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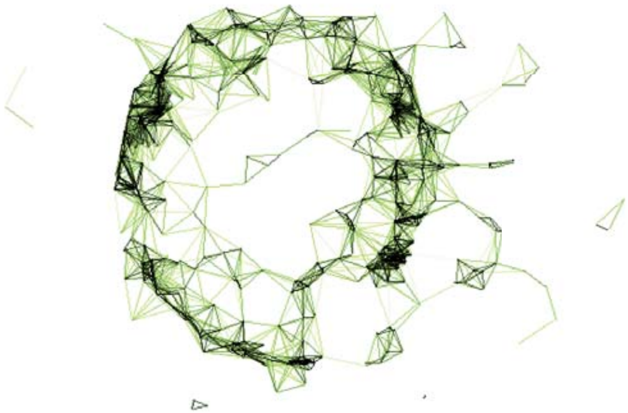
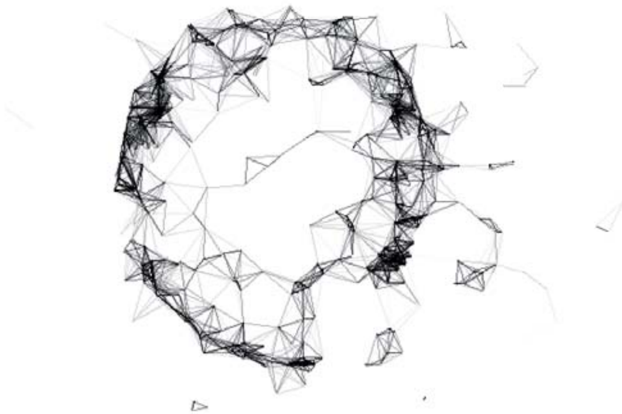


proximity

vertical agriculture the old pretoria west power station



to my family
whom i love very much

to my grandfather
who loved me very much

to my friends
this world is ours.

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By Calayde Davey

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Submitted in partial fulfilment of the requirements for the degree of
Magister in Architecture (Professional)

Faculty of Engineering, Built Environment and Information Technology
University of Pretoria, Department of Architecture
November 2010

....index

figures

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figures

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abstract

The thesis addresses the proximity of contemporary global human issues to local human issues and presents an architectural solution. By identifying, exploring and drawing closer the proximities between these global and local issues, new solutions can be developed for local application. There are new fields created for architecture when we understand and connect the proximity of objects of both cultural and biophysical creation, and when we understand and build on our ever-narrowing proximities between what has been and what is to come. The narrowing global conditions have direct implications on us as individual human beings and our individual local societies. These proximities have been explored, developed, and resolved for local application. The resulting research field for urban agriculture ultimately guided an appropriate architectural response within the city of Pretoria, South Africa.

Opposite - Definitions of *proximity*
[Oxford 2003, Princeton 2005]

proximity

1. [n] the property of being close together
2. [n] the region close around a person or thing
3. [n] nearness in space or time or relationship

law of proximity

when two or more objects are close to each other, they may be seen as a perceptual [virtual] unit

