divided between the living wall and the building.

Living wall / The material used for the living wall is bricks from the demolished buildings on the site. The bricks are staggered on top of each other with gaps between them to create habitats for the insects and plants to grow. The bricks will be in contact with water, so naturally moss and algae will grow to add to the ecosystems and provide nutrition for the insects.

The Building / The building will be in contrast with the living wall; therefore, instead of clay bricks, a combination of concrete bricks will be used for infill. The combination of steel frames and welded wire mesh panels for the plants create a lightweight effect. A reinforced concrete base is used to anchor the building to the ground and help illustrate the progression into nature. As the ground surface should always be permeable to allow water to seep through the soil, gaps between walkways and water channels on the side of the building is an appropriate response.

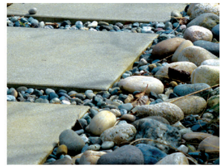
10.4.2
MATERIALS PALETTE /

MATERIALITY OF FLOOR SURFACES / Transition towards building


Planted flowers

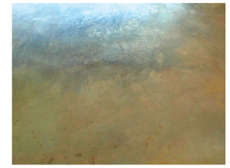

On site Grass


Grass between Concrete slabs

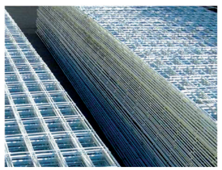

Rocks between Concrete slabs

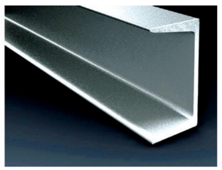

Gabion walls held together by welded wire mesh


Precast concrete slabs

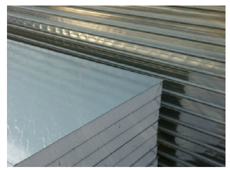

Power floated concret floor in-situ

MATERIALITY OF WALL ENVELOPE / Transition towards building

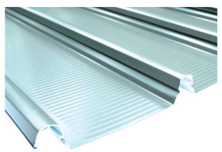

Welded wire mesh

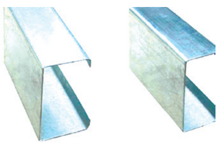

Taper flange C channel profile

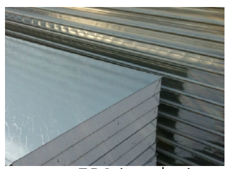

Concrete blocks


EPS insulation; galvanised metal skin

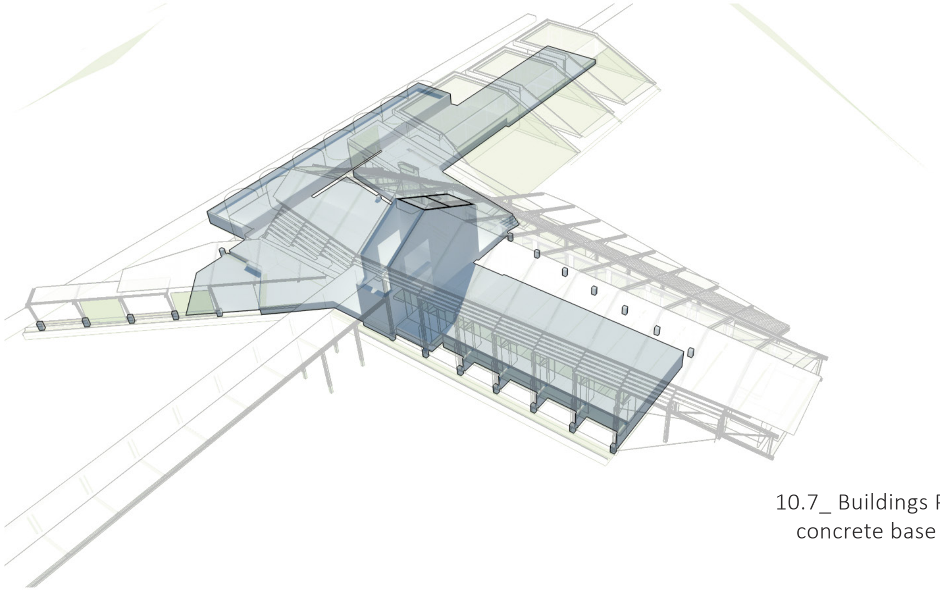
MATERIALITY OF ROOF


Concealed fix klip-lok roof sheeting

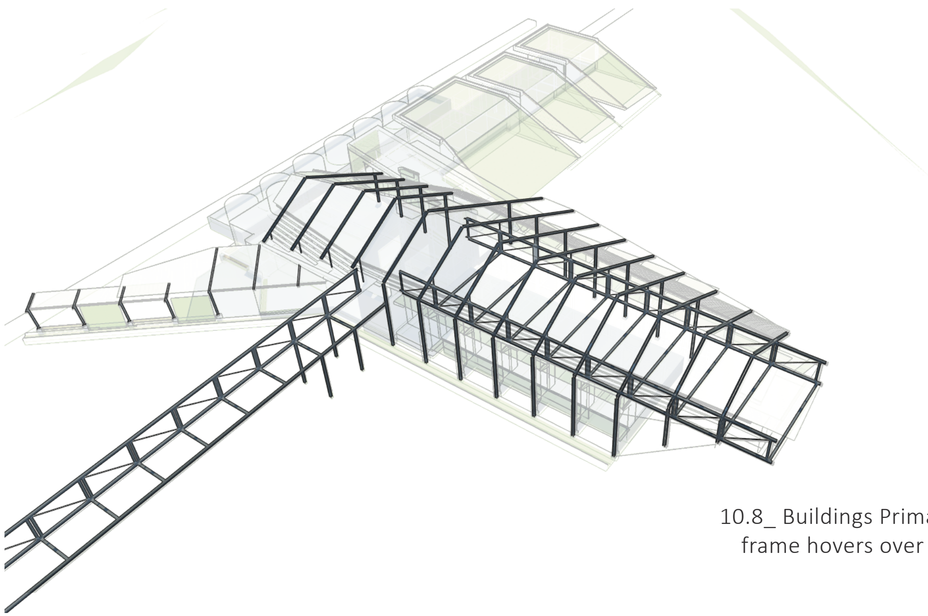

Purlin; Steel lipped C- channel


EPS insulation; galvanised metal skin

10.6 _ Material palette (Author, 2015)



10.7_ Buildings Primary structure; concrete base acts as an anchor (Author, 2015)



10.8_ Buildings Primary structure; Steel frame hovers over site (Author, 2015)

10.5 / STRUCTURE

10.5.1
PRIMARY STRUCTURE /

The primary structure is the skeleton of the building that holds everything together. It starts from the living wall, as a concrete base anchored in the ground, and is then lifted from the ground, becoming a more lightweight frame.
The lightweight frame consists of a combination of steel channels and spacers. It holds water downpipes and services for the building. A vierendeel structure also forms part of the primary structure as it holds the first floor and permits it to cantilever above the ground, allowing the natural flow of water and ecosystems to continue on the site. Both primary structures are constructed of hot formed steel members with a heavy concrete base.

10..2
SECONDARY STRUCTURE /

The secondary structure supports the cladding and roof of the building. Apart from the steel vierendeel structure, the materials used are light steel frame materials (LSF) which consists of panels fixed onto the concrete floor with cold rolled steel C-channels, filled with insulation and fixed with treated wood panels.

10.6 / ENVIRONMENTAL CONSIDERATION

10.6.1

CLIMATE /

The site allows for the building to be orientated north. Even with minimal existing shade on the site, the building itself should be well screened in summer.

Climatic factors were considered to create a comfortable habitable space inside the building. The placement of green screens on the northern façade with sunshades at correct angles prevents direct sunlight from entering the building. The insect habitats also require different climatic conditions, which the building can provide. The southern side of the building is shaded and mounds beside the building allow for beetles to burrow their holes in the soil. The northern side is mostly sunny with creepers allowing butterflies to create homes underneath the leaves.

Diagram 1; illustrations of climatic factors

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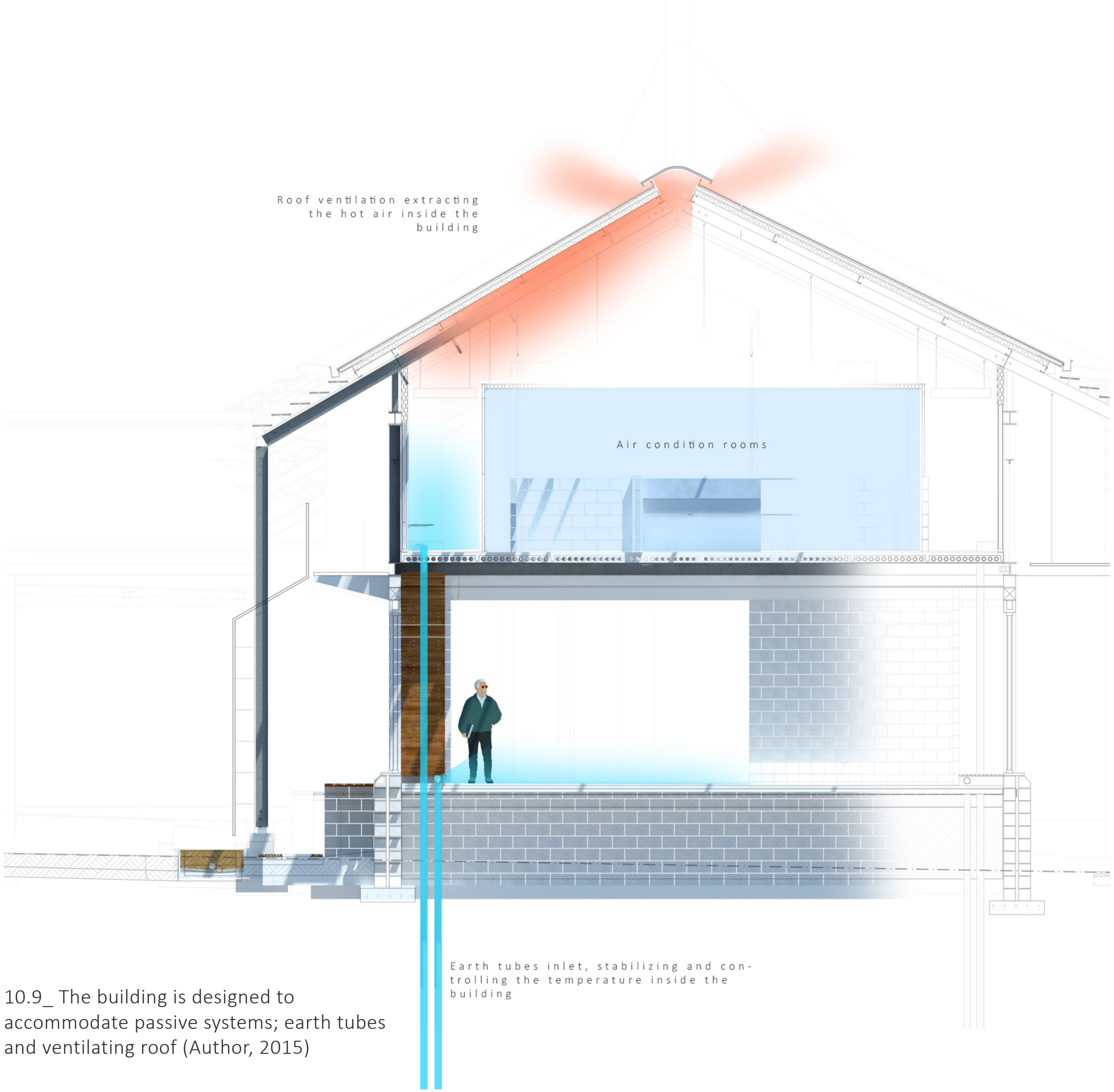
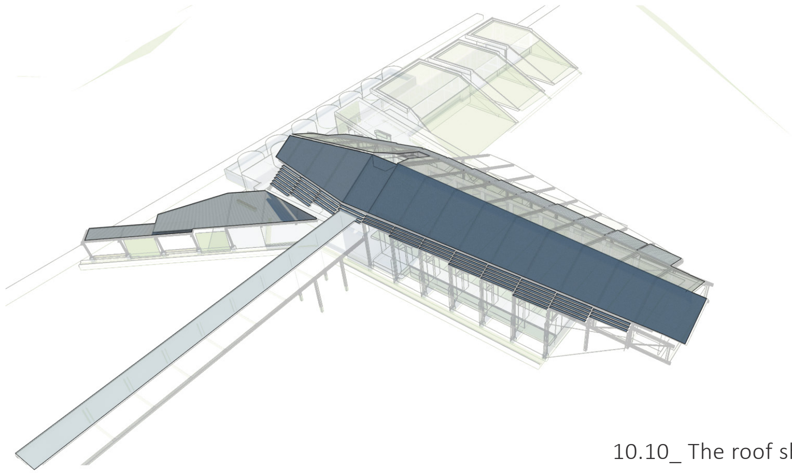
10.6.2

EARTH TUBES /

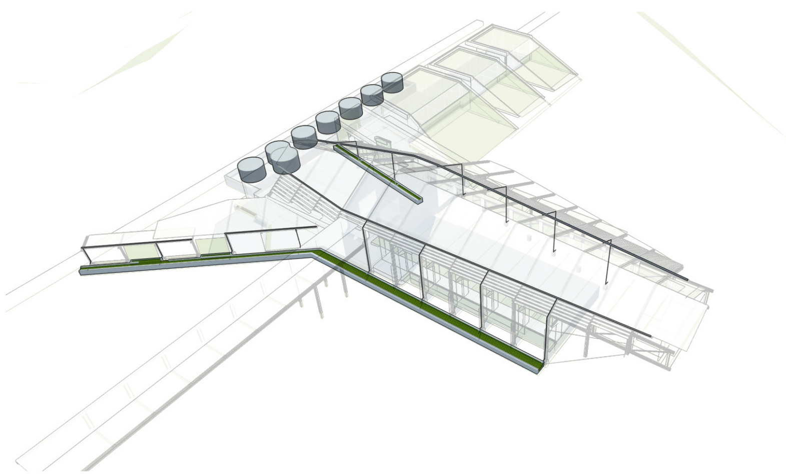
The ground floor of the building mostly consists of open-plan offices, which are ventilated through strategically placed louvered windows that can be adjusted by the occupants of the space. The temperature inside the building is controlled through the use of earth tubes that run 3 meters under the soil, where the temperature stabilizes (what is the temp.?). The tubes enter the building at the ground and first floor with the assistance of fans powered by photovoltaic panels. The stabilized air entering the rooms controls the temperature inside the building. The heat gathered inside the building is extracted through a ventilated roof and solar chimney assisted stack.



10.9_ The building is designed to accommodate passive systems; earth tubes and ventilating roof (Author, 2015)



10.10_ The roof shape allows the heat gathered in the building to rise(Author, 2015)



10.11_ Water collected from the roof is led to a central point (Author, 2015)

10.7 / TECHNOLOGY

10.7.1
FAÇADE /

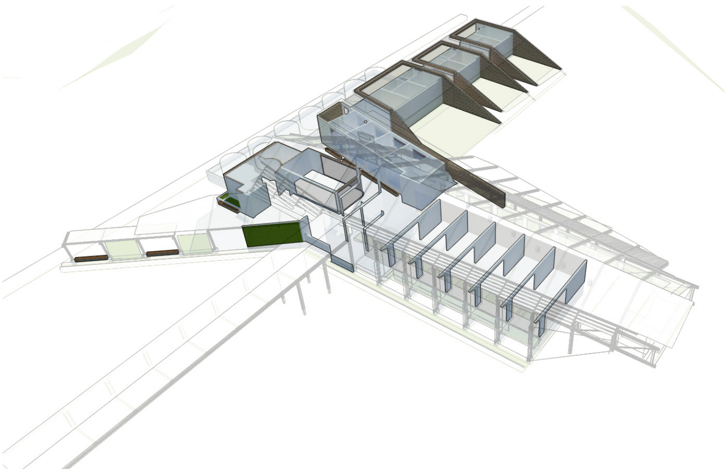
The façade of the building envelope represents the relationship between nature and the building. It is the welded wire mesh that allows the plants to grow on the façade. This green screen becomes the insect habitats and provides natural shade for the people inside the building during summer. It also creates a covered gathering space outside the building where occupants can enjoy the beauty that nature provides.

10.7.2
ROOF /

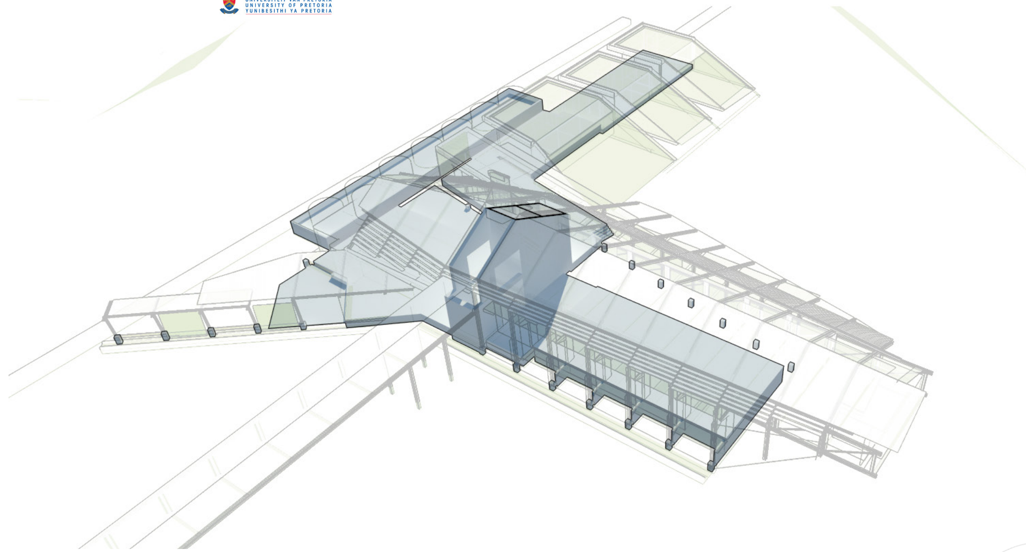
The roof is the sheltering envelope of the building. Its purpose is to protect the inhabitants of the building from weather, heat, wind and sunlight. It plays an important role in collecting rainwater and then distributing it to storage tanks. The roof form also allows the air that heats up inside the building to flow to the solar chimney.

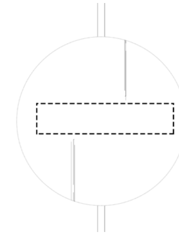
10.7.3
SERVICE /

The services needed in the building are the air-conditioning piping that enters the insect rooms and the extraction fans that exit the rooms. The extraction fans are located in the ceiling of the roof, but are held by a steel frame that suspends from the primary structure.

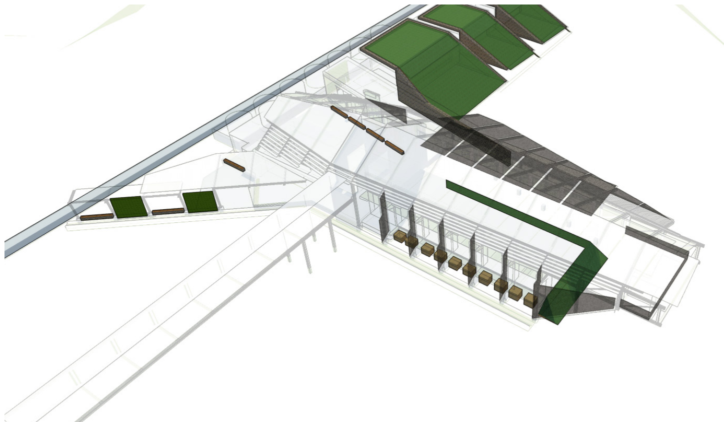


10.12_ The infill walls on the ground floor (Author, 2015)

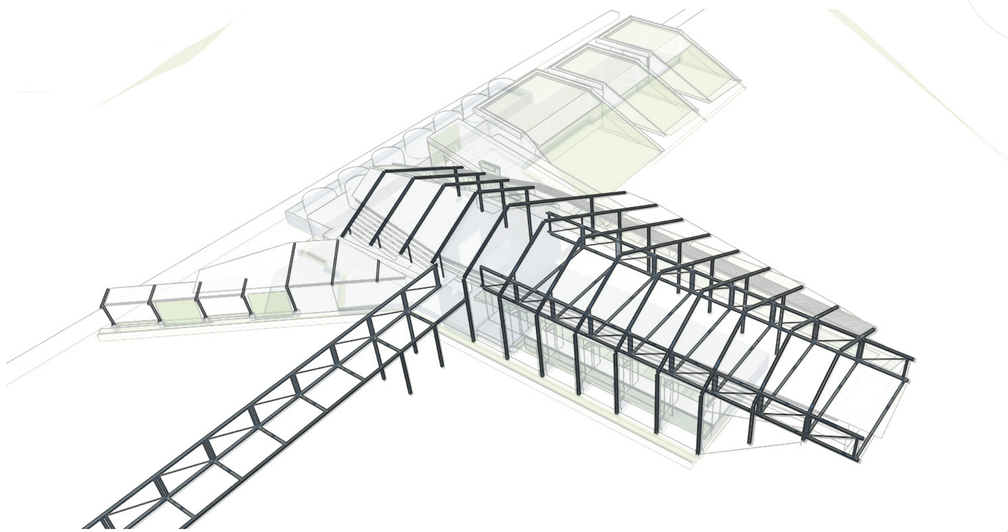


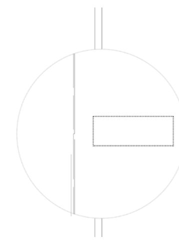


PRIMARY STRUCTURE SYSTEM /
The concrete base is the anchor of the building and intersects the environment



10.13_ Habitat spaces created inside and outside of the building (Author, 2015)

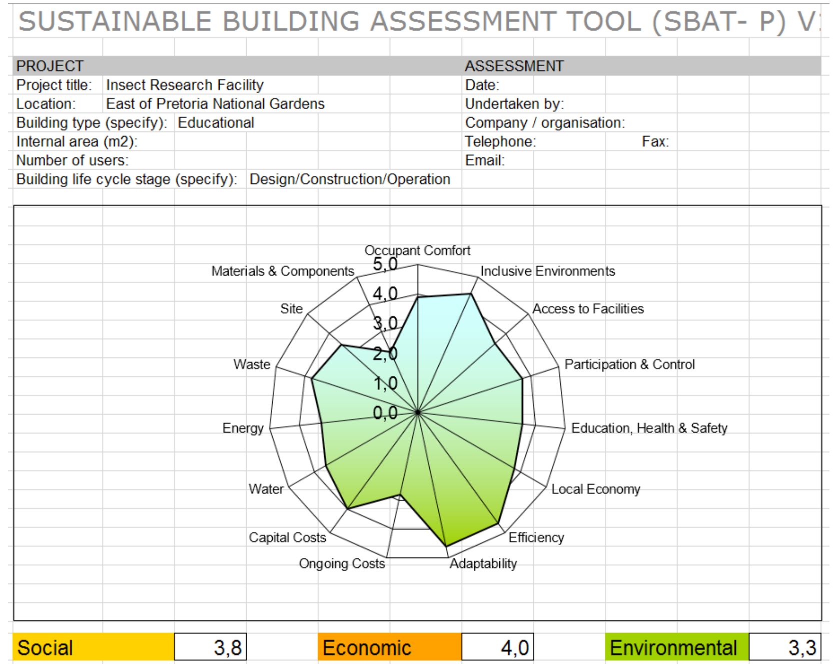




STEEL STRUCTURE /
The steel structure detatches itself from the concrete base the further it moves along north to the natural zone, it cantiliviers using the structural force of the lattace girder.