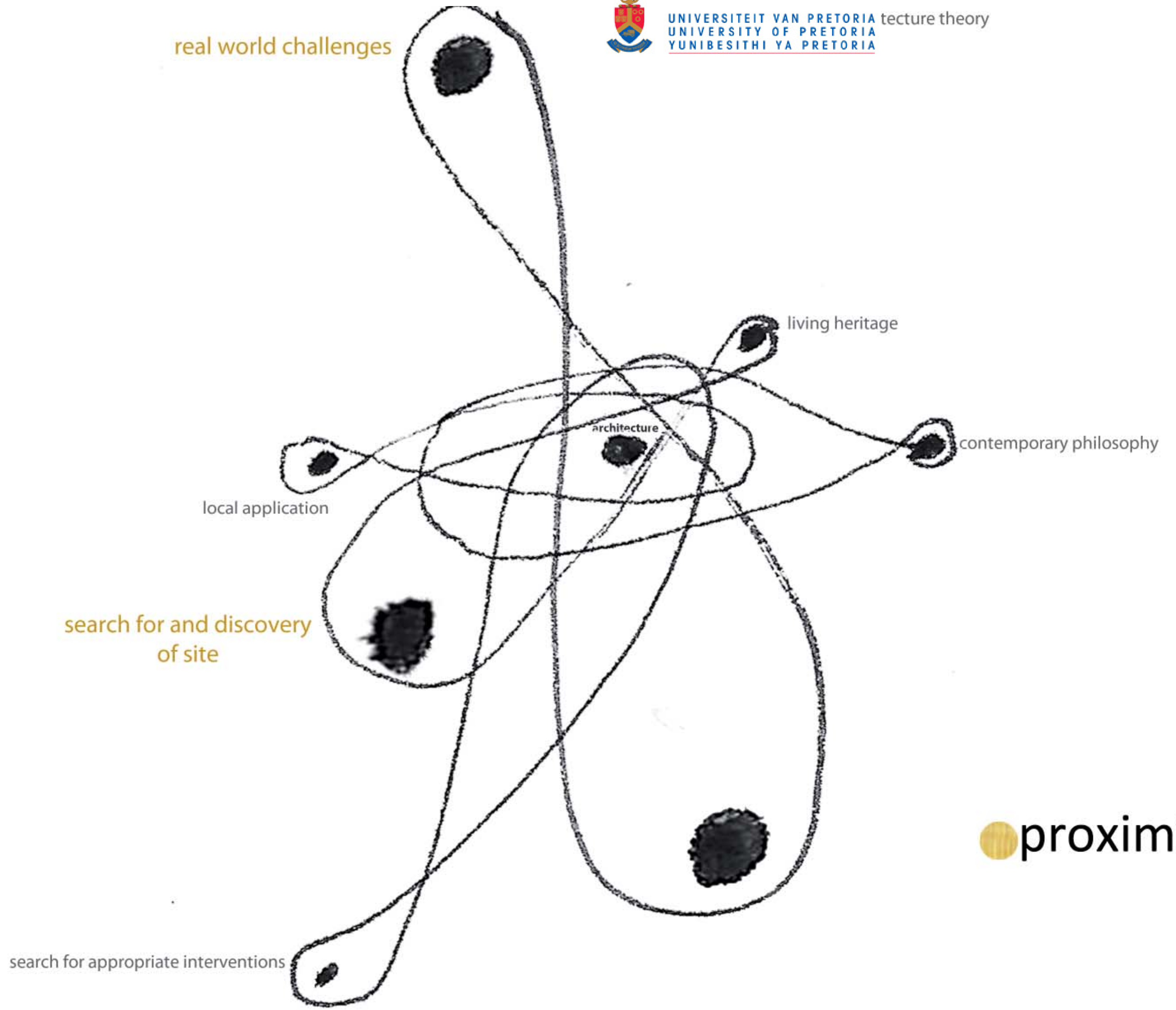
preface

The study of the relationship between space and time is all consuming - from our sciences to our daily lives and interactions. The world we live in is full of great and fascinating paradoxes - we are growing increasingly closer to each other and increasingly apart from each other; we are interacting closer with nature and yet we move away further from the "natural". We are moving closer to history and closer to our future as we have the total ability to manage our physical and metaphysical environments ourselves.

The duty of architecture and the built environment is to understand and interpret physical and metaphysical role-players in order to innovate responsibly - to investigate, understand and connect issues that are related but removed from each other. When the proximity of such issues are drawn closer and the issues start to overlap, new fields for innovation are created. This thesis draws closer the proximities of global issues to local issues and develops an architecture within the new field that they create.

The project is organic and process-orientated. It is directed to both the past and the future. The thesis is written in a narrative manner so as to better relate the process involved in the unfolding of the design solution - in a spirit of discovery, exploration and progressional fantasy.

Figure 1: Investigation topics that inform the development of the project [author, 2010].


real world challenges
living heritage
architecture
contemporary philosophy
local application
search for and discovery of site
search for appropriate interventions

proximity

chapter one

greater proximities

The exploration on proximities drives the project investigation from a greater background study to a specific site and program. Decision are made from an applied research methodology and critical analysis. The architectural project and its context was localised within the city of Pretoria, South Africa. Drawing closer the proximity of global issues to local issues, the field for design and development was found within the site of the Old Pretoria West Power Station. Simultaneously, the same research methodology led to the development of the program of urban agriculture, and specifically vertical agriculture.

21st century
urgent urban challenges

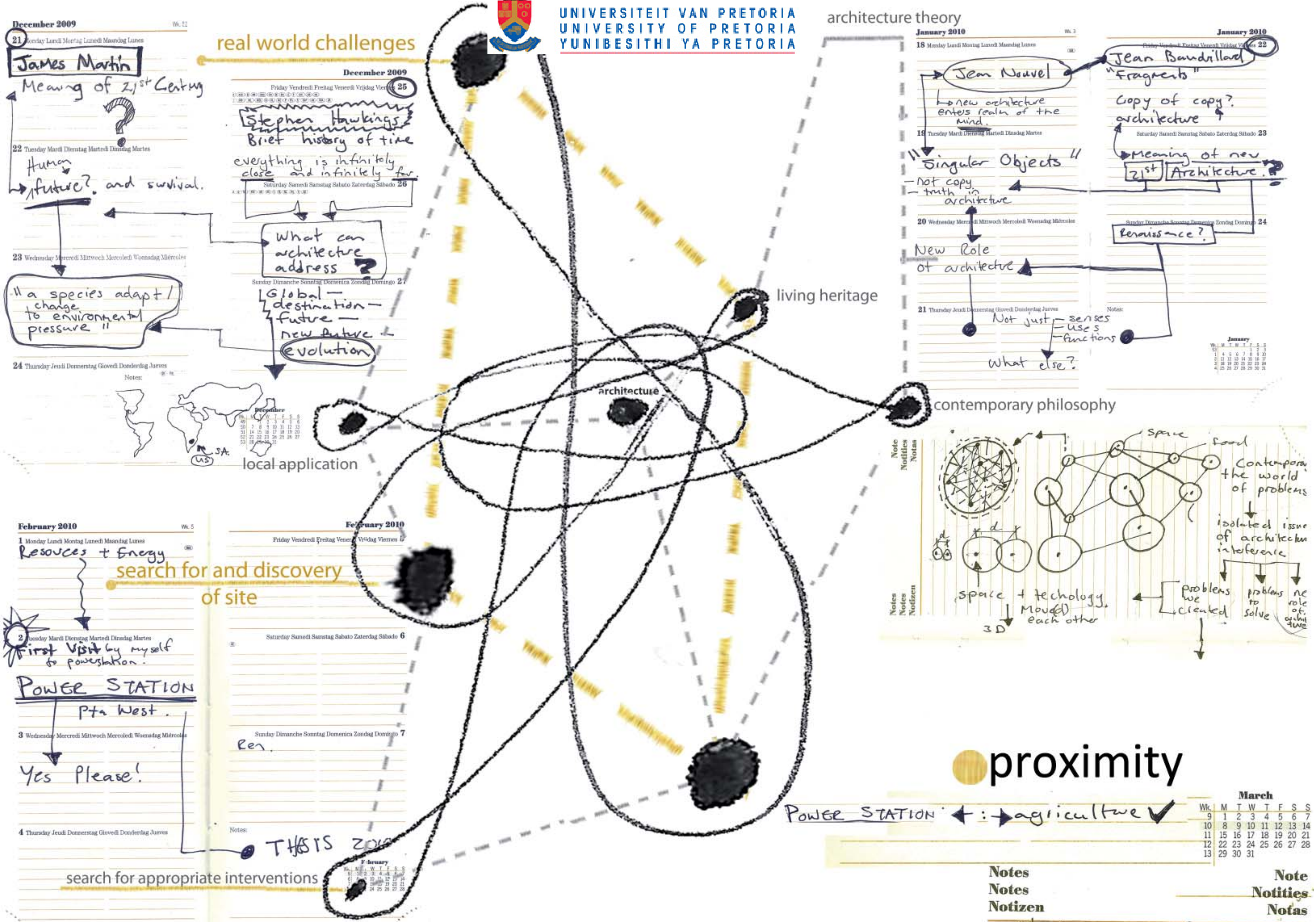
The research questions rose firstly from a background study on the current zeitgeist of the 21st century and its projections for the next century and beyond. From this background study, the initial direction of the project was driven by three topics: the Megacity phenomenon; increasing scarcity of resources (especially land and water) and the true power of humanity's control over its own future.

By closing in from these greater proximities to local proximities, new roles for architecture can be found. The field created between them is further investigated for a conclusion on site choice and program choice.

"...the 21st century is an extraordinary time - a century of extremes. We can create much grander civilizations or we could trigger a new Dark Age. There are numerous ways we can steer future events so as to avoid the catastrophes that lurk in our path and to create opportunities for a better worlds. A revolutionary transition is ahead of us.... this could be humanity's last century, or it could be the century in which civilization sets sail towards a far more spectacular future."

James Martin
The Meaning of the 21st Century, 2006

Figure 2: Investigation material that guides the development of the project [author, 2010].

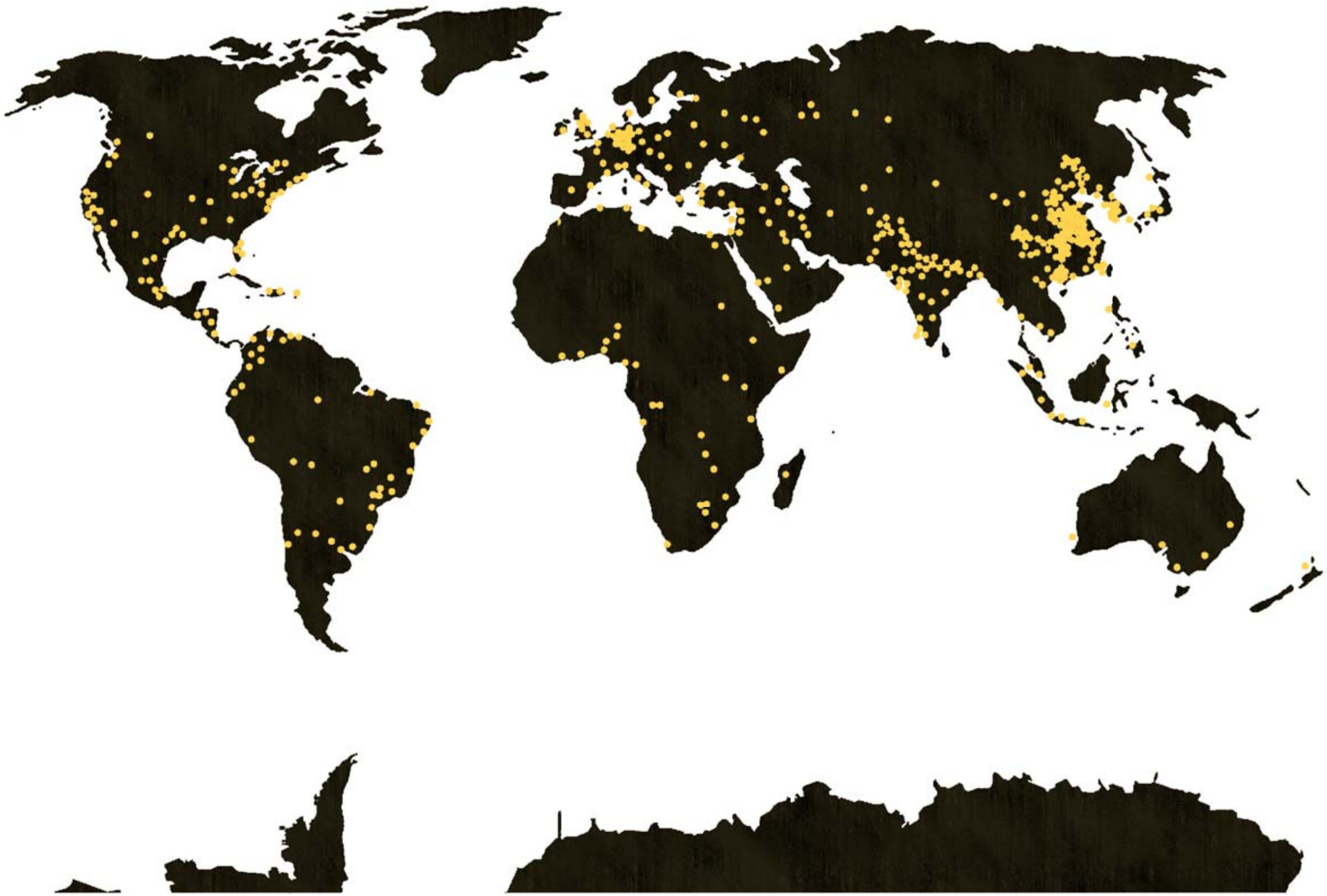

real world challenges
architecture theory
living heritage
contemporary philosophy
architecture
local application
search for and discovery of site
search for appropriate interventions
proximity
James Martin
Meaning of 21st Century
Human future? and survival.
Stephen Hawkings
Brief history of time
everything is infinitely close and infinitely far
What can architecture address?
"a species adapt / change to environmental pressure"
Global — destination — future — new future — evolution
Jean Nouvel
new architecture enters realm of the mind.
"Singular Objects"
- not copy
- truth in architecture
New Role of architecture
Not just — senses — uses — functions
What else?
Jean Baudrillard
"Fragments"
Copy of copy?
architecture
Meaning of new 21st Architecture?
Renaissance?
Resources + Energy
First Visit by myself to powerstation
POWER STATION
Pta West.
Yes Please!
THESIS 2010
POWER STATION ← : → agriculture