10.8 / SBAT PERFORMANCE

The SBAT analysis tool was used to rate the proposed architectural intervention.



10.14_ The SBAT analysis illustrates the proposed architectural interventions performance (Author, 2015)

10.9 / FINAL FLOOR PLANS

10.9.1
WATER CALCULATIONS

Hard surface collection in ZONE 1:
221 147m2

BUILDING 1:
Workers/12
Water Usage/12 x 5 = 60l per day
Roof Catchment/ 940.13m2

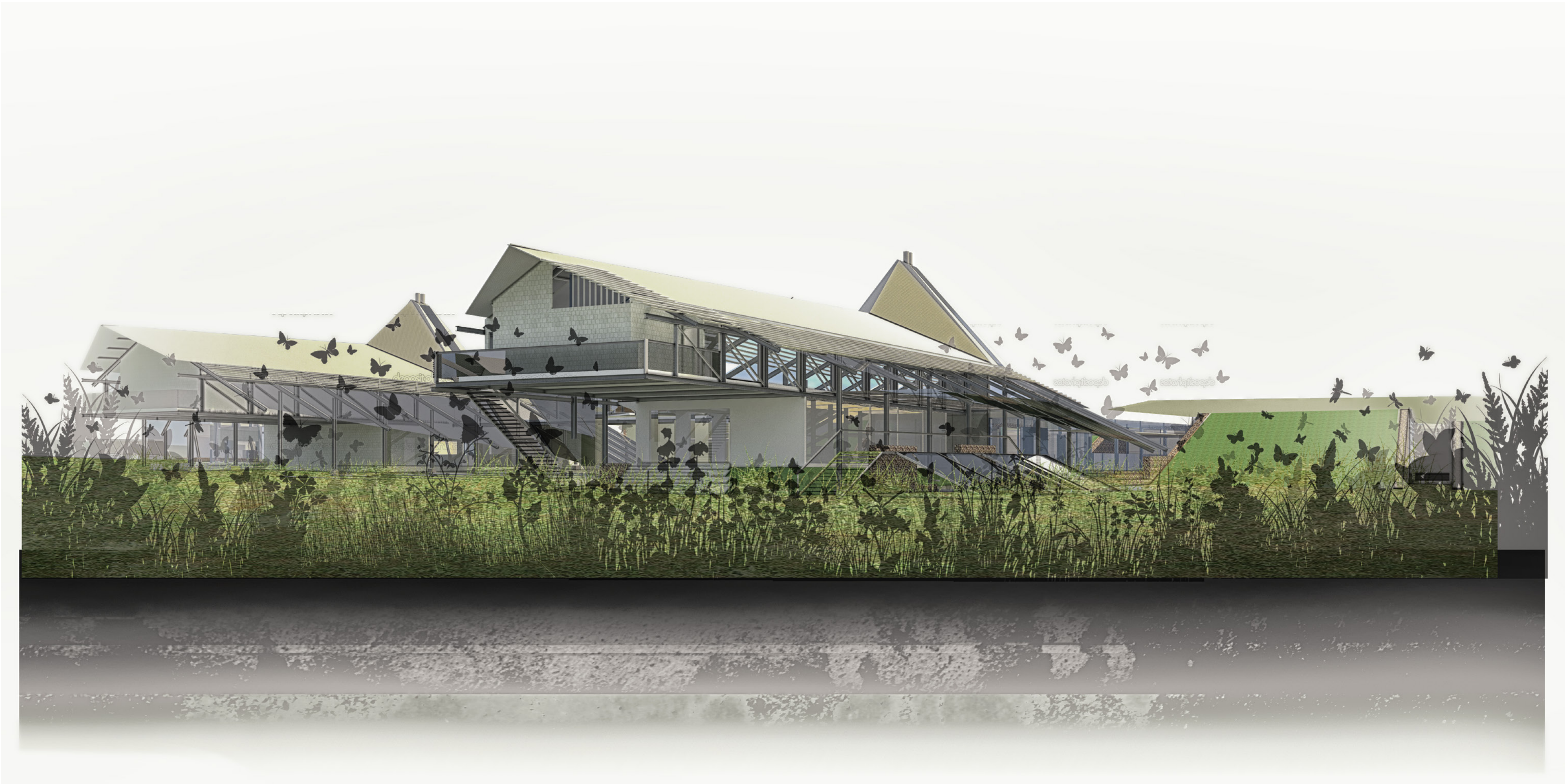
BUILDING 2:
Workers/15
Water Usage/12 x 5 = 75l per day
Roof Catchment/ 1 110.95m2

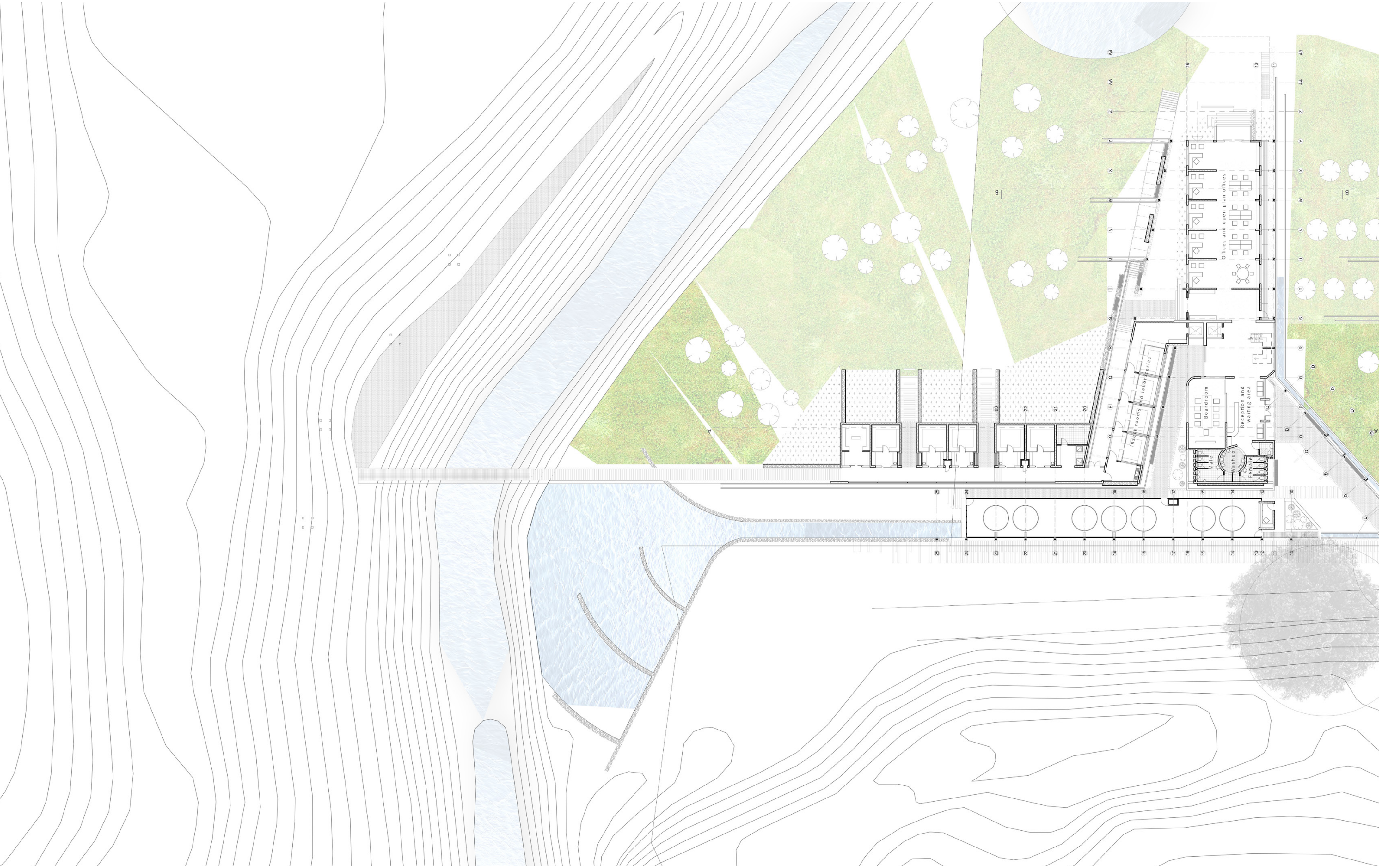
BUILDING 3:
Workers/40
Water Usage/12 x 5 = 200l per day
Roof Catchment/ 1 136.13m2

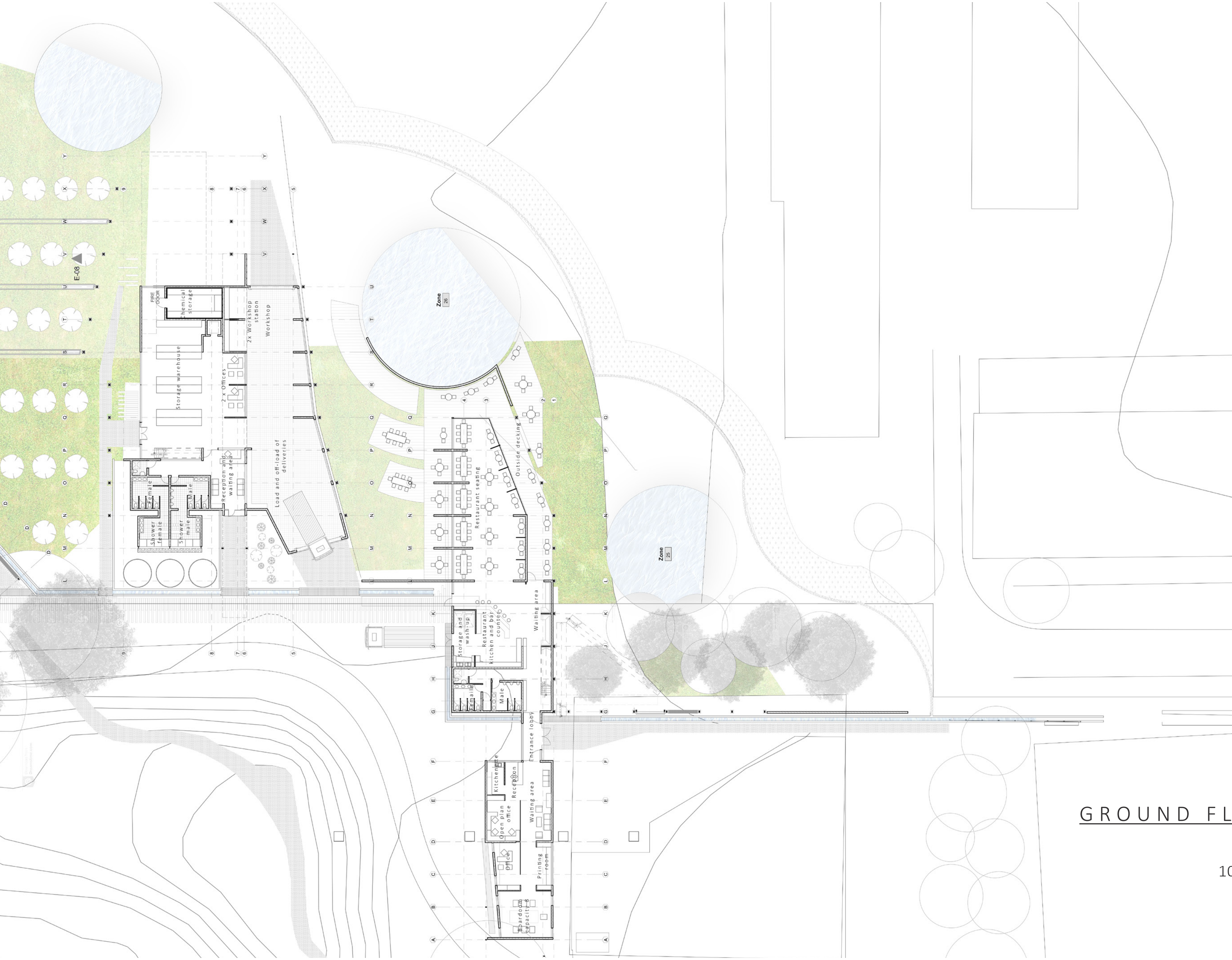
Water Storage/Water Ponds

A: V = 4.02 x 1011
B: V = 5.94 x 1011
C: V = 8.06 x 1011
D: V = 2.71 x 1012
E: V = 4.78 x 1011

10.15_ The water calculations of the macro site impacting the proposed site (Author, 2015)

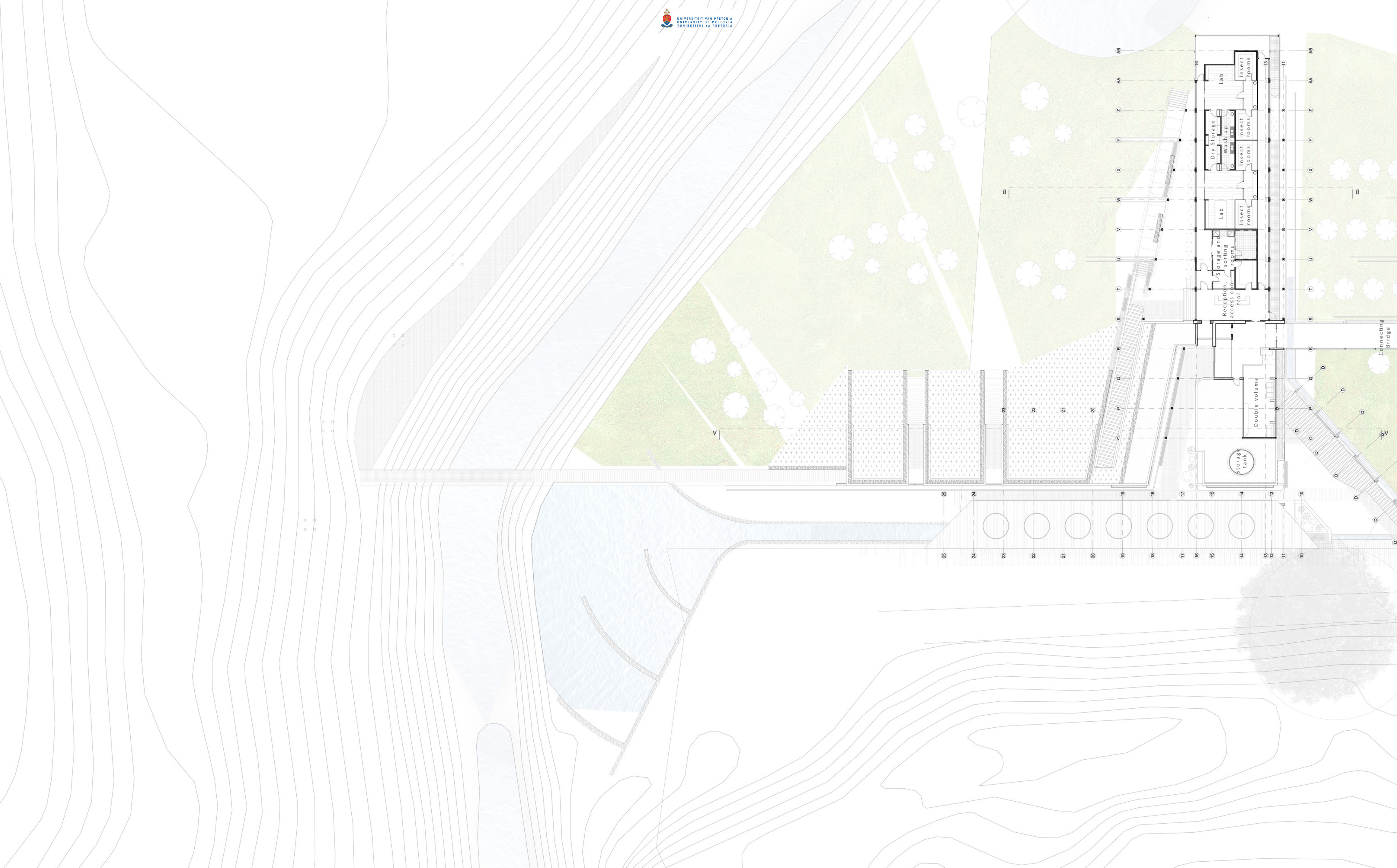



Offices and open plan offices
Insect rooms and laboratories
Boardroom
Reception and waiting area
Male
Washup



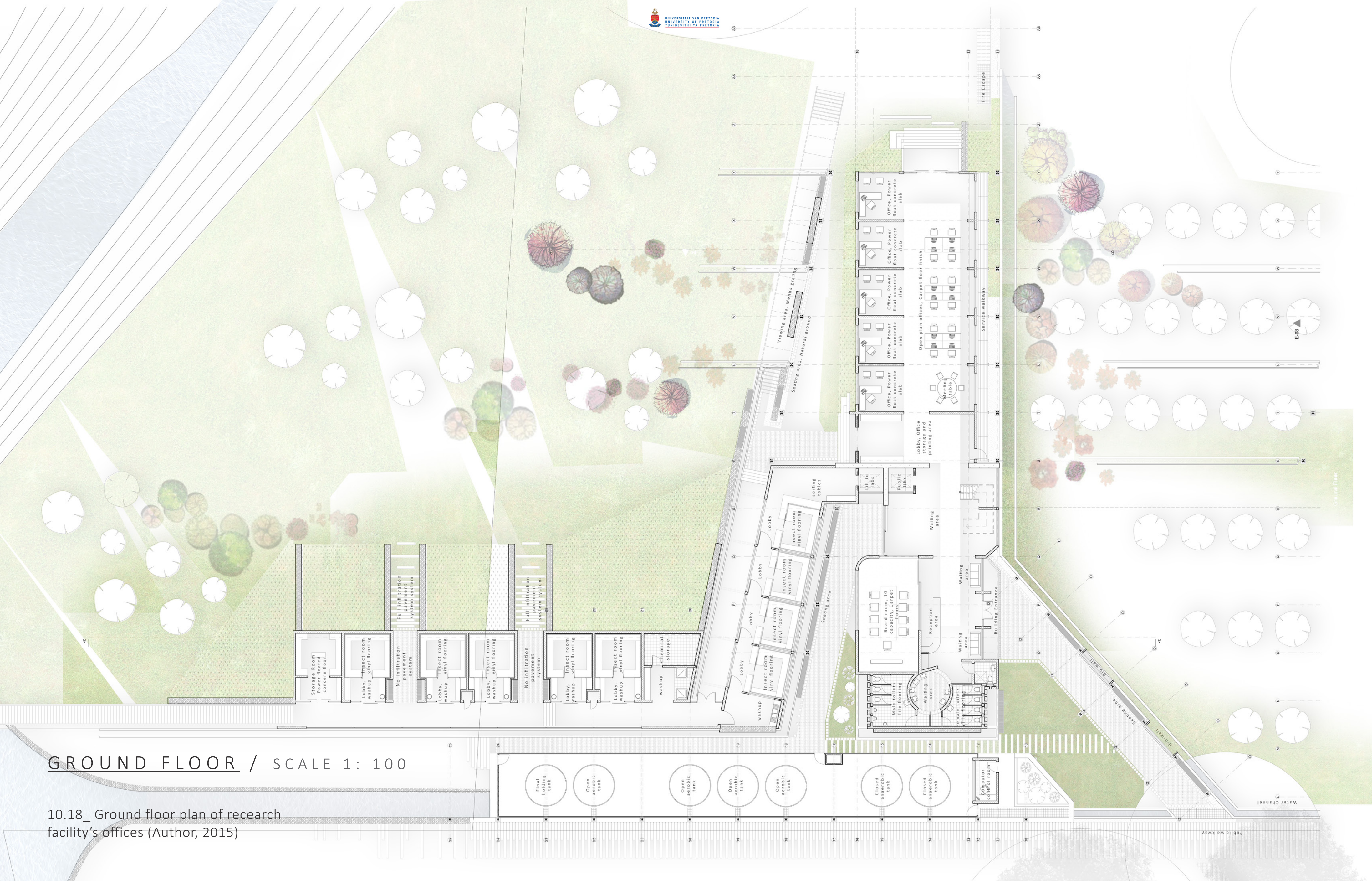
GROUND FLOOR / SCALE 1: 200

10.16_ Ground floor plan of recearch facility (Author, 2015)


Lab
Insect rooms
Dry Storage
Wash up
Insect rooms
Insect rooms
Lab
Insect rooms
Storage and sorting rooms
Reception, access control
Connecting Bridge
Double volume
Storage tank

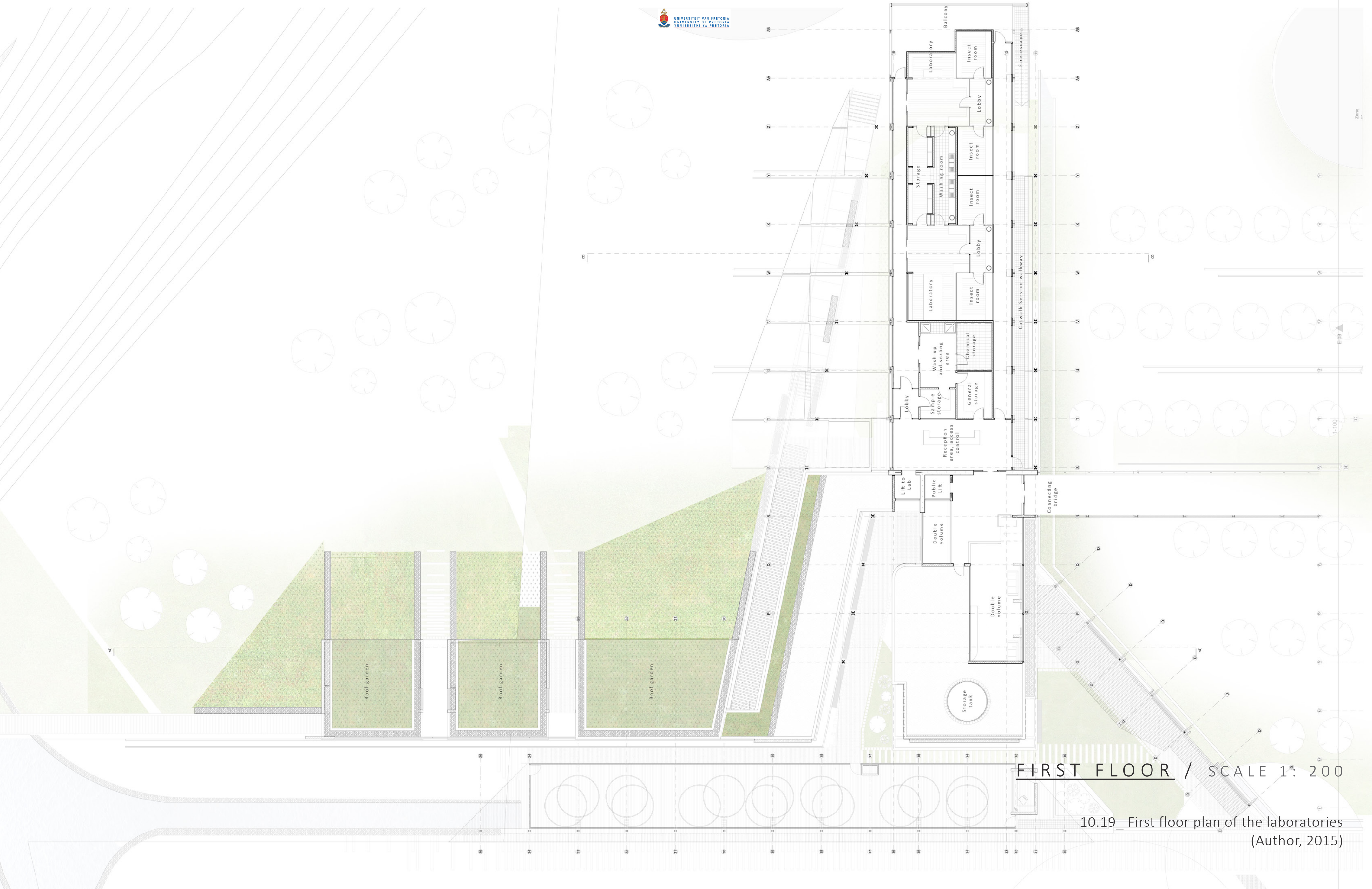
FIRST FLOOR / SCALE 1: 200

10.17_ First floor plan of recearch facility (Author, 2015)



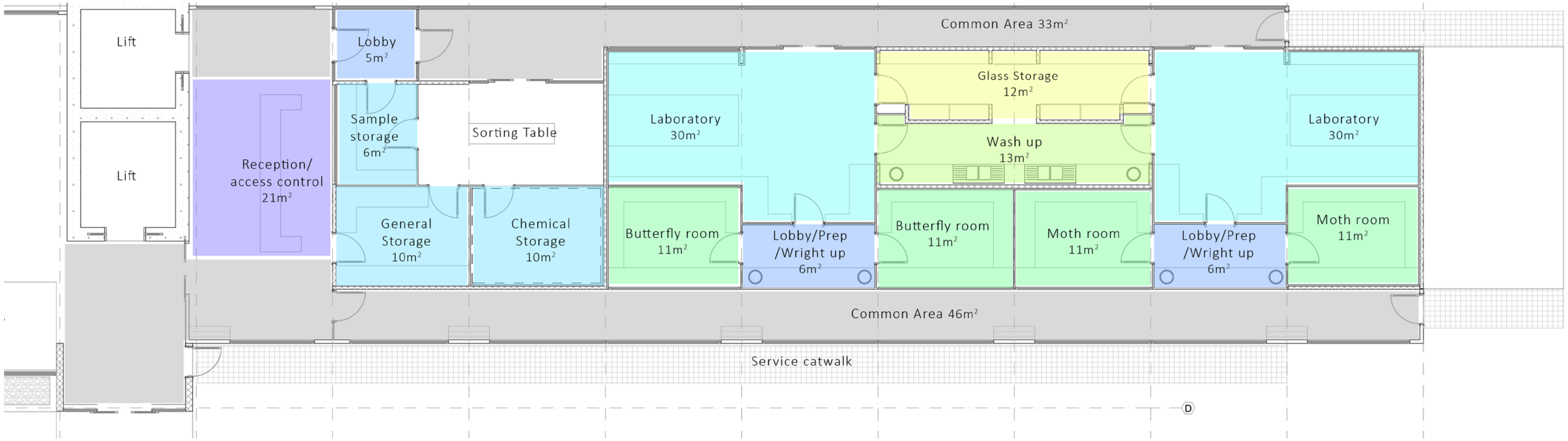
GROUND FLOOR / SCALE 1: 100

10.18_ Ground floor plan of recearch facility's offices (Author, 2015)

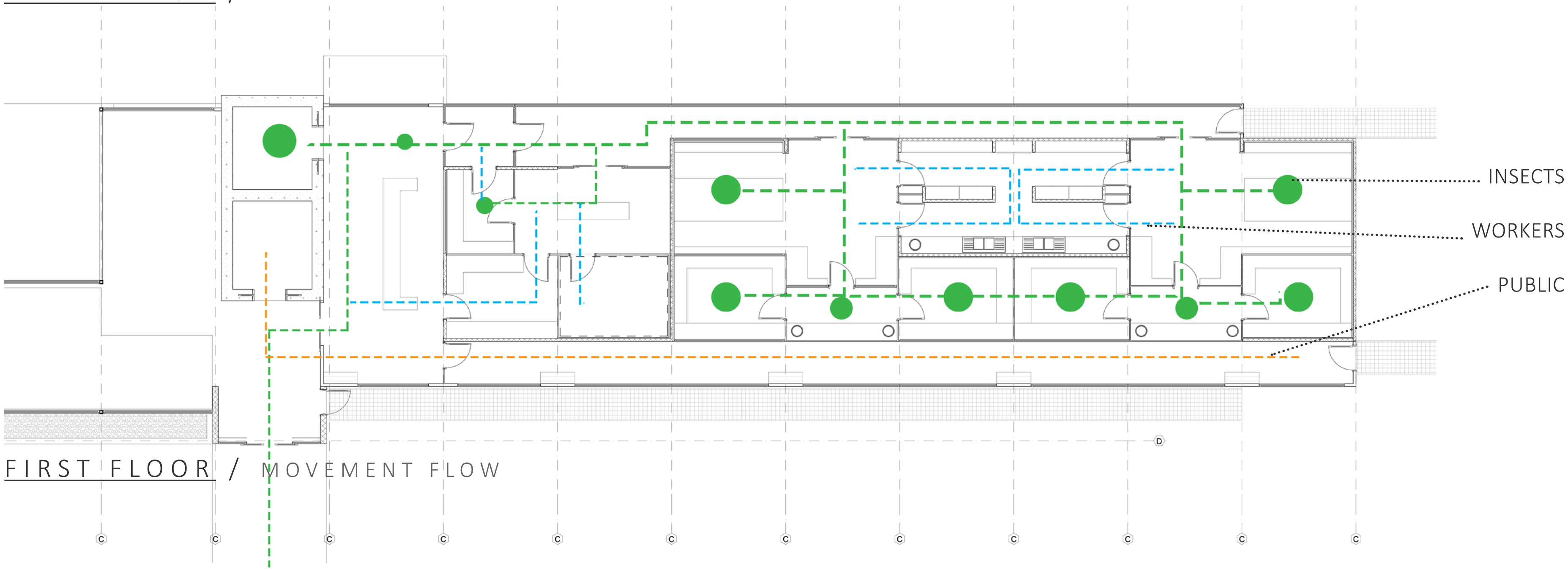


FIRST FLOOR / SCALE 1: 200

10.19_ First floor plan of the laboratories (Author, 2015)

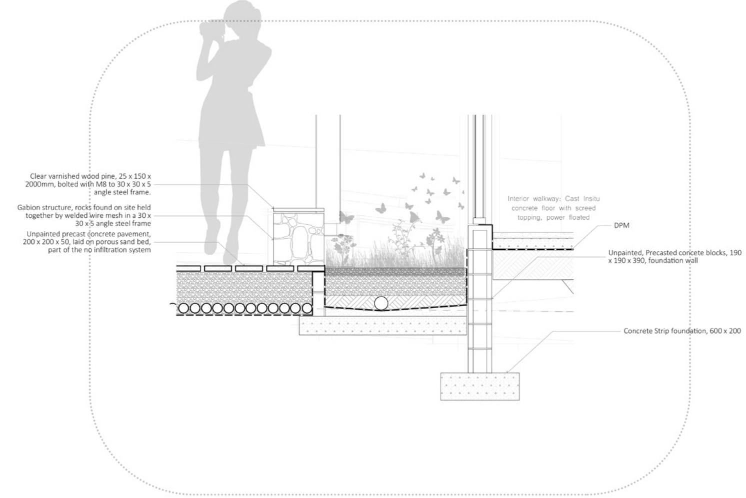


FIRST FLOOR / LABORATORY LAYOUT OF INSECT ROOMS

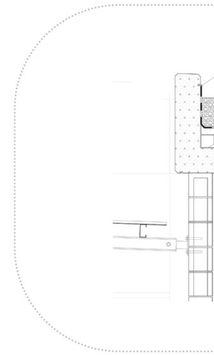


FIRST FLOOR / MOVEMENT FLOW

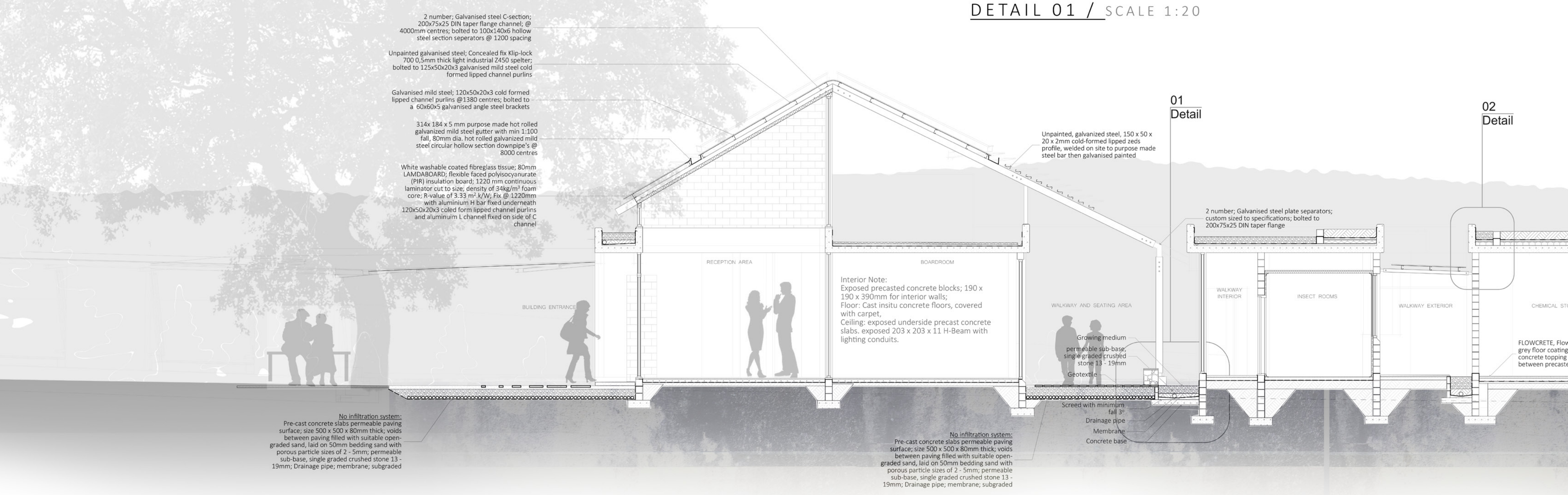
10.20_ Zoning plan (left) and the movement flow (right) of the First floor of Research building laboratories (Author, 2015)