proximities our current world

In his book, "The Meaning of the 21st Century", James Martin illustrates the importance of the 21st century. In the past, world history took its course and was marked by scholars decades, sometimes centuries later. Event and direction happened almost per chance and evolution was slow. Now, in the 21st century, we are for the first time dually active participant and historical witness of our own time [Martin, 2006:226]. Long-term future scenarios are moving ever closer to our present short-term decisions as global issues are affected by the direction of individuals and individual societies. The 21st century is the emergence of literal global consciousness: we are intertwined in each other and with the earth, for better or for worse, as we are closing in on not only physical human proximities (visible energies and resources) but also on metaphysical or virtual proximities (invisible, digital or microscopic energies and resources). We are comprehending and directing our own evolution via the emergence of digital culture and the origin of truly abstract and "invisible" landscapes (virtual media) and "invisible" technologies (nano- and biotechnologies) [Martin,189-274].

Martin further stresses the fact that at the end of the 21st century, we are either going forward as a civilization or stepping into a prolonged new Dark Age [Martin, 2006:xiii]. For progression, Martin relates the importance of the sustainment of localities within a global network. Furthermore, Martin illustrates a very unnerving fact - humanity's fate is not blindly fatalistic anymore, but rather humans have the ability to direct their own goal-orientated development and advancement into the future [Martin, 189-232].

Figure 3: Cities with populations over 1 million, 2006 [author, 2010].
adapted from wikimedia commons



james martin

The Meaning of the 21st Century, 2006

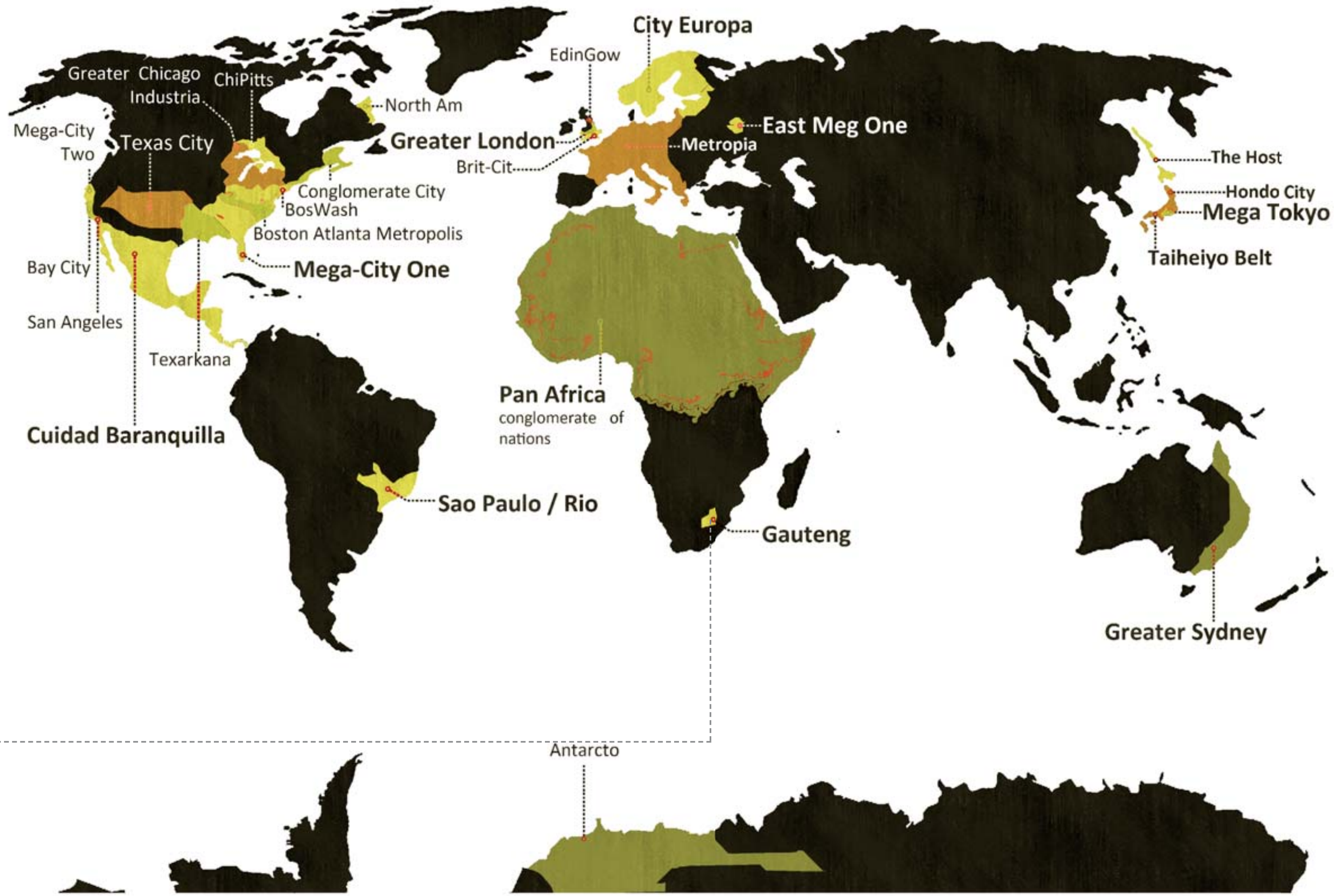
Martin is futurologist and researcher at Oxford. He won the Pulitzer Prize for his insightful book, 'The Wired Society." He is founder of the James Martin 21st Century School, Oxford (founded 2005) and also the World Education Corps (2002).

global 20th century

distance is gone, locality is everywhere

near future megacity phenomenon

Figures 4: Predicted megacities of the future [author, 2010] *adapted from http://io9.com*



Cities are developing into inevitable megacity scenarios, and the future of architecture is certainly urbanistic [Nouvel, 1997:95]. Proximities increase as we crowd closer, but we traverse further for our limited resources - land, water and food. Furthermore, cities are expanding onto traditionally "no-go" industrial peripheries and we are now faced with exploring new typologies of industrialised urban cells - places where production and living collide. The human habitat is slowly trying to evolve into habitats that are self-sustaining local entities. This is evident through new legislations suchs as *Green Star* or *Leed* rating systems as well as in local policy making [SANS 204-1:2008], and most importantly on socio-economic level through the Green Economy revolution [South African Cities Network, 2009:37]. We are, and must continue to, evolve into cultures that use intelligent technologies to be a productive and sophisticated civilization. This generation of professionals have exciting and daunting new roles to play in this Transition Century [Martin, 2006].