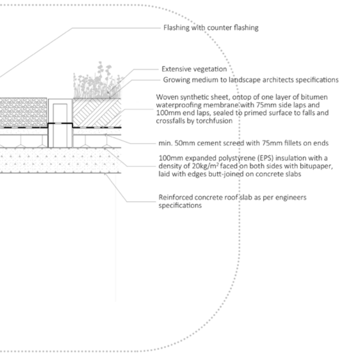
DETAIL 01 / SCALE 1:20



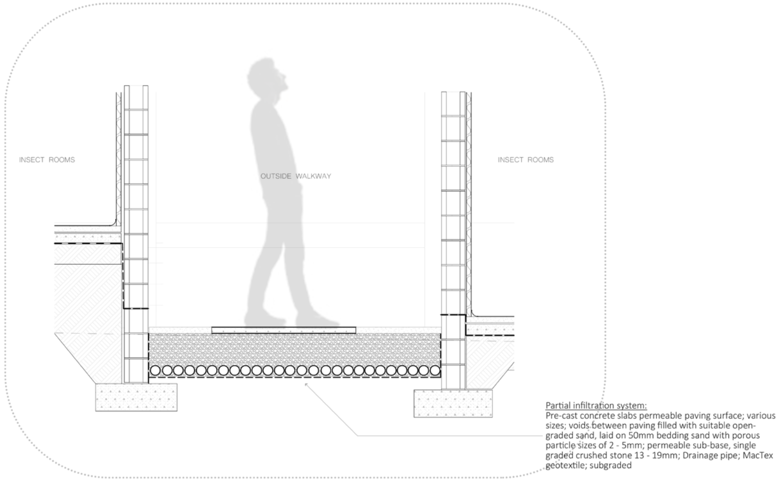
DETAIL 02



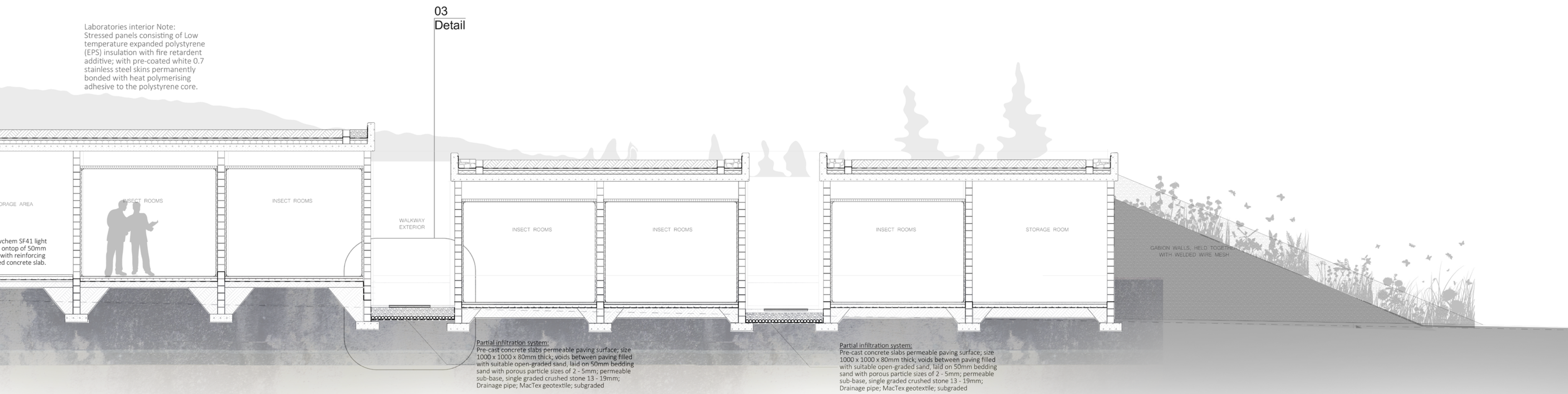
SECTION AA / SCALE 1 : 50



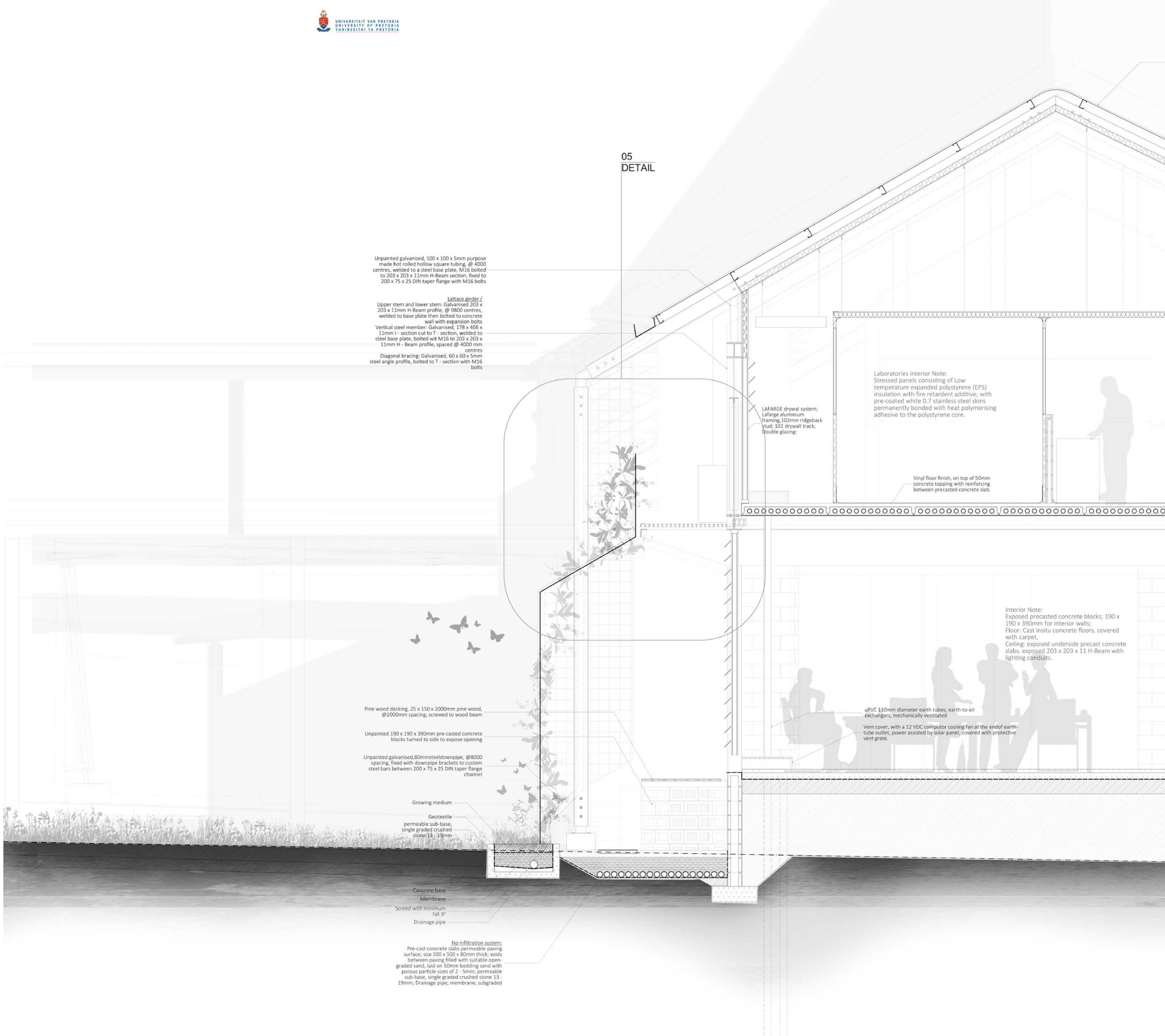
/ SCALE 1:20



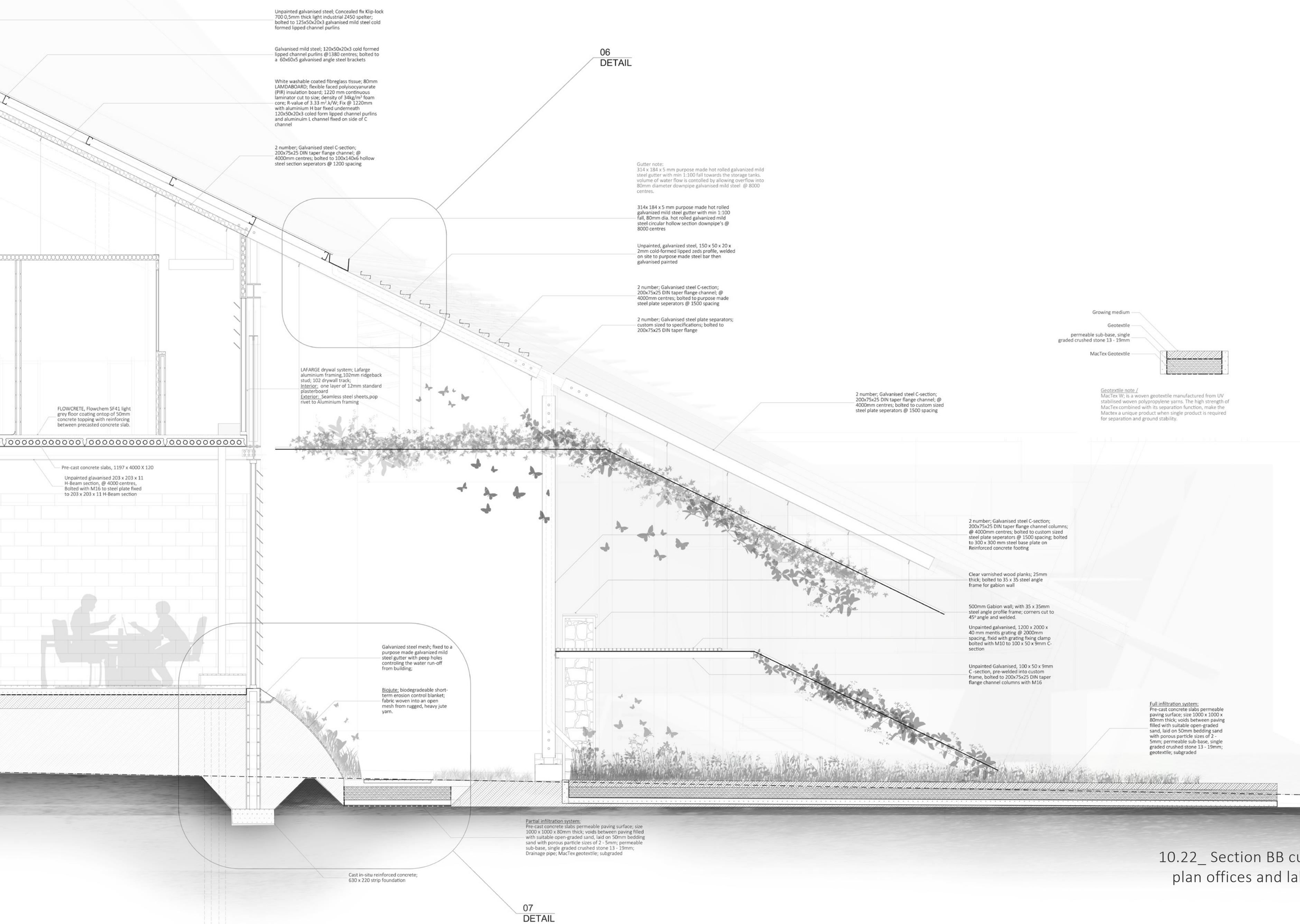
DETAIL 03 / SCALE 1:20



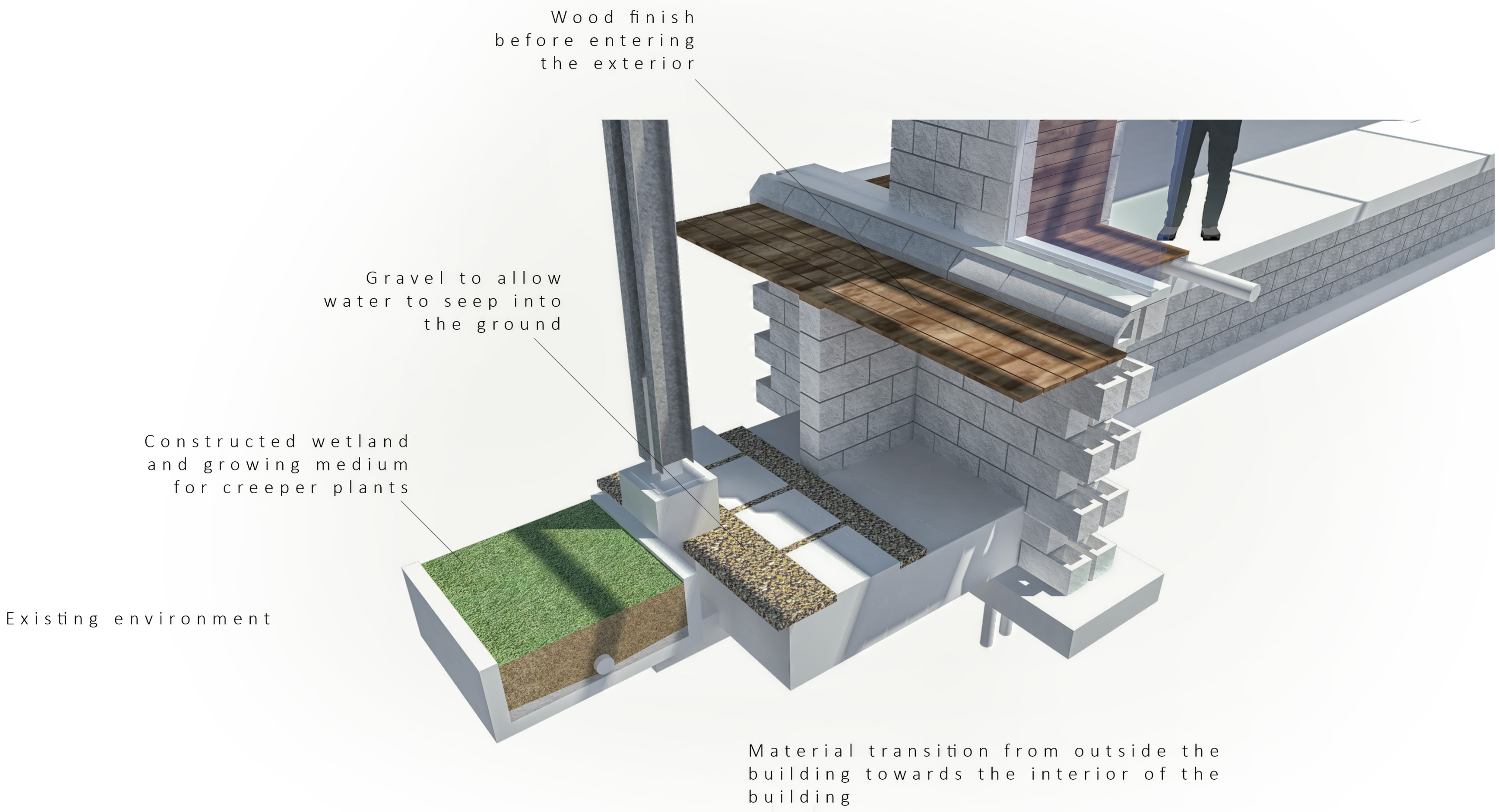
10.21_ Section AA cutting through the reception lobby to the end of the insect rooms (Author, 2015)



SECTION BB / SCALE 1 : 20



10.22_ Section BB cutting through the open plan offices and laboratory (Author, 2015)

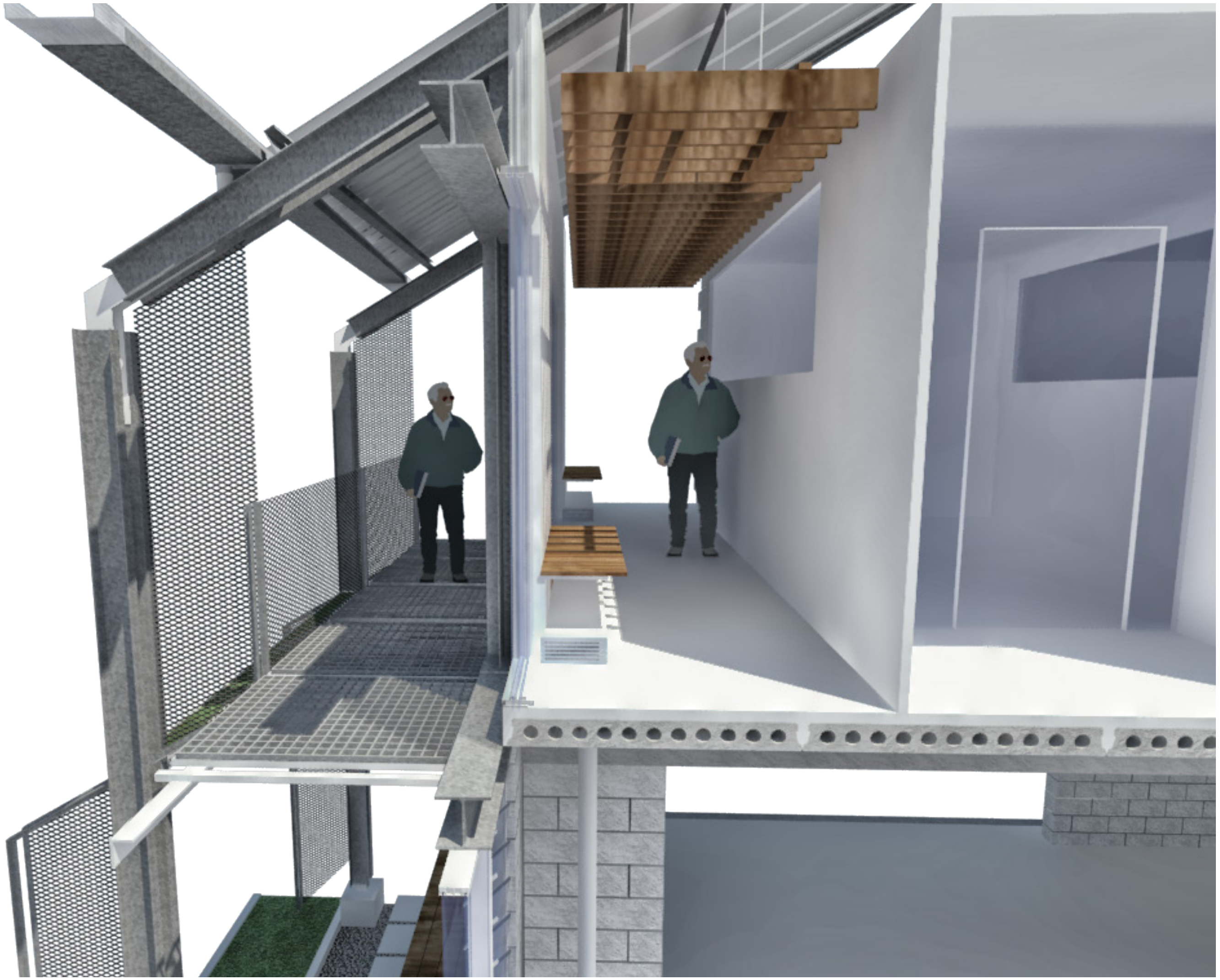


10.23_ 3D Detail of the transition from the exterior to the interior (Author, 2015)

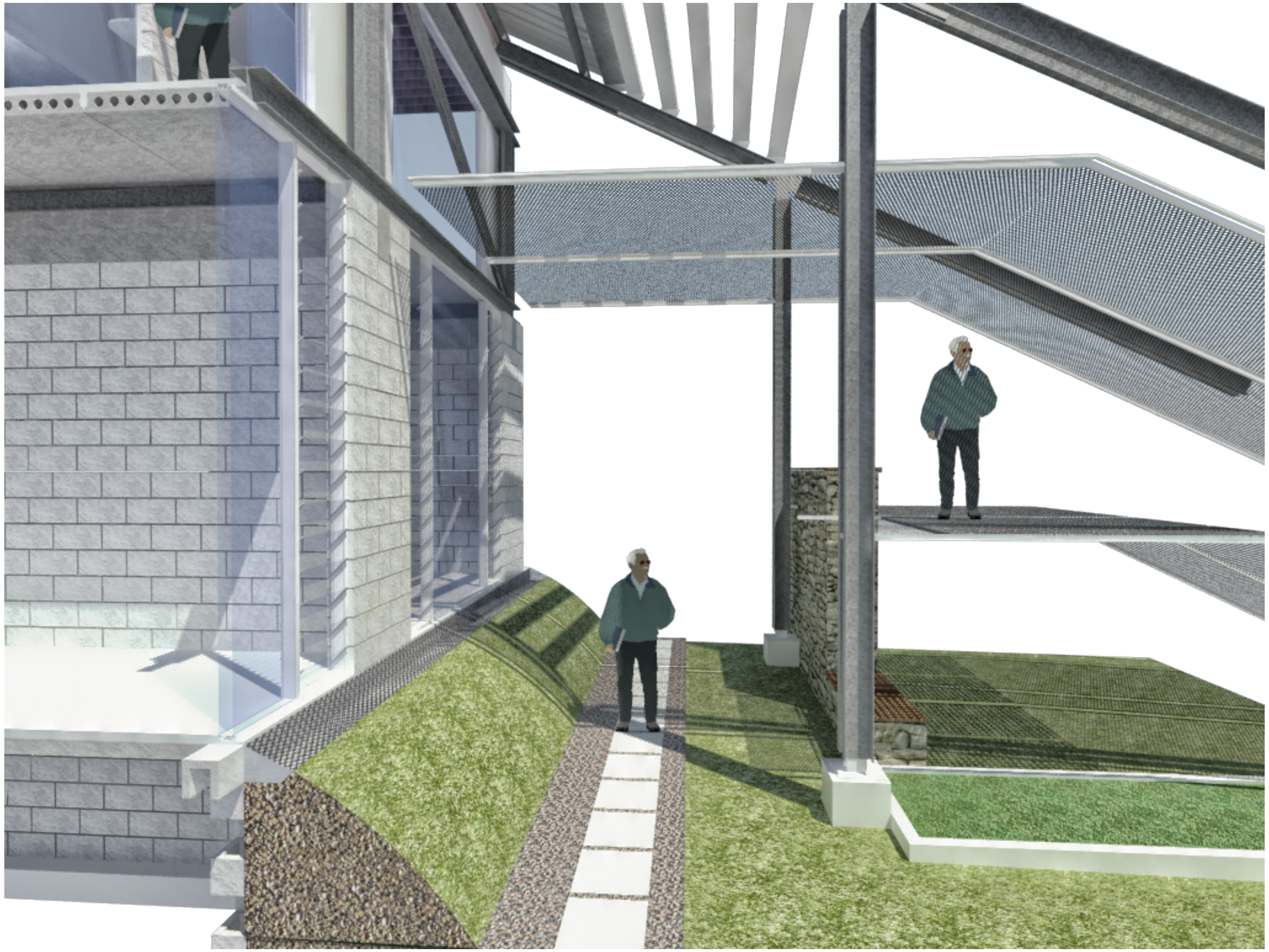
Creepers growing on the steel mesh on southern facade, provides habtats for insects

Insect Hotel, consisting of pallets and rubble creating holes and gaps for insects to populate, cool and shaded space for burrowing insects

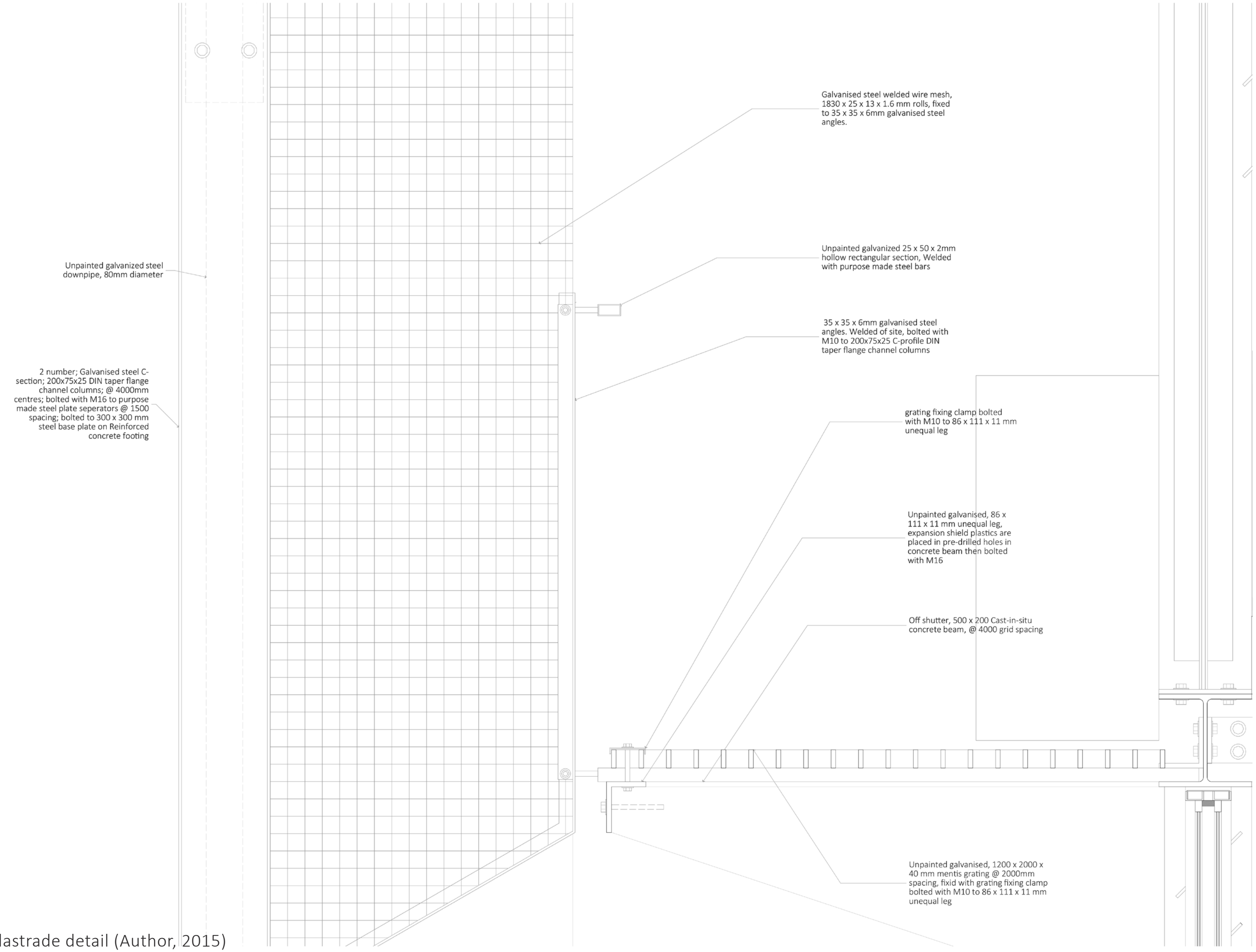
10.24_ The insect habitats on the southern condition of the building (Author, 2015)



10.25_ 3D Detail of the inside and outside space on the southern condition. The exterior being a service space and interior being viewing space (Author, 2015)

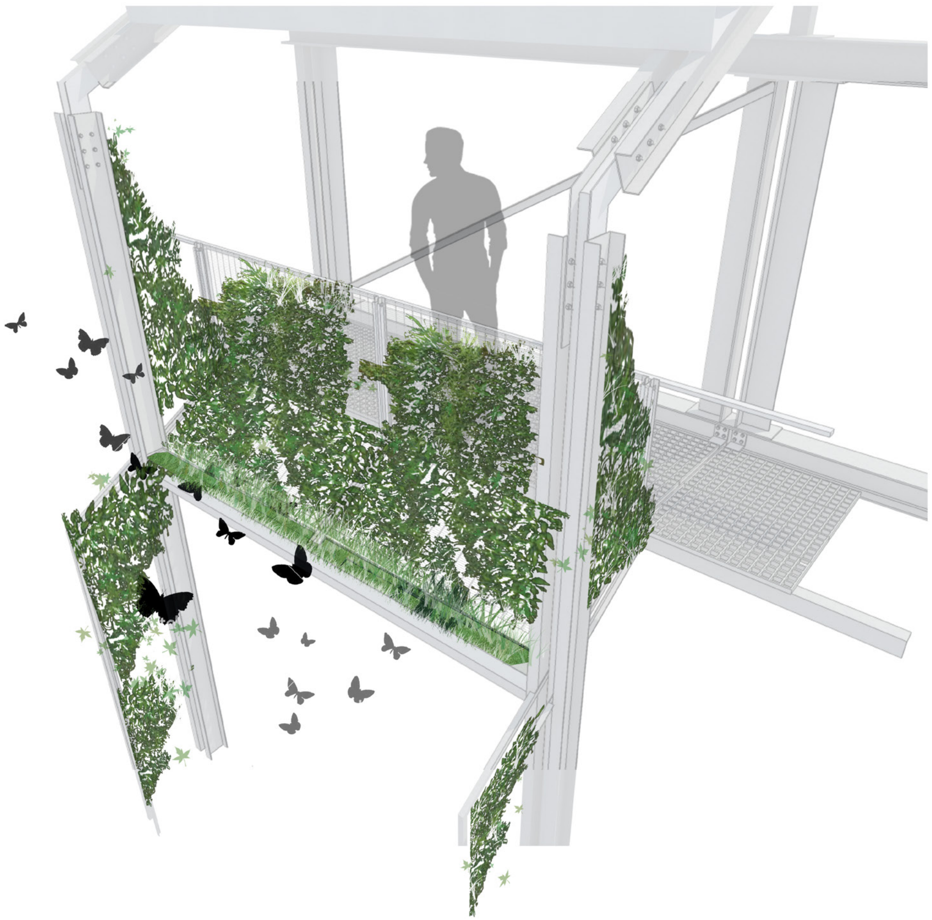


10.26_ Spaces created on the northern condition of the building for humans and insects. Steel mesh for plant creepers, creating shade for people (Author, 2015)

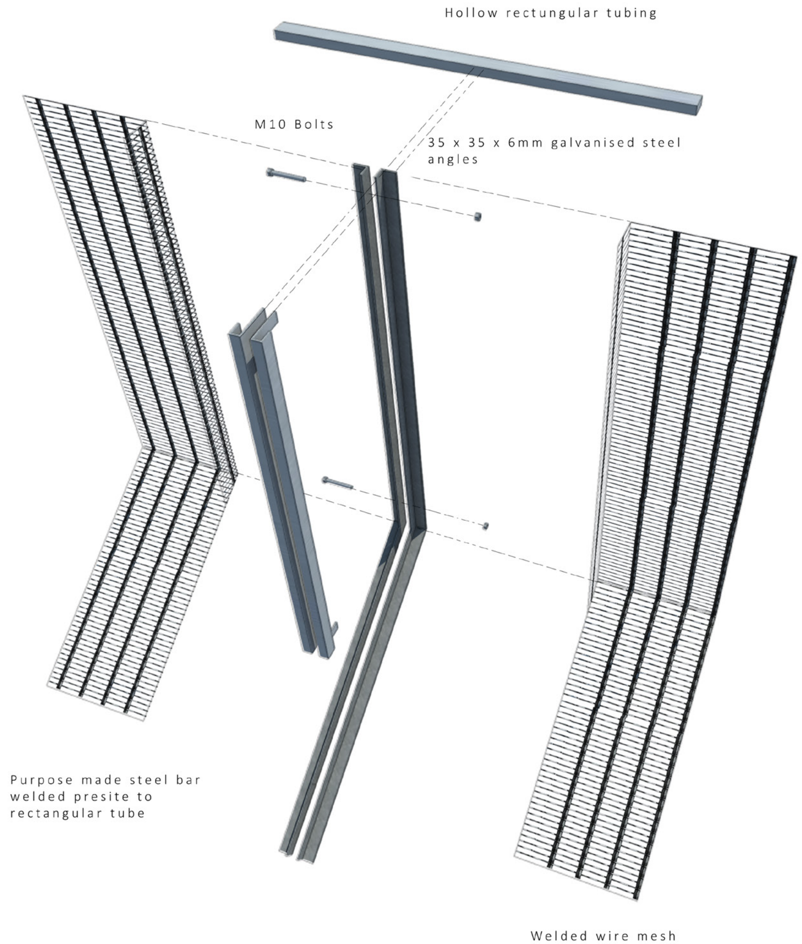


10.27_ Detail 5, balastrade detail (Author, 2015)

DETAIL 05 / SCALE 1:5

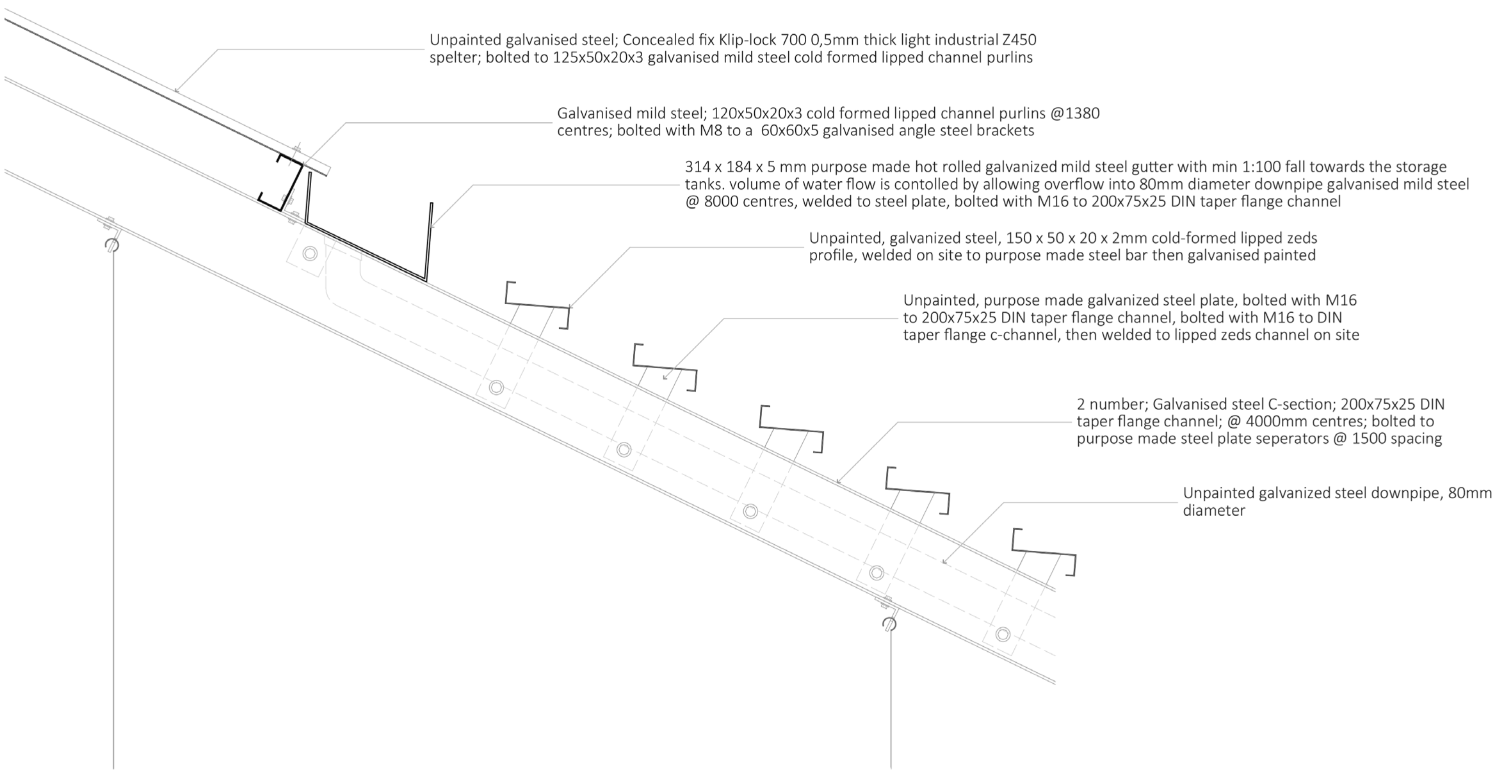


3D DETAIL 05 / INSECT HABITATS



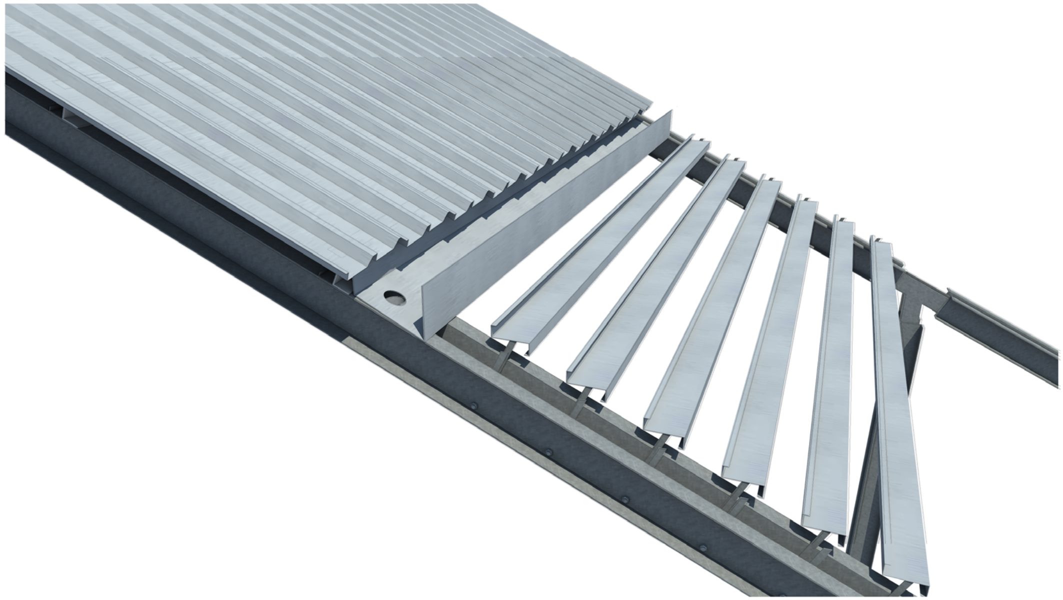
3D DETAIL 05/ EXPLODED BALUSTRADE DETAIL

10.28_ 3D balustrade detail expressing the concept of intersecting, overlapping and detaching (Author, 2015)

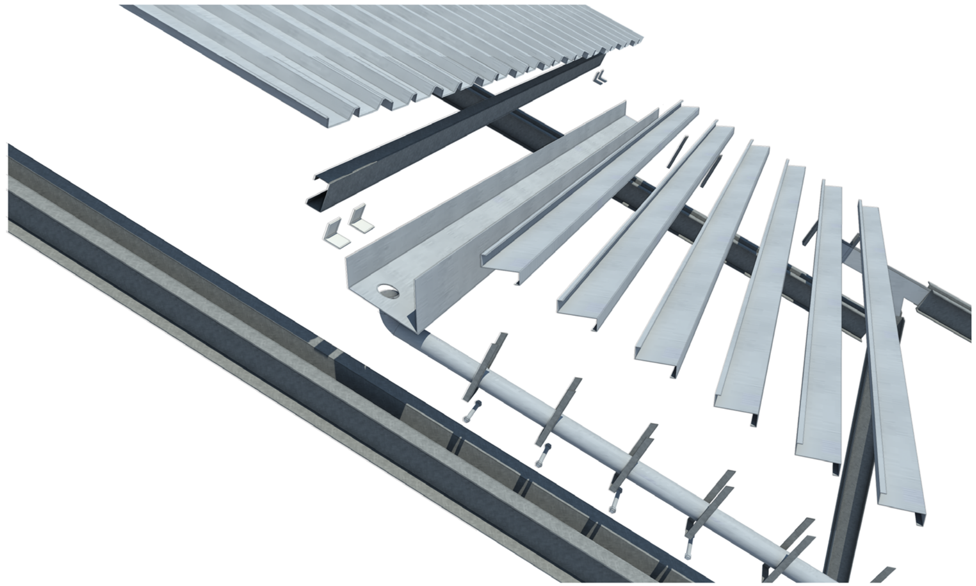


DETAIL 06 / SCALE 1:10

10.29_ Detail 6, Roofing detail of gutter and sun shading (Author, 2015)

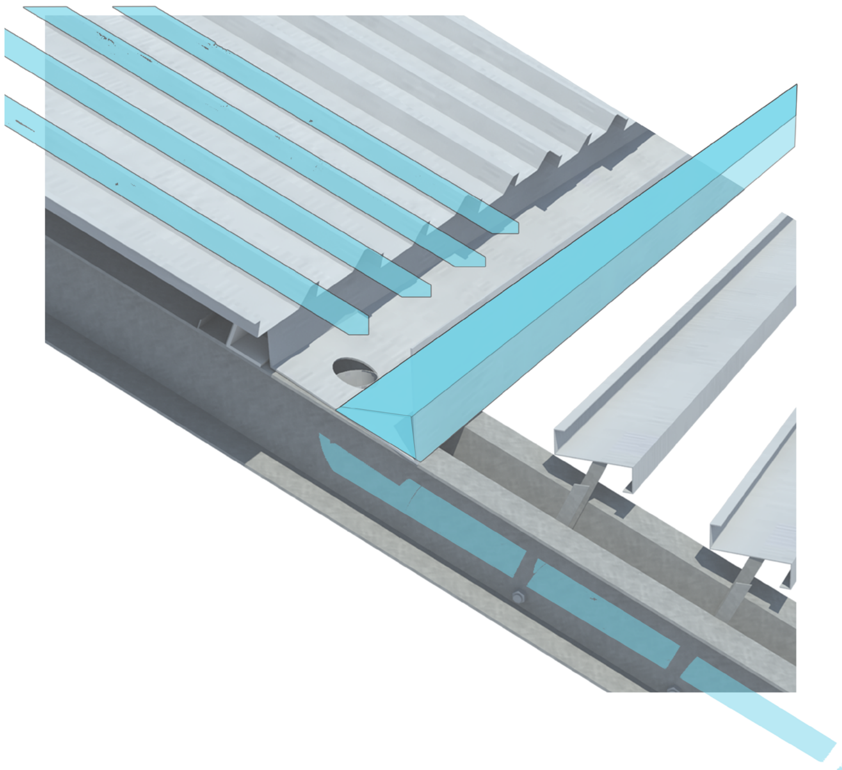


3D DETAIL 06/ MATERIALS ASSEMBLY

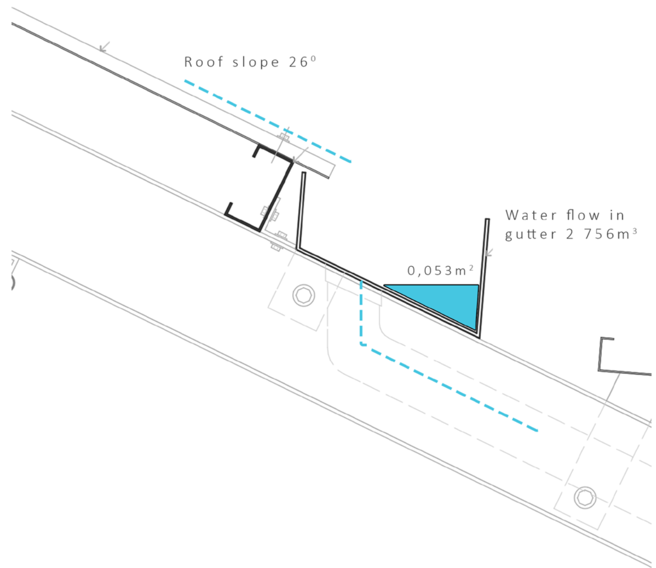


3D DETAIL 06 / EXPLODED DETAIL

10.30_ 3D exploded detail of roof construction
(Author, 2015)

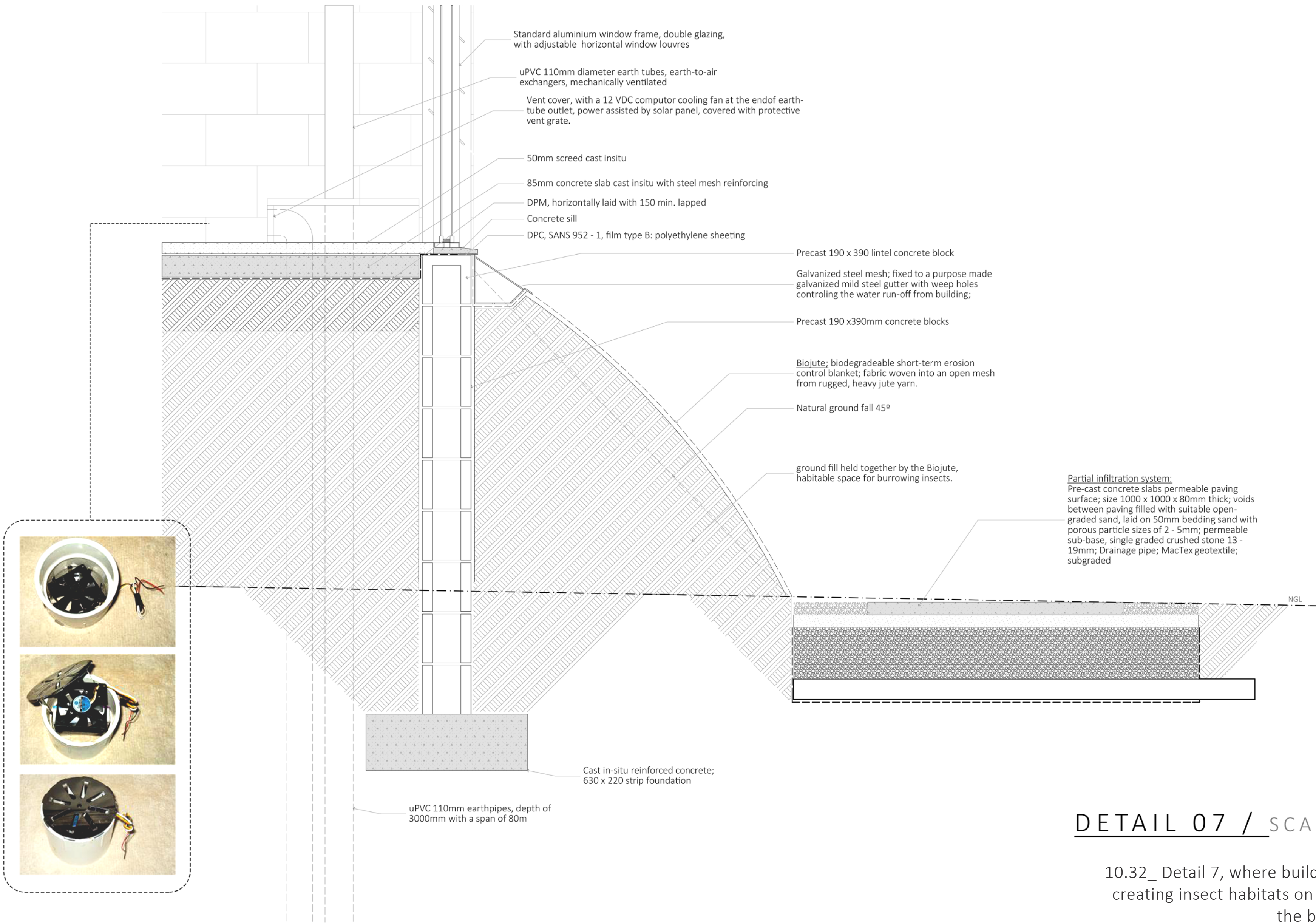


Water run-off from roof /
Roof Area north: 236 m²
Gutter capacity to hold water send water to storage tanks; 2 756m³
water overflow into 80mm diameter downpipe



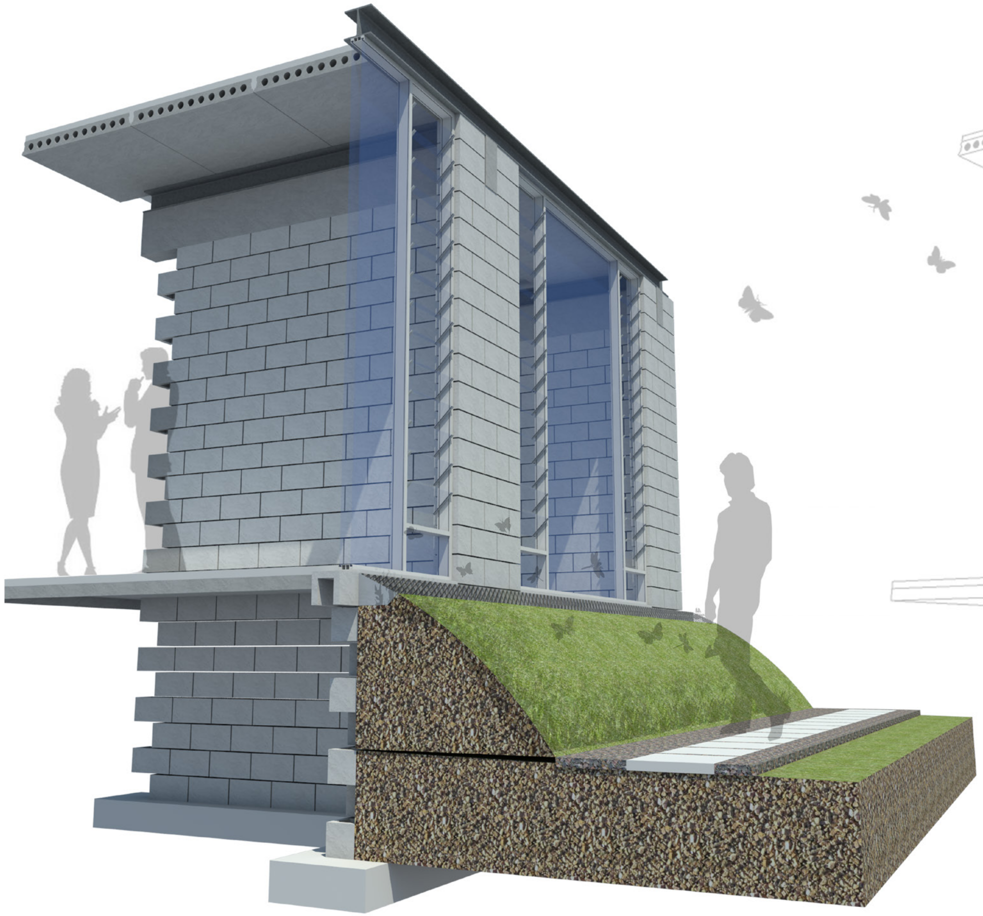
DETAIL 06 / GUTTER WATER CAPACITY

10.31_ Detail 6, Diagram explaining the use of water in the gutter (Author, 2015)