South Africa is already moving towards its own powerful megacity as the Federal and Commercial capitols collide

r i c h a r d r o g e r s

World Sustainable Building Conference, Tokyo, 2005

"...the urgent task is to forge an environmentally responsible modern architecture, to use technology to **achieve beneficial ends** - the ultimate aim being to achieve carbon dioxide neutral environments...."

"...by **fusing** social concerns, technological and structural innovation and environmentally responsible design, I'm convinced that a truly modern architecture for the 21st century can be created...."

nd study, the most pressing issues are listed [Martin,281-293] in order to understand where architecture can play its new role in the development of the 21st century. By identifying which global issues are directly related to architecture and the built environment, it became clear that architecture and the built environment can answer to many of the most pressing global challenges that we are faced with today when taking on the role of a producer of energy and resources.

The earth [1] and ecology is the most important informant on program and site choice as the project aims to draw closer on the proximity of the built environment of the 20th century to a ecological environment of the 21st century. This indicates that the project should minimise its impact on the earth by decreasing its carbon footprint as much as possible. The building must therefore develop on or re-use existing built fabric, incorporate renewable and sustainable materials and structure choices and be as self-sufficient in its energy consumption and supply as possible.

The next issue addressed is that the project must be economically profitable, economically sustainable, create work and aid in alleviating local poverty [2]. The project must provide work for a workforce of a majority of simply educated persons (or even non-educated persons) and unskilled labour. The program and building must be instructional and exemplary in order to empower individuals or groups to learn and apply knowledge from the project elsewhere.

The project aims to encourage lifestyle changes [3] by advocating localised, resource-efficient, sustainable, urban living as a norm - creating a sustainable productive culture. This means that project must also be public in nature and participate with urban activities in an active (formal) as well as a passive (informal) manner.

This project addresses these issues and strives to provide a solution to global challenges in a local environment in the pursuit of localised, resource-efficient, sustainable urban cells. By identifying these global issues locally in the city of Pretoria, the project intensifies the proximity of global issues to local problems and opens up a field for development for architecture and the built environment to take progressive steps forward. The project aims to be a pilot project for South Africa. The lessons learned here must be improved and developed on further to aid in the development of not only South African cities, but also in the advancement of civilization as a whole [15].

Cities need to respond and start to cultivated resource-efficient, local, productive societies. The conclusion is drawn that the issue of production and industry is an incredibly important factor in the direction that urban development takes. By drawing closer on the above mentioned issues, it became clear that the program and site must address issues of industry and production processes in an urban environment

The role of architecture and the issue of production and industry and the urban environment is investigated further.

challenges connecting proximities

the new role of architecture as producer can answer to the most crucial of these challenges directly

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1 the earth 2 poverty 3 population 4 change of lifestyles 5 war 6 globalism 7 the biosphere 8 terrorism 9 undiscovered areas of creativity 10 disease 11 new human potential 12 the singularity 13 existential risk 14 transhumanism 15 advanced civilization

progressive role of architecture

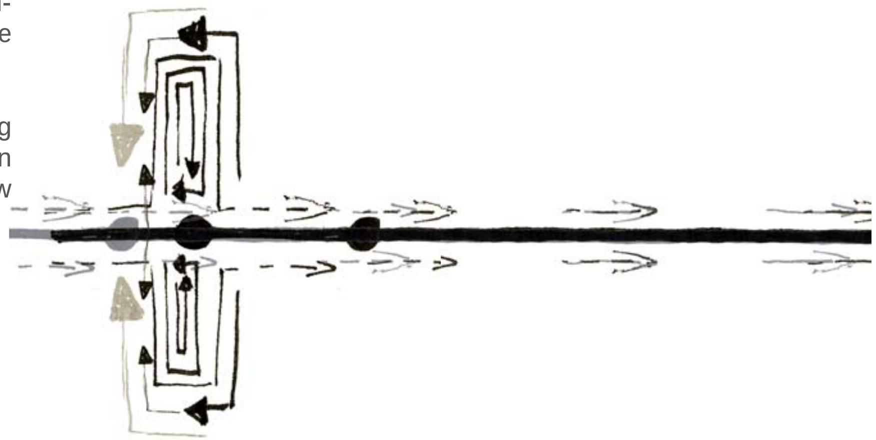
An interesting dichotomy formed as humanity starts to focus on true sustainability. The world's view of itself has changed from isolated fortress cities into a hybrid, global system of networks in urbanity – where the connection of localities is the most important aspect. We stress narrowly on locality but connect endlessly worldwide. In this way, as individuals or as societies, we are daily narrowing our proximities with increasingly different cultures and sub-cultures, and also with new professions, new materials and virtual media. These proximities crash with each other sometimes intentionally but mostly spontaneously and spur on exciting developments. Surely, architecture should be informed by its own time and project innovation towards the future similarly? Should we not adopt additional or new roles in architecture before we call a "new building" 21st century "architecture"?