DETAIL 07 / SCALE 1:10

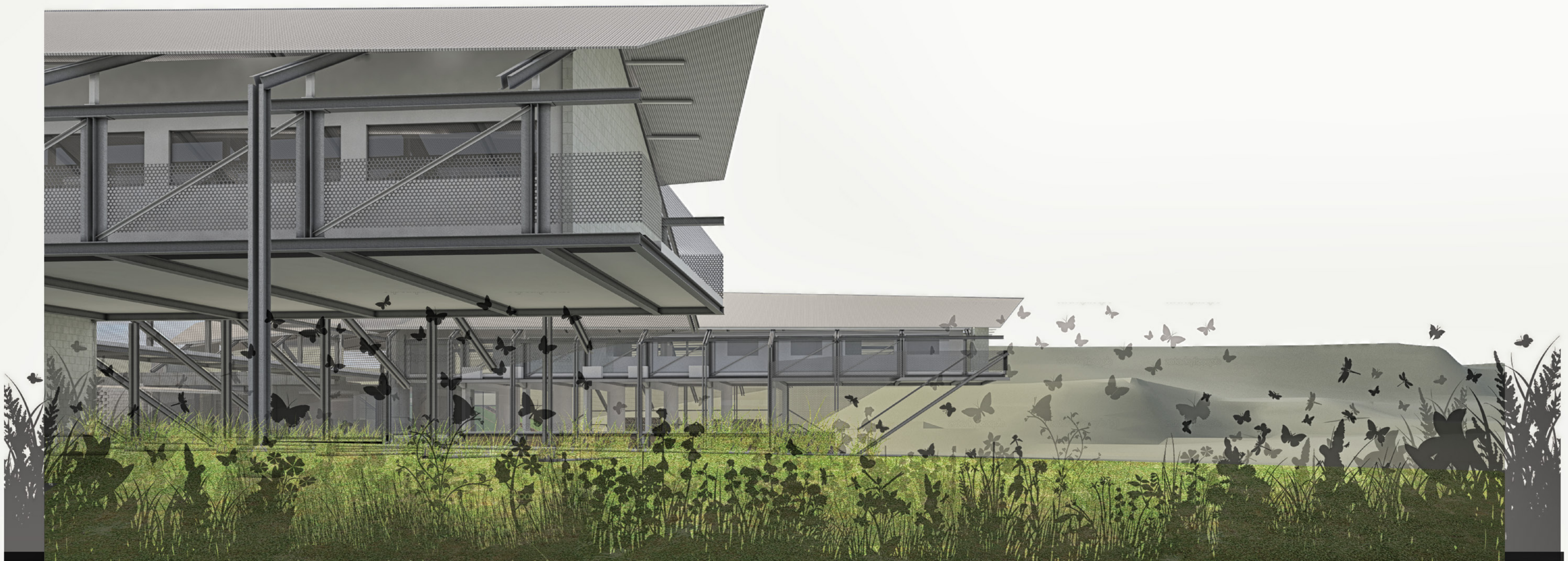
10.32_ Detail 7, where building meets the ground creating insect habitats on northern condition of the building (Author, 2015)



3D DETAIL 07 / MATERIALS IN CONTEXT

3D DETAIL 07 / INSECT HABITATS

10.33_ 3D Detail 7, Explaining materials and use of insect habitats (Author, 2015)

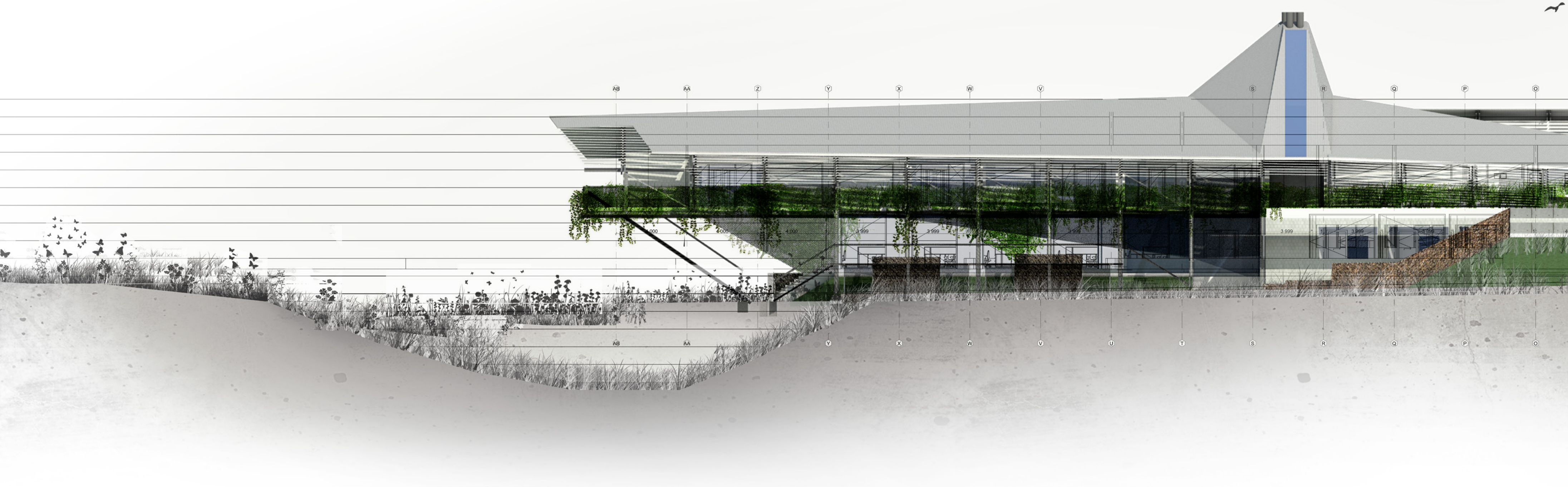


NURTURNG ARCHITECTURE

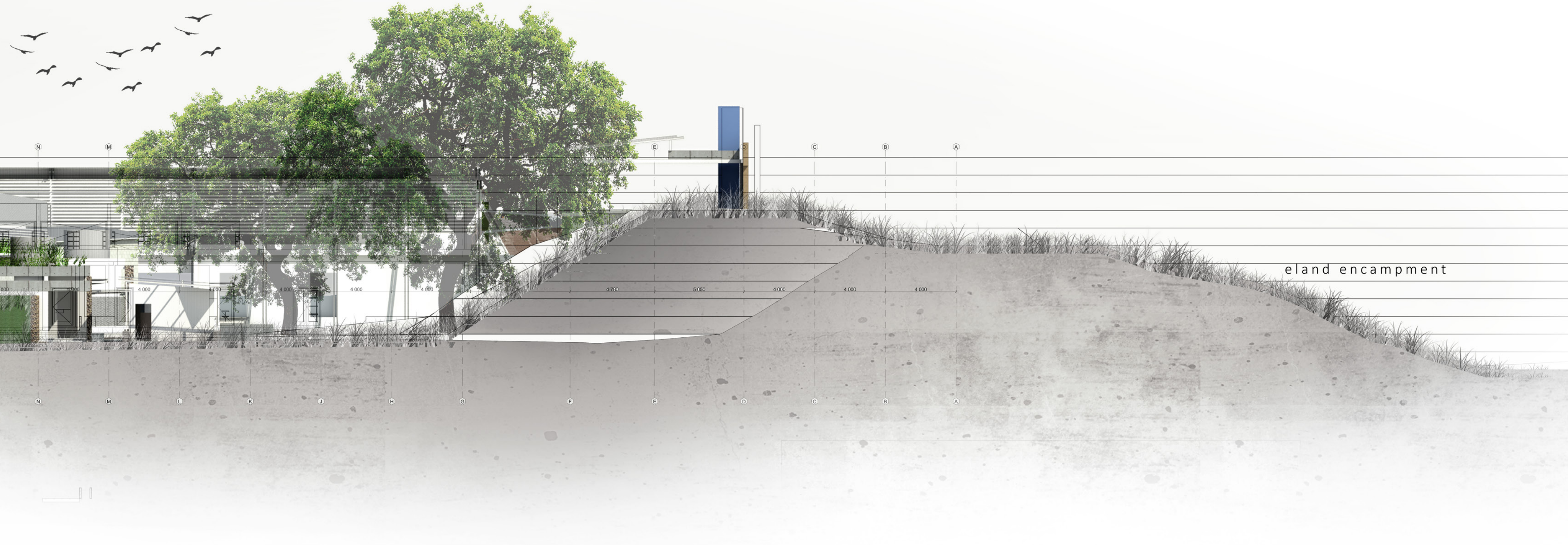
SHIFTING CONVENTIONAL ARCHITECTURAL APPROACHES TOWARDS REGENERATIVE ARCHITECTURE

AN EDUCATIONAL ENTEMOLOGY RESEARCH FACILITY IN THE FORGOTTEN ORIGINS OF PRETORIA CENTRAL

JOHANN .H. BOONZAAIER
2 7 0 9 8 2 9 1



10.34_ North elevation of entomology research facility, explaining the release into nature, the final detachment from the bio-wall (Author, 2015)


eland encampment

CLOSING

11 / CONCLUSION

The intention of this dissertation is to question the current approach to sustainable design. It is developed by realizing what the impact of the built environment is on the global warming crisis, and acknowledging that it results in the loss of ecosystems. This led to the investigation of regenerative theories and the role architectural design can play in enhancing ecosystems and creating a mutually beneficial relationship between nature, man and the building.

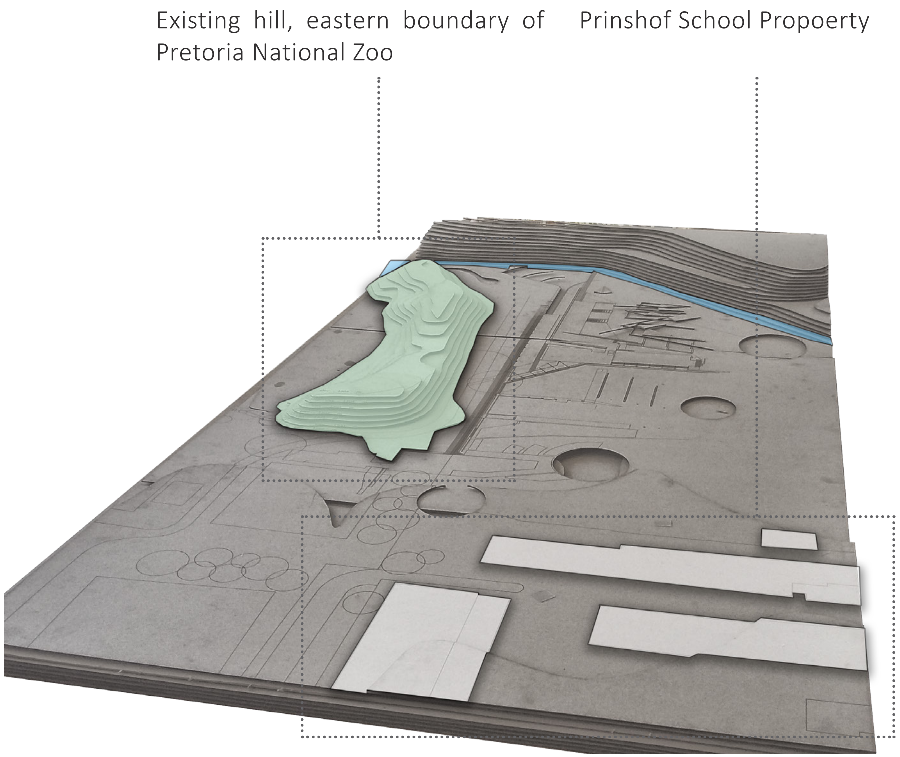
Sustainability is slowing down the process of degeneration, and, although this is essential, it is insufficient. Developing relationships between living things is required to achieve a regenerative condition. Regenerating the evolving resiliency and matrix of life in each place is the other half of achieving a sustainable condition. Insect pollinators function as part of ecosystem services and are essential to humanity's survival. But they are threatened by global warming and climate change due to human actions. This led to the design of an insect research facility that creates ecosystems and habitats for the pollinators to enhance biodiversity and revitalize the earth's resources.

By applying regenerative theory and adapting Steward Brand's 6 'S', a new type of reciprocal element was discovered in the building envelope, which creates a mutual functional space where humans and nature can co-exist.

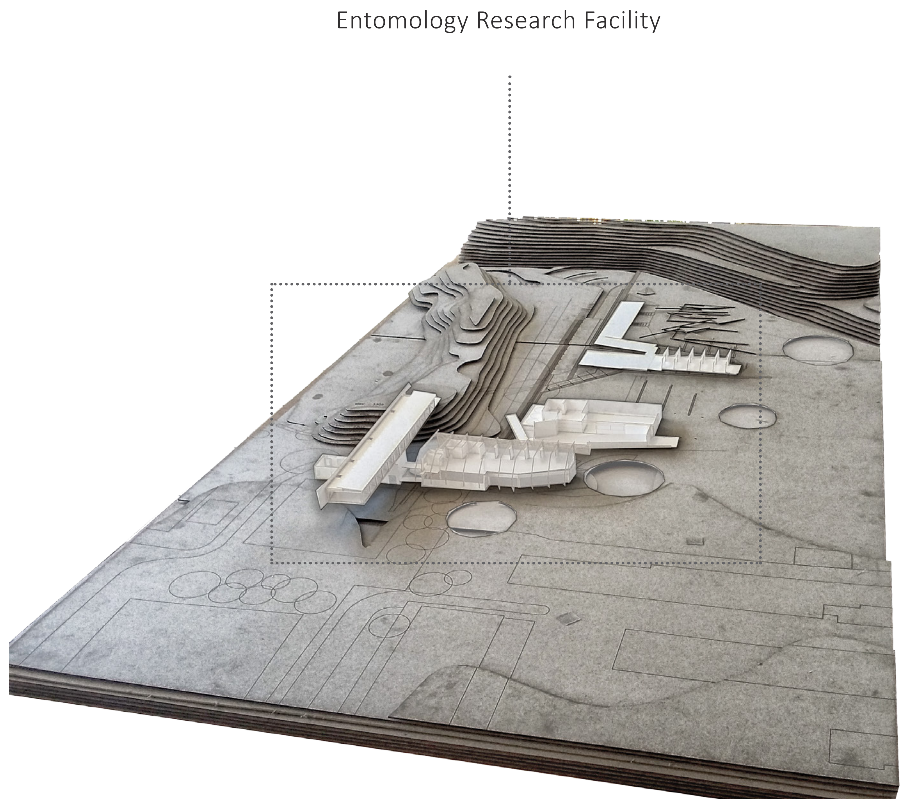
The implementation of green infrastructure on the site counters the destruction of natural habitats and allows the increase of biodiversity to restore functioning ecosystems; safeguarding and enhancing natural features (Yeang, 2008: 128).

The proposed architecture allows for the restoration of destroyed habitats on the site by employing a series of water catchments and constructed water channels to assist in the growing of various plants and flowers and to create habitats and nutrition for wildlife. The building becomes part of the environment. Additionally, by utilizing the site as part of a building layer formed by the structure of the building, a habitable space for humans is created inside the building. The green facade not only creates habitats for insects but also controls the temperature inside the building.

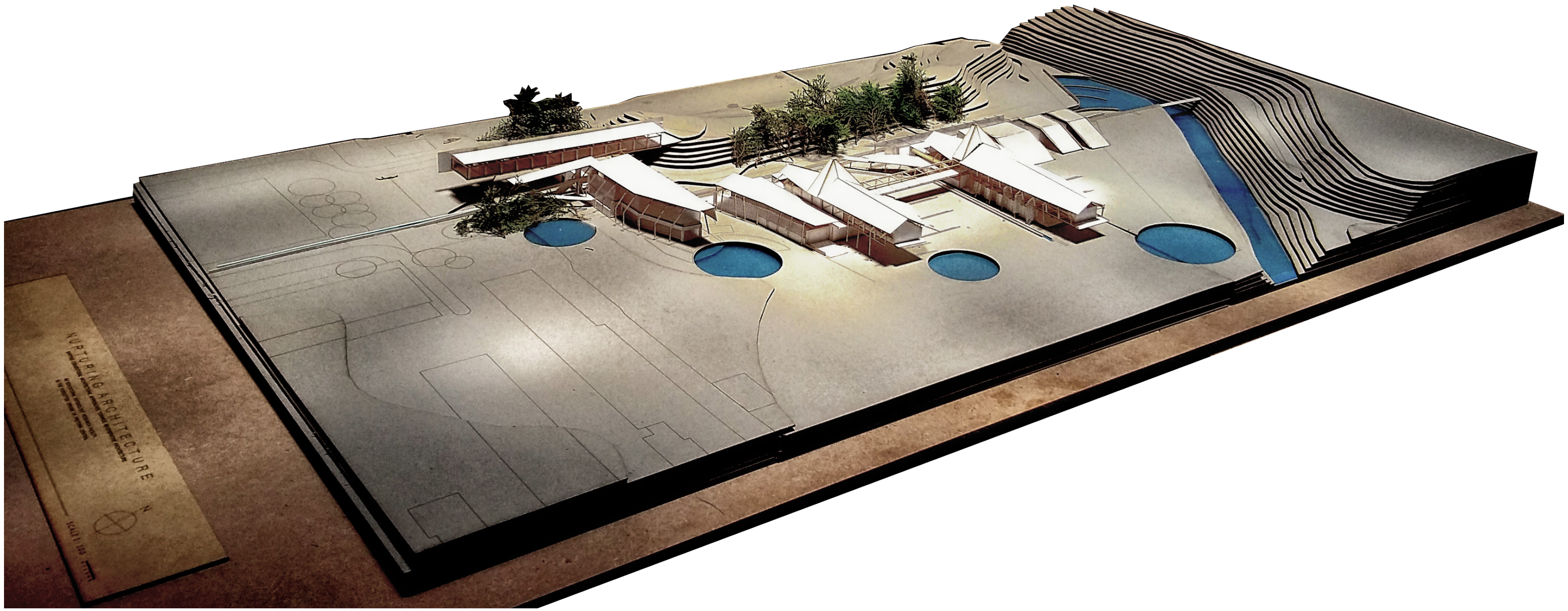
Considering the principles of regenerative design; the building functions as a restorative device that gives back to its surroundings more than it takes away.



11.1_ Site model in progress, before the placement of proposed building (Author, 2015)



11.2_ Site model in progress with the proposed building (Author, 2015)



11.2_ Final Site model (Author, 2015)

11.3_ Final Site model (Author, 2015)

11.2 / FINAL PRESENTATION

11.4_ Final presentation in room 3:15 Boukunde building 26 November 2015 (Author, 2015)

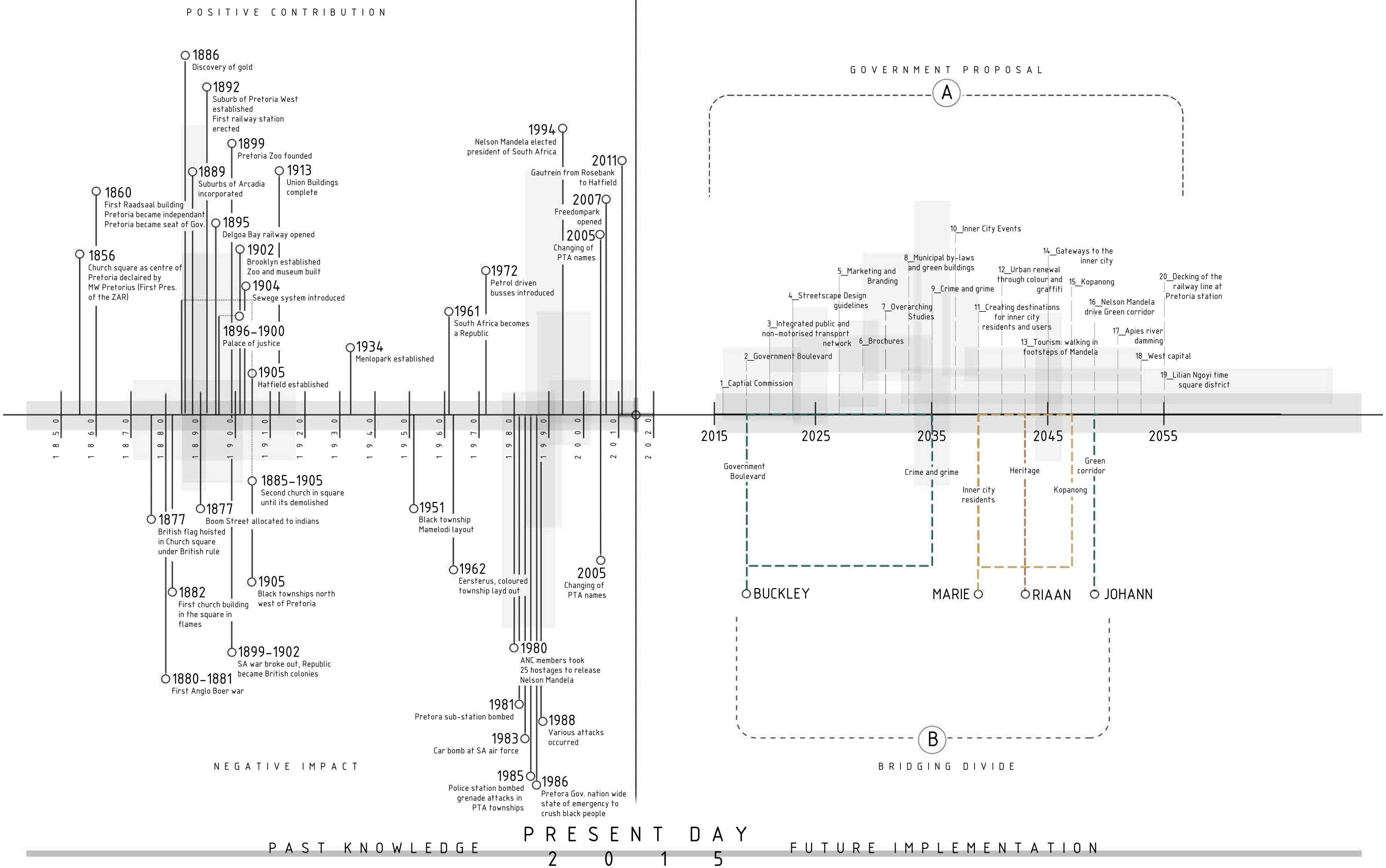
12 / APPENDIX

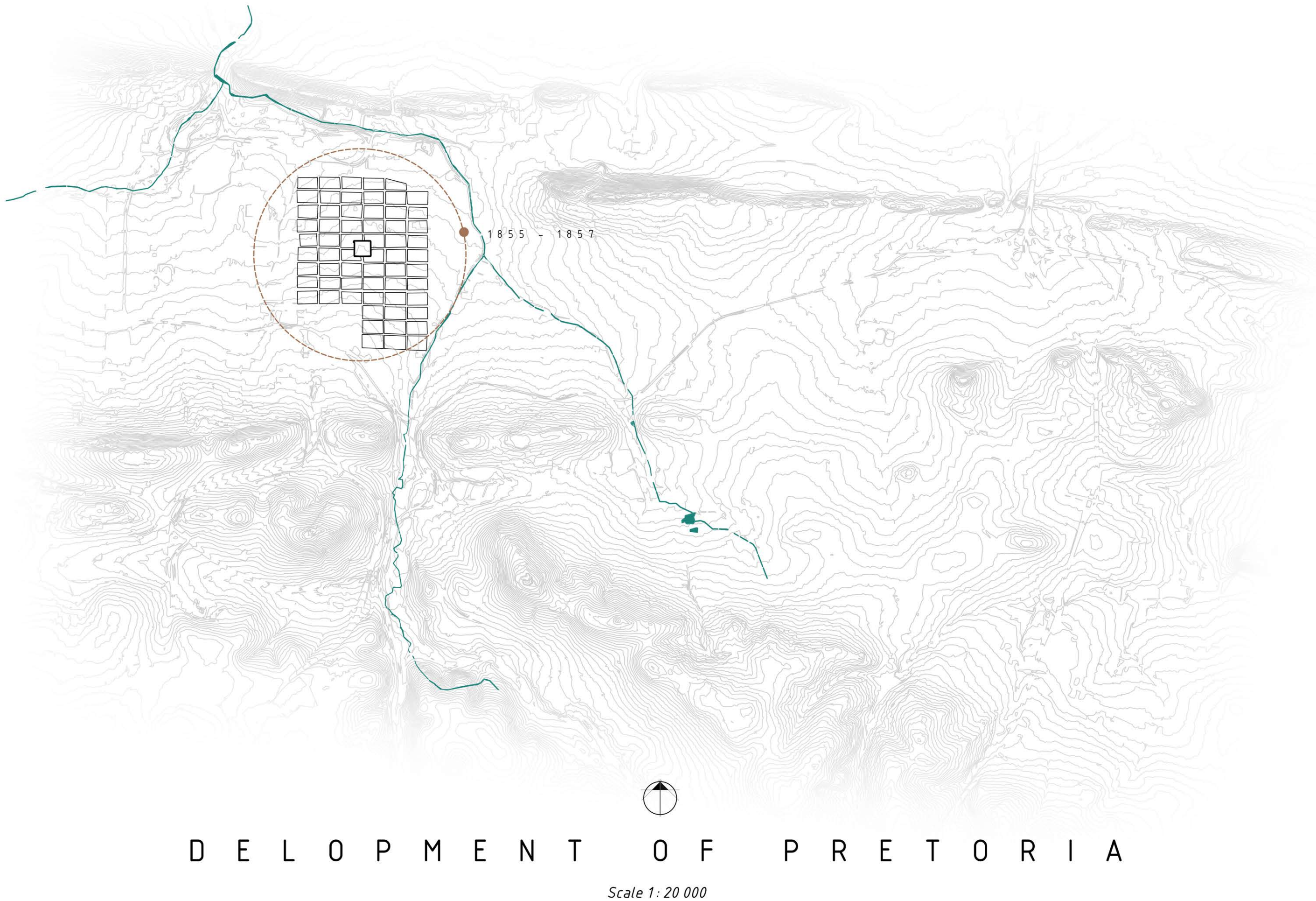
12.1 / GROUP PRESENTATION

The Focus of the Group framework was based on the development of the Tshwane's 2055 vision, and how this influences the growth of the city. To understand the future of Pretoria, one must first understand how it started and developed. This project only focuses on certain aspects of the development and therefore will not cover the entire history of Pretoria.

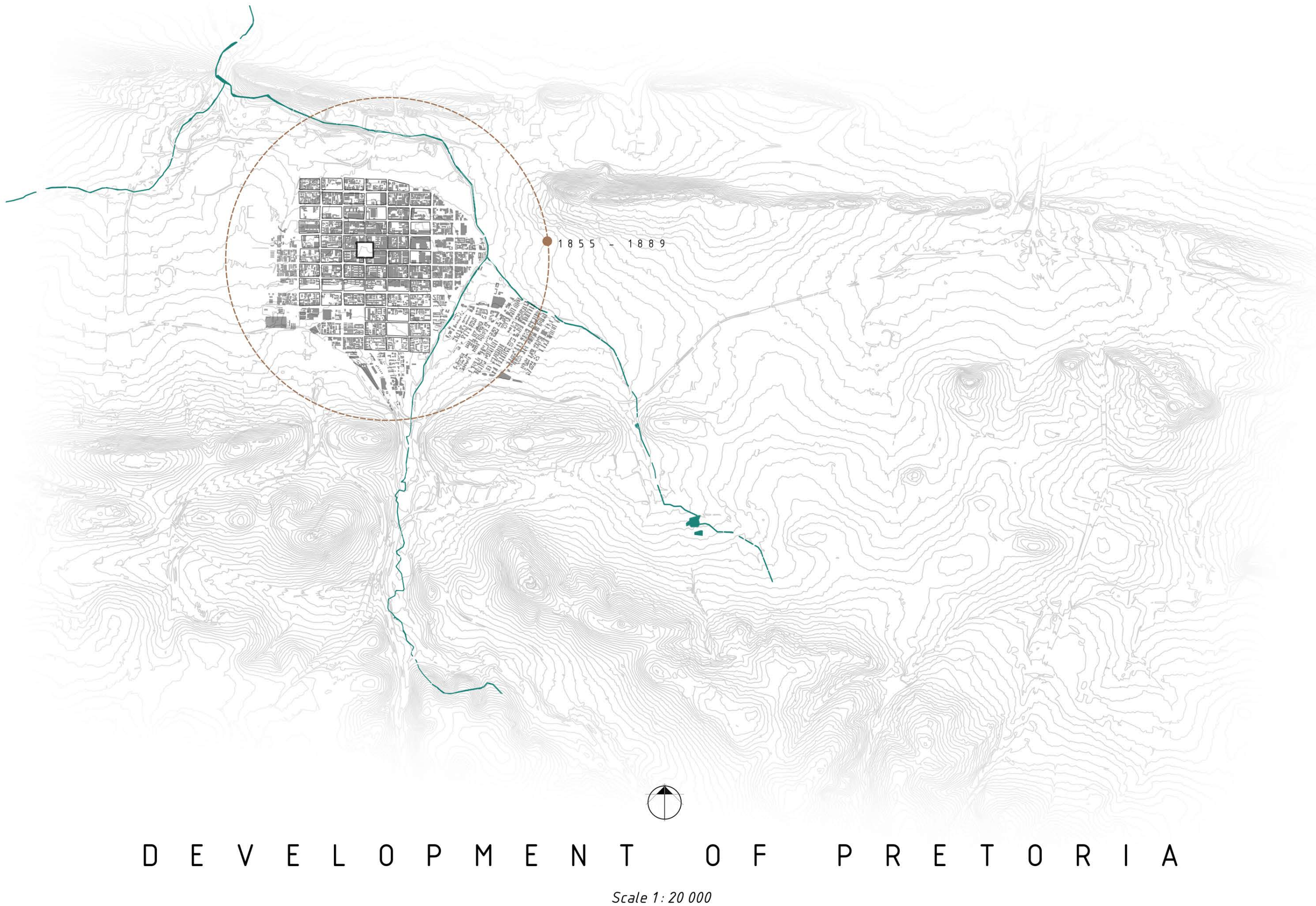
MAPPING

investigating the north south axis of the city(pretoria)

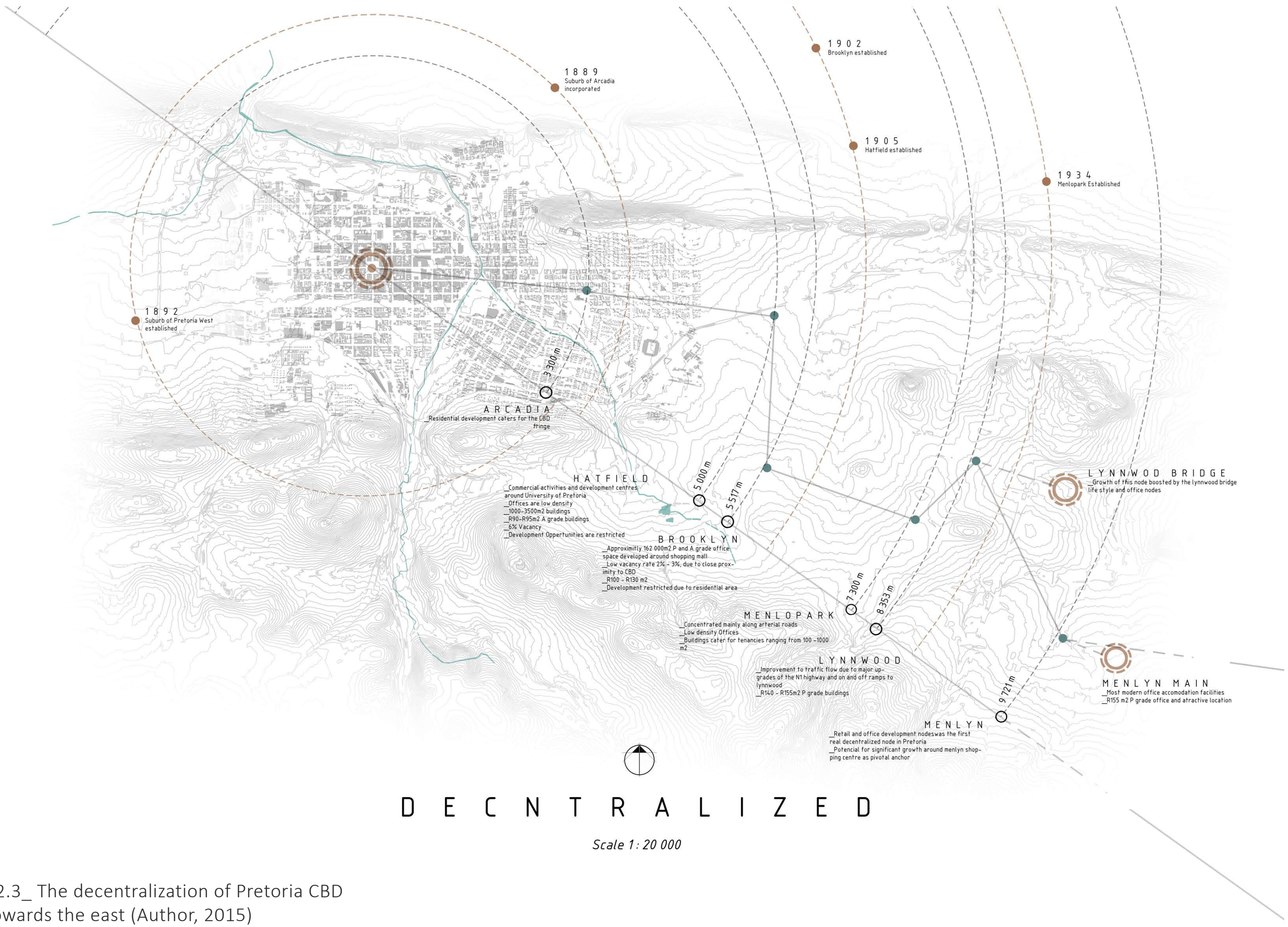

POSITIVE CONTRIBUTION
1886 Discovery of gold
1892 Suburb of Pretoria West established First railway station erected
1899 Pretoria Zoo founded
1889 Suburbs of Arcadia incorporated
1913 Union Buildings complete
1860 First Raadsaal building Pretoria became independant Pretoria became seat of Gov.
1895 Delgoa Bay railway opened
1856 Church square as centre of Pretoria declaired by MW Pretorius (First Pres. of the ZAR)
1902 Brooklyn established Zoo and museum built
1904 Sewege system introduced
1896-1900 Palace of justice
1934 Menlopark established
1905 Hatfield established
1961 South Africa becomes a Republic
1972 Petrol driven busses introduced
1994 Nelson Mandela elected president of South Africa
2011 Gautrein from Rosebank to Hatfield
2007 Freedompark opened
2005 Changing of PTA names
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
1885-1905 Second church in square until its demolished
1877 Boom Street allocated to indians
1877 British flag hoisted in Church square under British rule
1905 Black townships north west of Pretoria
1882 First church building in the square in flames
1899-1902 SA war broke out, Republic became British colonies
1880-1881 First Anglo Boer war
1951 Black township Mamelodi layout
1962 Eersterus, coloured township layd out
2005 Changing of PTA names
1980 ANC members took 25 hostages to release Nelson Mandela
1981 Pretora sub-station bombed
1988 Various attacks occurred
1983 Car bomb at SA air force
1985 Police station bombed grenade attacks in PTA townships
1986 Pretora Gov. nation wide state of emergency to crush black people
NEGATIVE IMPACT
GOVERNMENT PROPOSAL
A
10_Inner City Events
14_Gateways to the inner city
8_Municipal by-laws and green buildings
12_Urban renewal through colour and graffiti
5_Marketing and Branding
20_Decking of the railway line at Pretoria station
15_Kopanong
9_Crime and grime
4_Streetscape Design guidelines
16_Nelson Mandela drive Green corridor
7_Overarching Studies
11_Creating destinations for inner city residents and users
3_Integrated public and non-motorised transport network
17_Apies river damming
6_Brochures
13_Tourism: walking in footsteps of Mandela
2_Government Boulevard
18_West capital
19_Lilian Ngoyi time square district
1_Capital Commission
2015
2025
2035
2045
2055
Government Boulevard
Crime and grime
Heritage
Green corridor
Inner city residents
Kopanong
BUCKLEY
MARIE
RIAAN
JOHANN
B
BRIDGING DIVIDE
PAST KNOWLEDGE
PRESENT DAY 2015
FUTURE IMPLEMENTATION



12.1_ The development of Pretoria from a central grid in the 1800 (Author, 2015)



12.2_ The development of Pretoria bridged the Apies river on the east (Author, 2015)



12.3_ The decentralization of Pretoria CBD towards the east (Author, 2015)

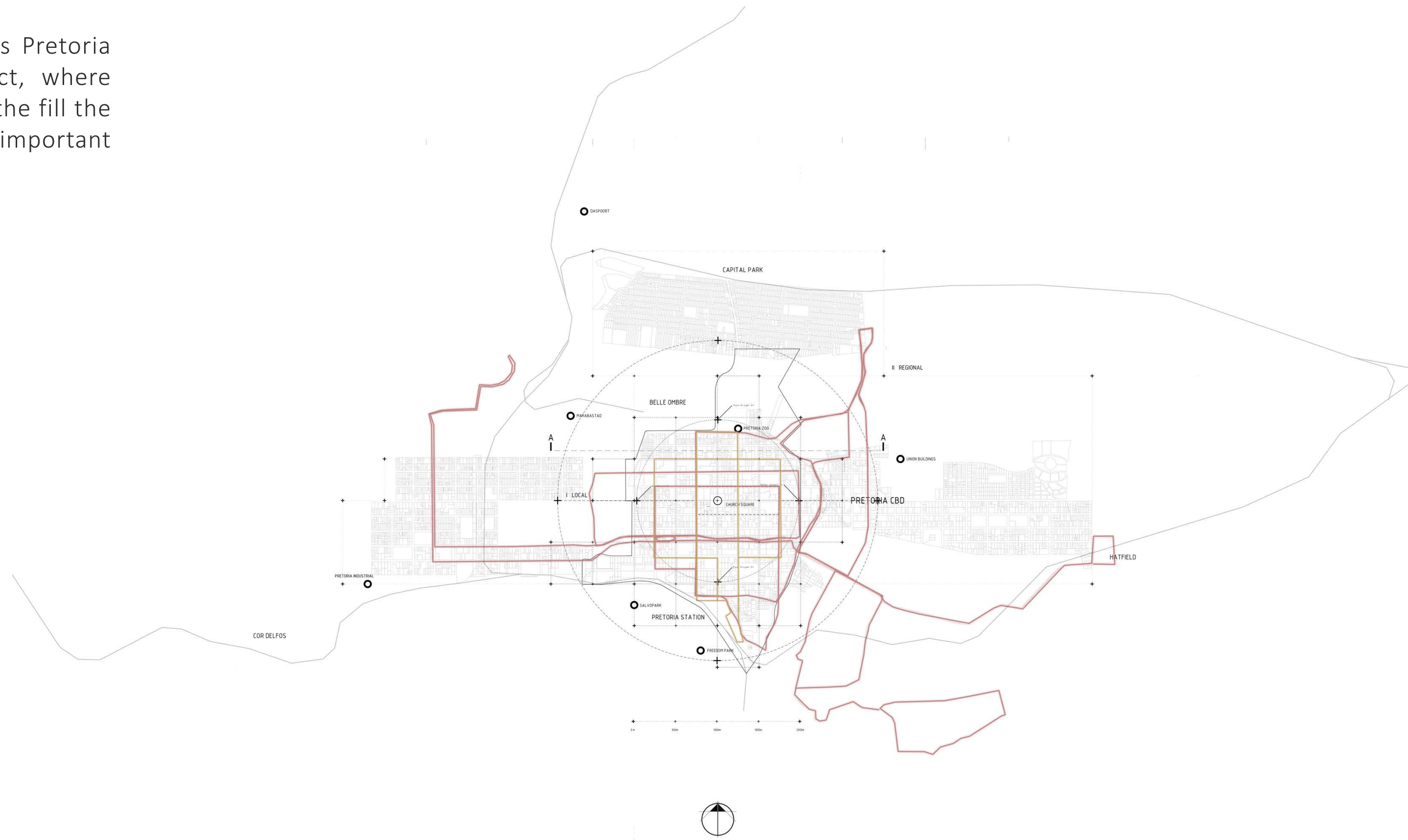
The Group then focused on the access in and out of Pretoria, and found that public transport in the form of Train stations and bus routes are very limiting, with the only access ftom the north (at Marabastad) and the south.

T R A I N   R O U T E S

Scale 1 : 20 000

12.4_ Train routes access to Pretoria Central
(Author, 2015)

The bus routes from the train station covers Pretoria CBD aswell as the outscirts of this district, where informal ways of transport is then relied on the fill the gaps. Therefore the informal transport is very important in this aspect.