After considering this background study on the 21st century, it became clear that the field of architecture must develop many more attributes. In addition to sensory or sensational design, ergonomics or tectonics of object or space, architecture now has an additional characteristic: that of a local provider and supplier. The architect Jean Nouvel has a similar viewpoint and he believes that as a profession, architecture has the tendency to become too isolated [Nouvel, 1997]. Architects can too easily interpret the real issues of our time superficially and represent these solutions as visual misnomers, without really addressing them and their implications in their totality [Nouvel, 1997]. The contemporary philosopher Jean Baudrillard, who conversed closely with Nouvel on this topic, agrees and comments that the 21st century asks of architecture to be more than a reaction of physical dimensions only, but also reaction on a greater scale of metaphysical dimensions of virtuality and seemingly invisible systems and landscapes [Baudrillard & Nouvel, 2002:18].

To meet the challenges of the 21st century; to aid in the reintegration of production and industry into urban society; and to fulfil the need to generate sustainable urban cells and networks, the project aims to develop a the new role for architecture in a 21st century productive culture. From stagnant, passive and consuming buildings towards progressive, active and productive buildings, the new role of architecture is future-driven and goal-orientated and the new building aims to be a productive, active participant and catalyst for sustainable urban living.

The new role of architecture therefore implies that the building must be actively producing energy or resources within an urban environment and stimulate sustainable urban living. The new role of architecture is an architecture of production.

Figure 5: Architectural progression is informed by the discovery of new future-orientated roles [author, 2010]



passive^architecture

challenging a stagnant, passive architecture of consumption by investigate new roles for architecture

“When a philosopher says that philosophy proceeds by concept, science by prospect, and art by precept and effect, he is drawing our attention to the prospect, to that which science can contribute. Heidegger’s provocative statement comes to mind: “Science doesn’t think”. That’s not what it’s there for.”

jean nouvel
selections from *Lectures at the Centre Pompidou,* 1997

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“I want to ask the contemporary architectural world how **architecture for the coming era** should be manifested. Regarding the expression of the ideas that will be proposed, an abstract methodology is fine....practical proposals for compositions of systems are also welcome. The issue is not to discover new values in architectural elements, but to construct **new relationships between architecture and nature....”**

tadao ando
at the *World Sustainable Building Conference, Tokyo,* 2005

t

productive architecture

creating new roles for architecture by investigating future-orientated, roles architecture can have as an active, productive supplier of energy and resources

integration industry and production

From the transition of the 20th century into the 21st century, the Megacity phenomenon changed the urban condition in its relationship with production and industry. The pre-modern industry and production components [1] were mostly smaller, localised and internal scenarios within the walls of the city. They had a close proximity with urban program and processes. With the progression of the Industrial Age and the 20th Century, proximities shifted between industry and urban conditions. The intensification of the industry and production components became increasingly necessary yet increasingly alienating human environments. This cause them to be pushed out from the city to become unfavourable edge conditions [2].

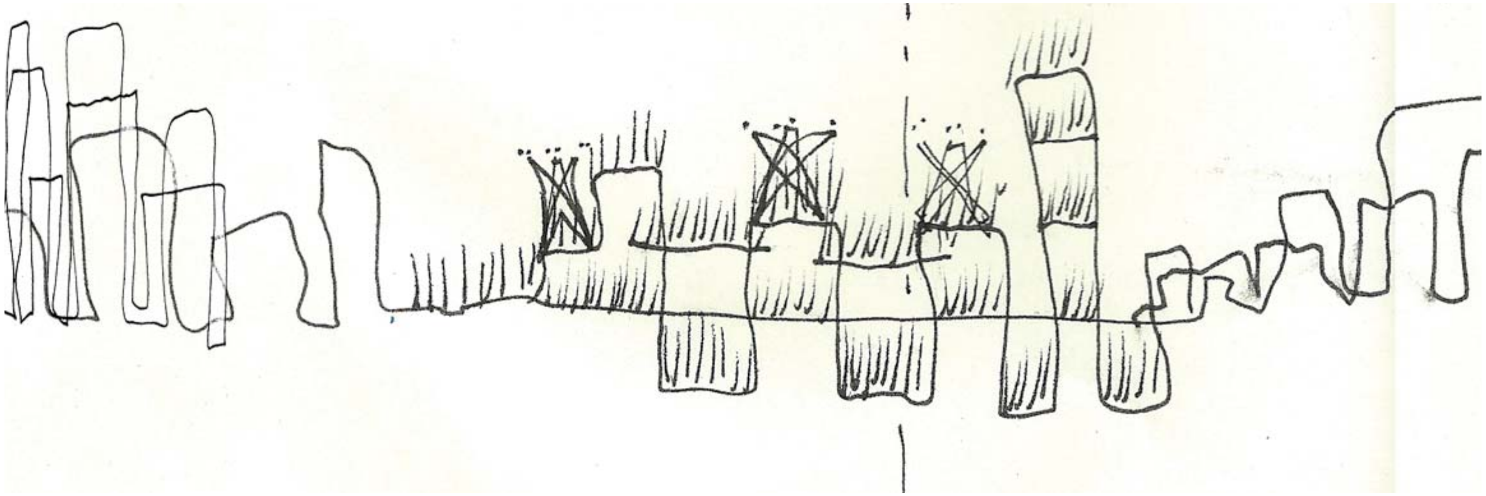
In the 21st century, however, the Megacity phenomenon drives cities into conditions of edgelessness as extreme populations and urban sprawl overtakes the traditional edge conditions of cities [3]. The proximities between urban conditions and industrial processes close in and they start to envelop each other. Also, the old technology of the 20th century - especially technologies involved in energy production and the energy industry - cannot cope with the demands of the 21st century and the environments that housed them are abandoned. Lastly, the need for cities to become resource-efficient and sustainable, requires new urban form and reform - networks of urban cells configure to form of smaller, localised, productive urban societies.

The closing proximities of production and the urban environment open a field for creative and progressive development for not only urban form, but also architecture and its role in productive urban environments. The site and program addresses the issue of 21st century urban conditions by developing on an industrial 20th century edge condition of the city of Pretoria.

A suitable form of production or industry to illustrated the integration of production and urban environment, as well as the new role of architecture as producer, is investigated further.