B U S R O U T E S

Scale 1 : 20 000

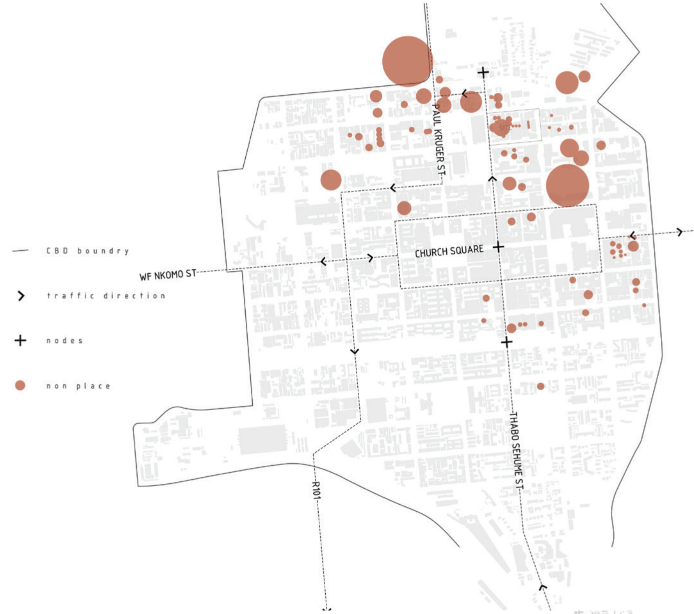
12.5_ Gautrain busroutes aswell as Areyeng bus routes in and out of the city (Author, 2015)

MAPPING

MAPPING

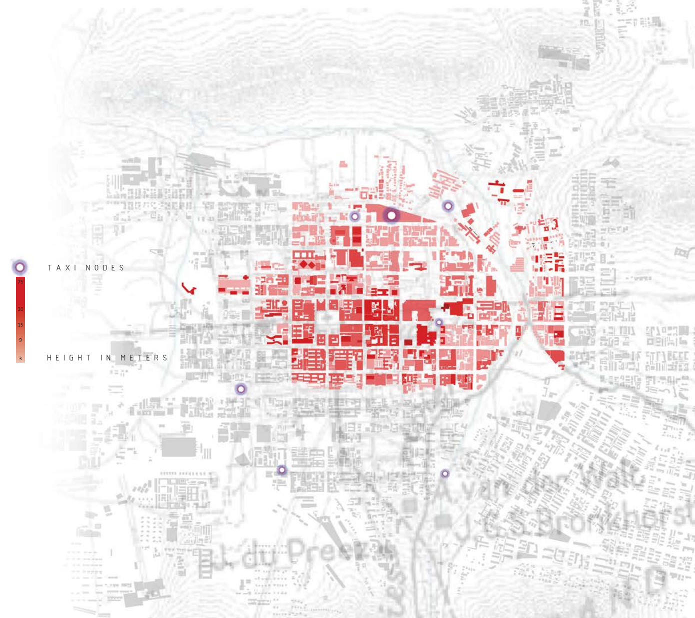
12.6_ Main streets on the grid of Pretoria entering the CBD (Author, 2015)

M A P P I N G



D E N S I T Y

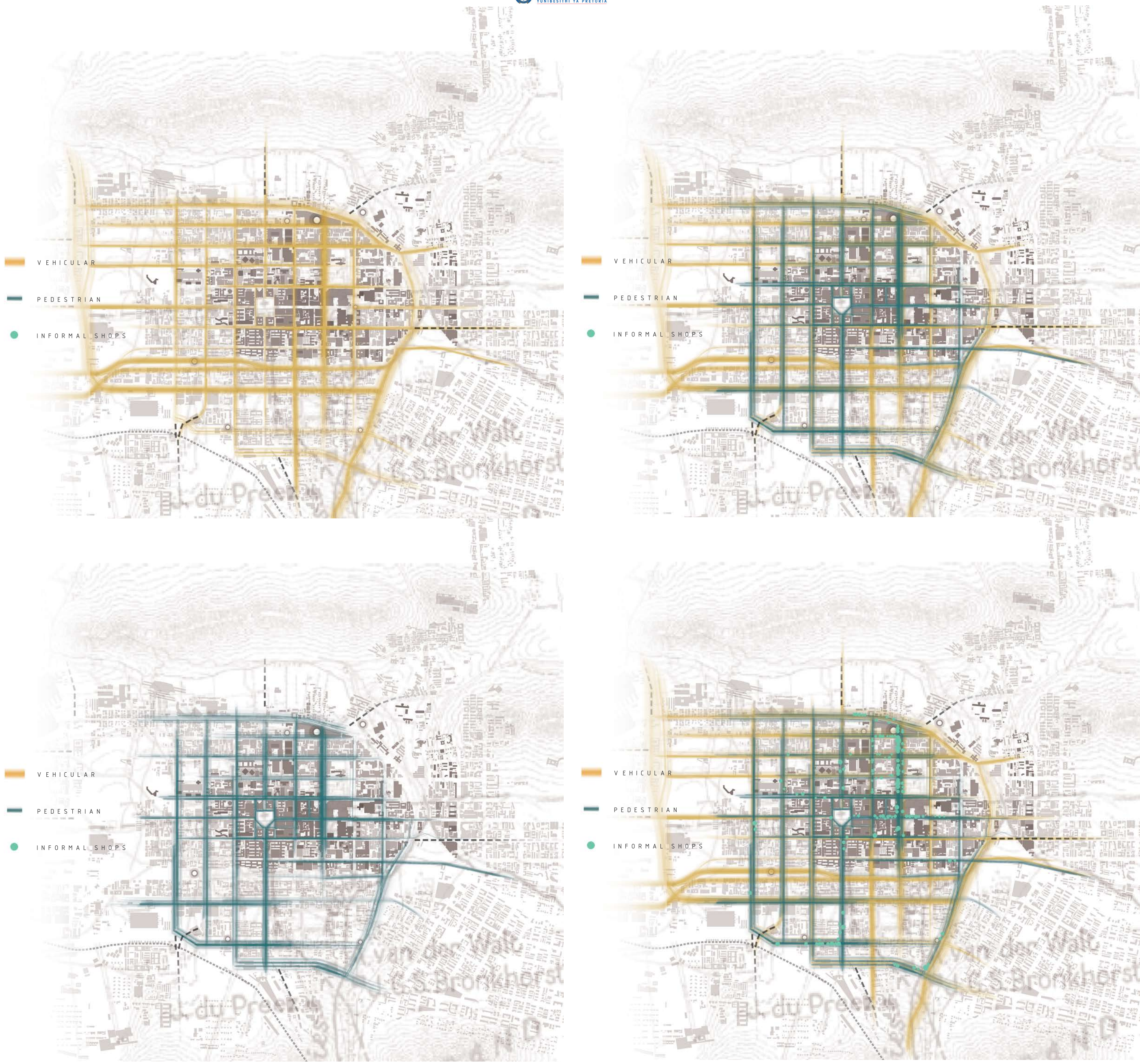
EXPLORING THE RELATIONSHIP BETWEEN THE DENSITY IN BUILDING HEIGHT AND MASS



12.7_ Foucing on the North East Quadrant of Pretoria CBD, Density in building height (Author, 2015)

M O V E M E N T

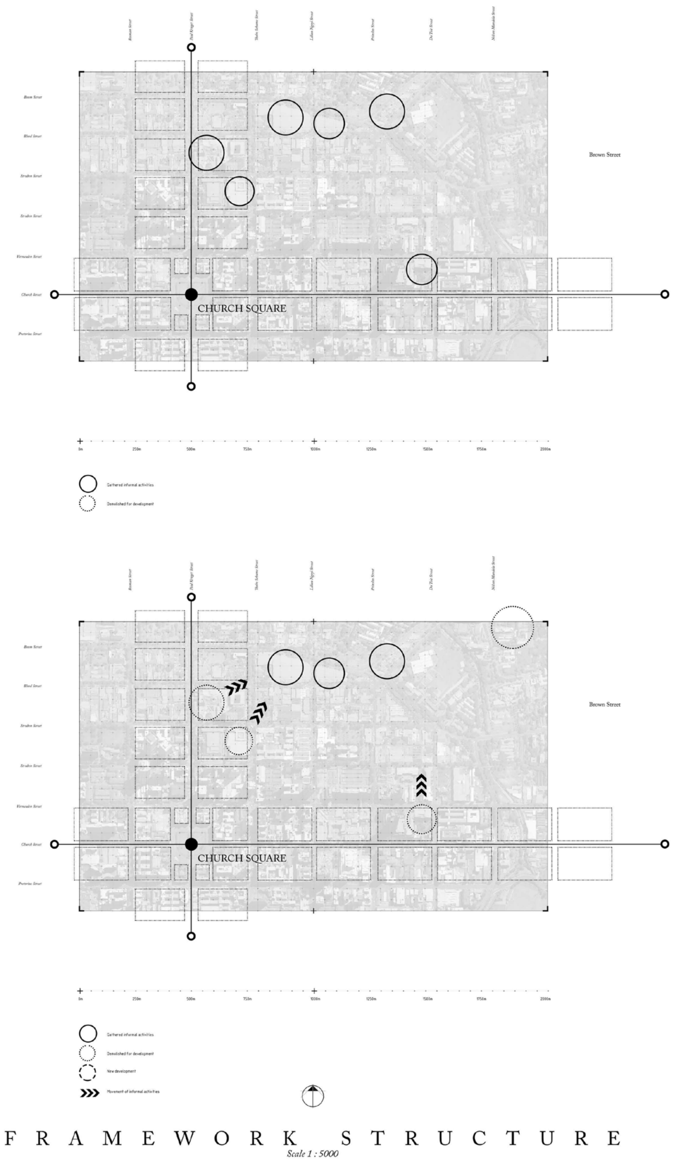
INVESTIGATING HOW CITY PLANNING AND SHAPE AS INFLUENCED MOVEMENT DENSITY IN THE CITY



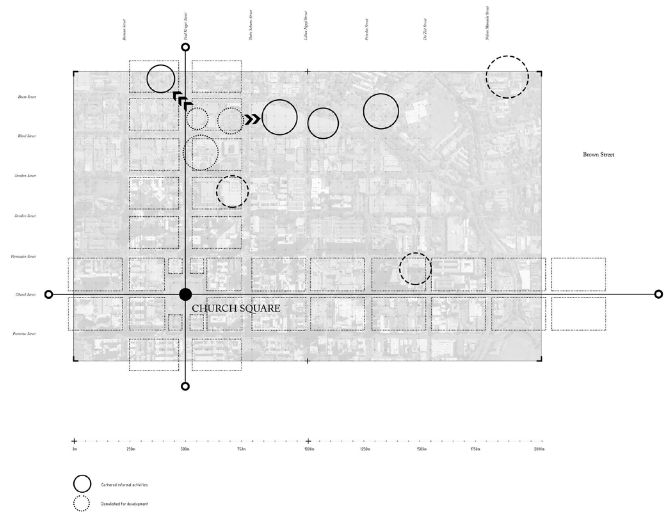
M O V E M E N T

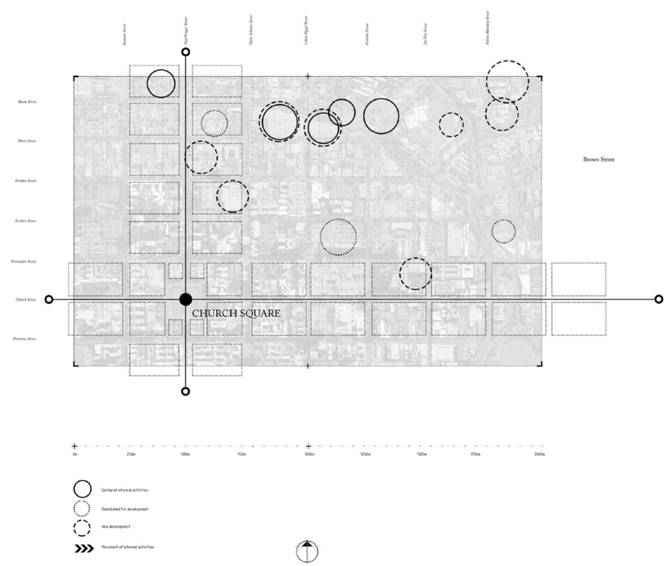
INVESTIGATING HOW CITY PLANNING AND SHAPE AS INFLUENCED MOVEMENT DENSITY IN THE CITY

12.8_ Movement in and around the CBD (Author, 2015)



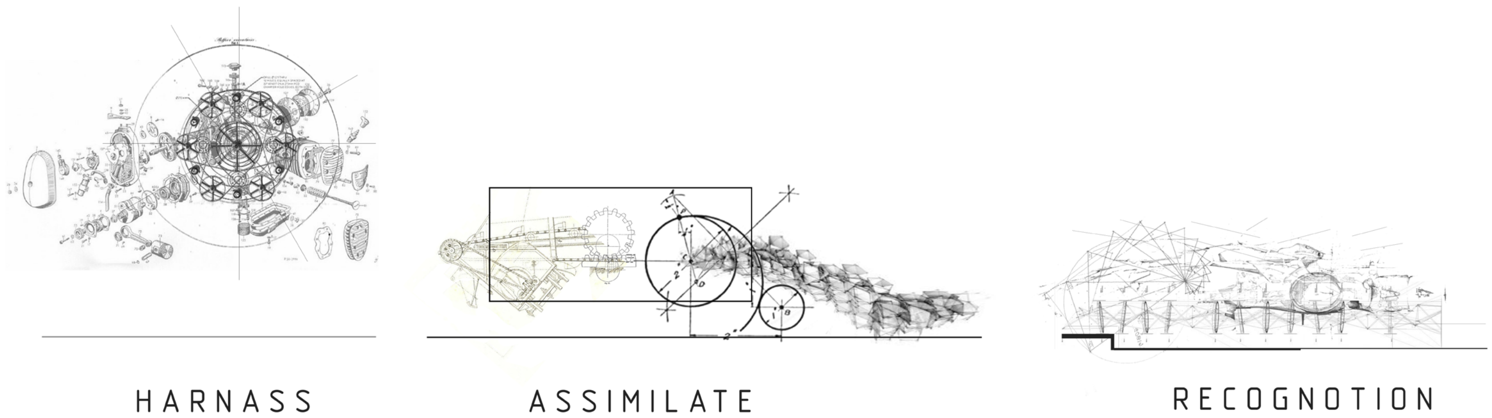
12.9_ The following diagrams explain how the informal condition in Pretoria keeps shifting, pushing them towards the eastern border of the CBD (Author, 2015)





F R A M E W O R K   S T R U C T U R E

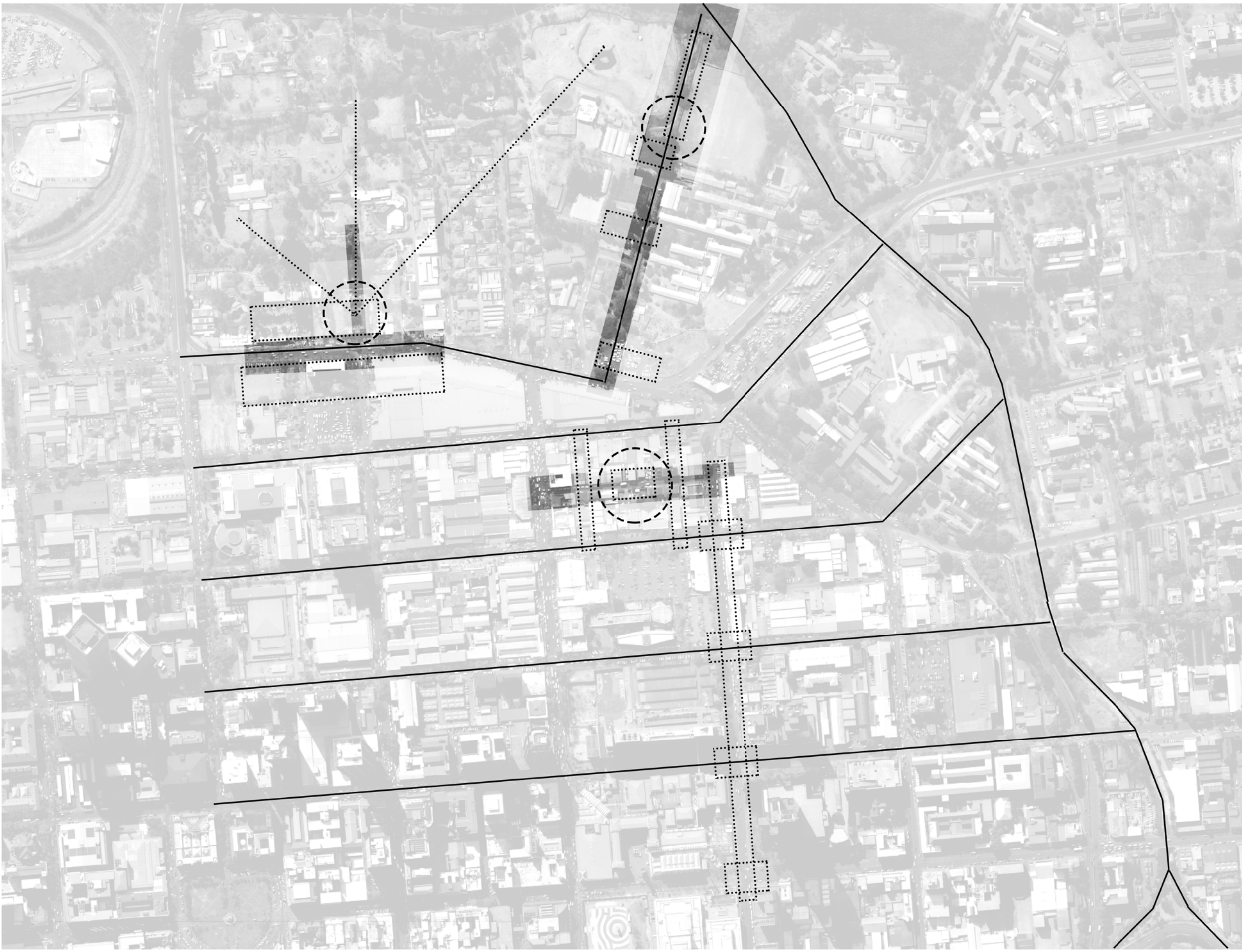
Scale 1 : 5000



U R B A N   I N T E N T I O N S

Scale 1 : 2000

12.10_ Concept diagrams of the group framework intentions (Author, 2015)



U R B A N   I N T E N T I O N S

Scale 1 : 2000

12.11_Abstract diagrams explaining framework intentions (Author, 2015)

"HARNESS"

Site pLan
Buckley Thomspon

12.12_ Harnessing the city's energy (Author, 2015)

"ASSIMILATION"

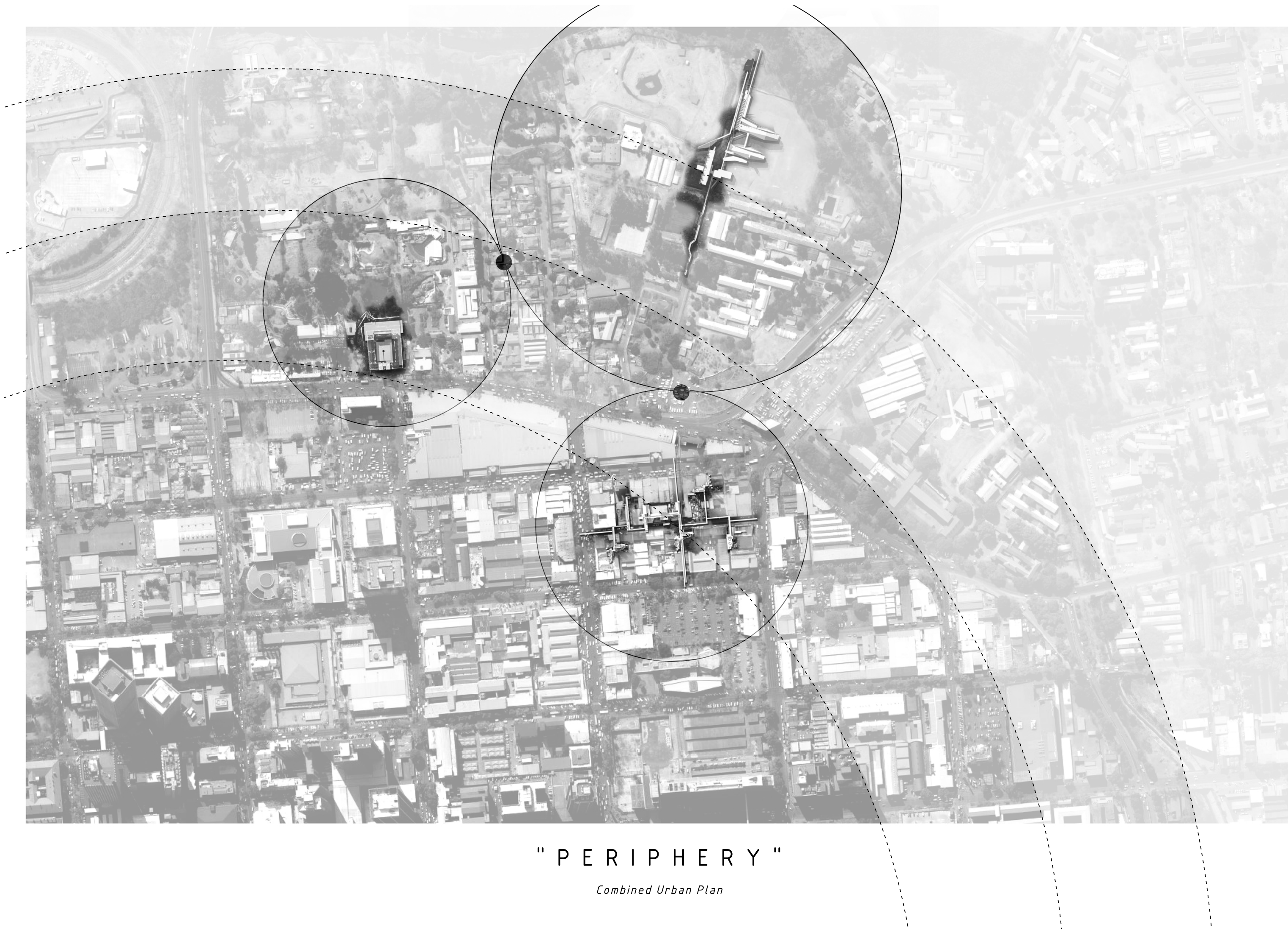
Site Plan
Riaan Hollenbach

12.13_ Assimilating the energy (Author, 2015)

"RECOGNITION"

Site Plan
Johann Boonzaaier

12.14_ Recognizing the lost energies
(Author, 2015)



" P E R I P H E R Y "

Combined Urban Plan

12.15_ Locality plan of Group Framework (Author, 2015)

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