Figure 6: Transitions of industrial conditions within an urban setting from Pre-Modern to the 21st century. This global phenomenon and transition of industrial urban landscapes is also found in Pretoria, South Africa, [author, 2010].

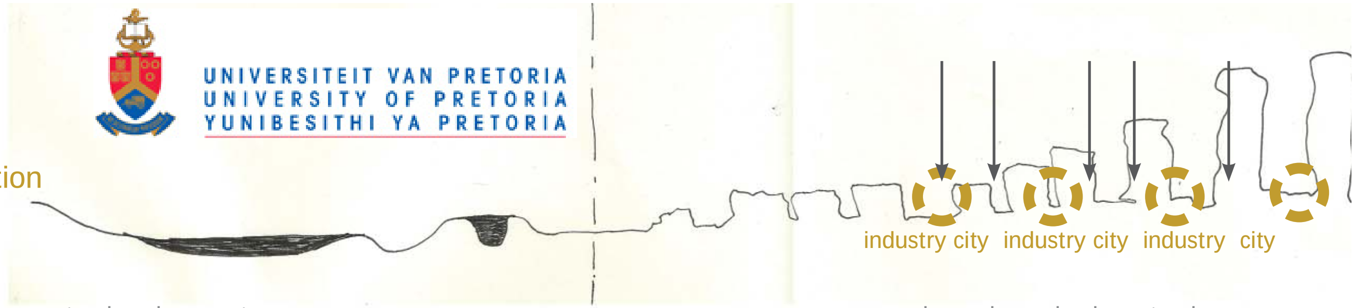
[3] **2000-2100** shifting proximity of industry and production within the urban environment



industry transition

world-wide urban phenomenon

[1] 1850 pre-modern city - edgeless production

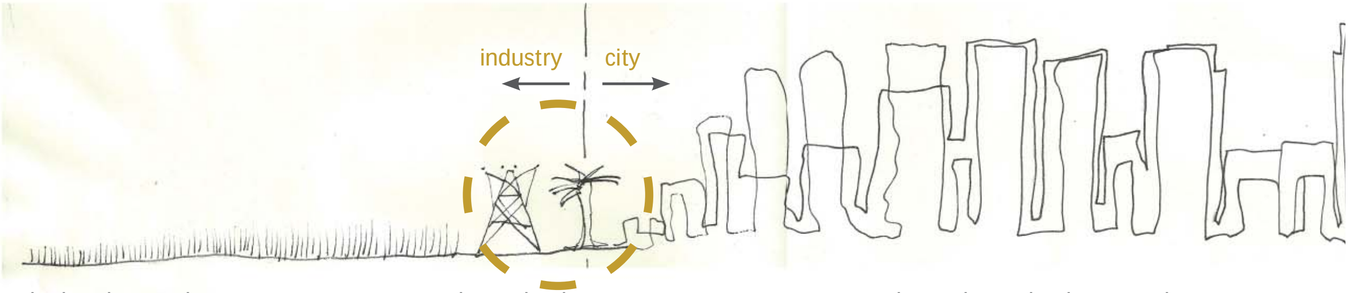


natural environment

clear edge by natural or man-made element (wall, river, hill)

clear urban edge by natural or man made-element
edgeless production

[2] 1900-2000 modern city - edge industry

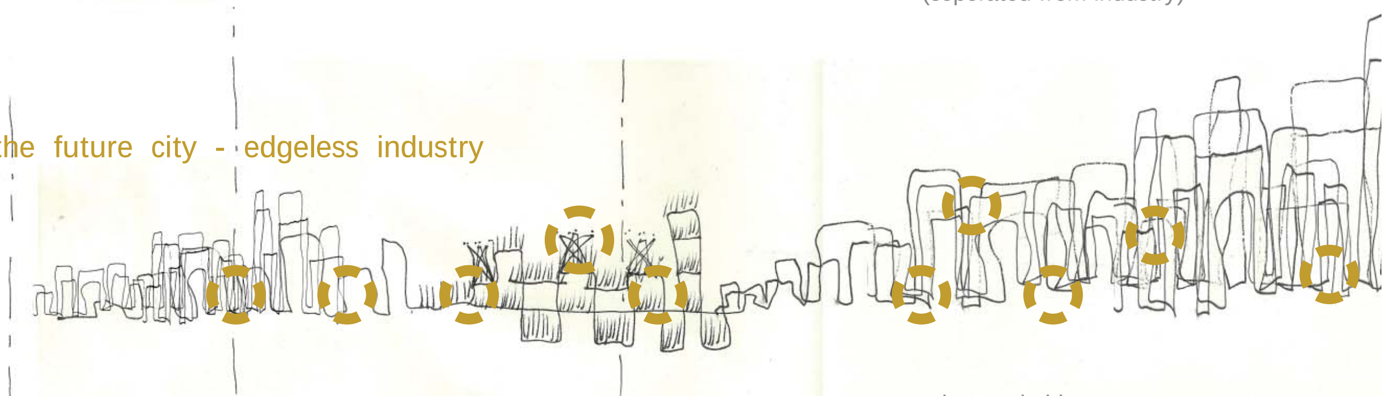


manipulated natural environment

clear edge by program
edge industry

clear urban edge by natural or man made-element
(seperated from industry)

[3] 2000-2100 the contemporary and the future city - edgeless industry



human habitat

edgeless from the “natural” (manipulated or wild) environments
edgeless industry

human habitat
integrated with industry

21st century
urgent human challenges

The conclusions drawn from the 21st century urban conditions and the new role of architecture as producer indicate that the topic of production in urban environments is the most pressing issue. Furthermore, within the past decade, food production and food supply has become an increasing concern and valuable commodity. Prices have in some instances surged by 50% to 200% [Eickhout et al, 2009].

The socio-economic problems that follow are enormous, yet the main issues are the speculation in food stocks (especially in low cereal stocks); unpredictable and extreme weather events; the rising industry of the production of bio-fuels competing with cropland for food production and finally, the very high oil and transport costs consumed by the food production in the traditional agriculture industry. The result is that either the food prices increase drastically, or cropland expansion occurs at the loss of valuable land and biodiversity [Despommier, 2008]. The global issue of food production for urban populations has local parallels in South Africa [Combrink, 2010]. The proximity between the issue of food production an urban density creates new field for architecture and urban design.

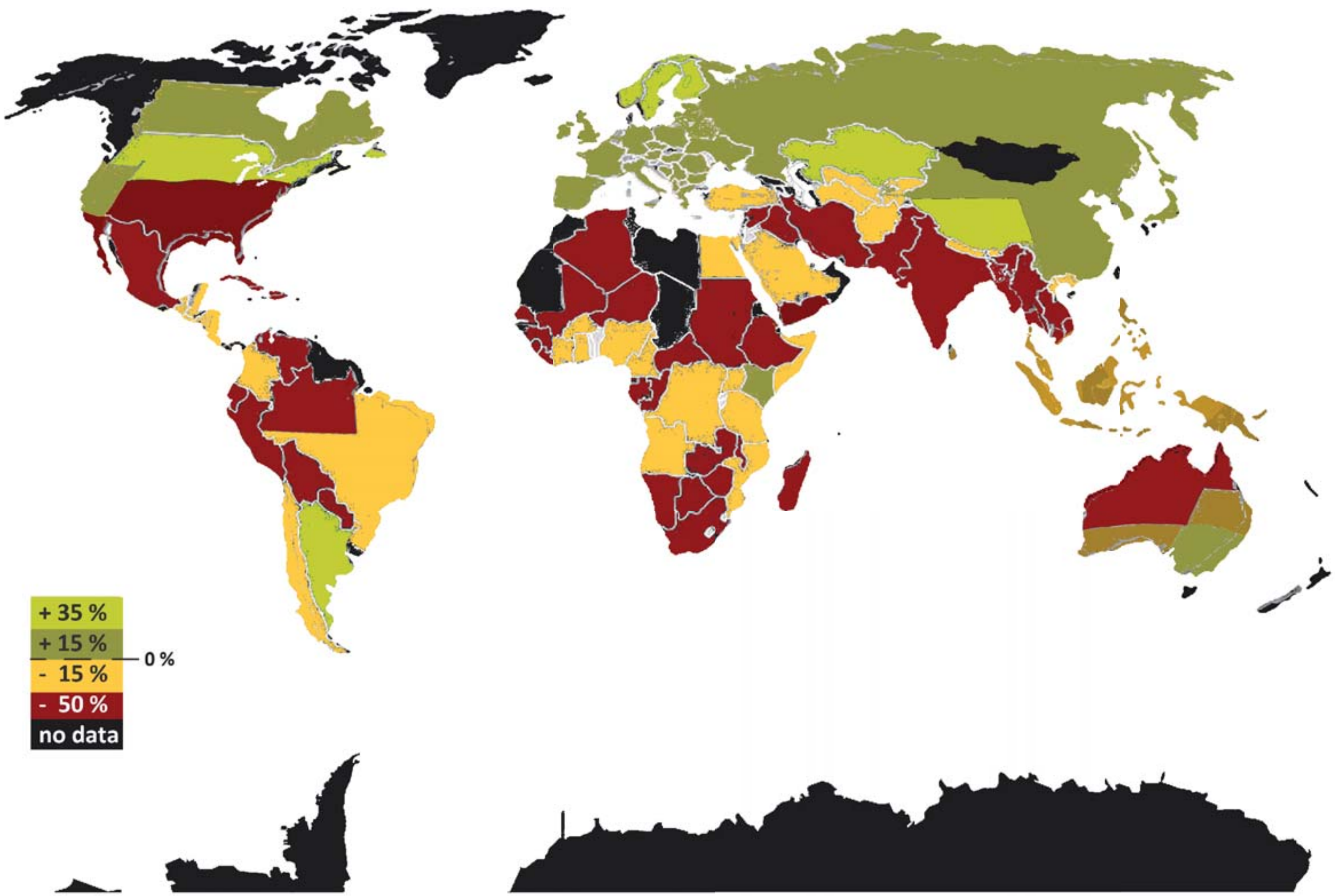
"...one solution involves the construction of urban food production centres - vertical farms – in which our food would be continuously grown inside of tall buildings within the built environment...All of this may sound too good to be true, but careful analysis will show that these are all realistic and achievable goals ..."

dickson despommier
The Vertical Farm, 2008

food shortage food crisis 2080

: Projected losses in food production due to climate change by 2080.
adapted from Eickhout et al, 2009:46, author 2010

According to Dickson Despommier, with the world population increasing (estimated almost 8.6 billion people within the next 50 years) it is simply impossible to cultivate enough arable land, outside cities, to meet food production criteria [Despommier, 2008]. However, the technologies for food production increase annually [Despommier, 2008] and urban agriculture is practiced successfully in countries like Cuba and Japan. By producing food at the same place of its consumption, the system of urban agriculture reinforces a healthy, sustainable and resource-efficient balance of production and consumption. According to architect and author Andre Viljoen, urban agriculture is effective, practical, time efficient and not only aids in reducing high embodied energy use caused by contemporary western food production systems, but also provides new opportunities for employment, security, and urban rejuvenation across many scales [Bohn, Howe, Viljoen 2005:12]. Urban agriculture advocates that the global and national food supply systems of countries are by definition local industries The advantages of commercial urban agriculture outweigh the disadvantages considerably. It is far easier and more profitable to pursue urban agriculture as a form of livelihood than ever before. The techniques are wide-spread - from low tech, low education systems like small plot intensive farming *(SPIN Farming)* to hydroponic and aquaponic agriculture. Vertical and urban farming is taking a turn for the best in local and commercial application worldwide through companies like *Brightfarm Systems* and projects such as *Gotham Green* (New York), or *Pasona* (Japan). The farming industry is closing proximity inwards towards the urban environment.



dickson despommier

The Vertical Farm Project, NYC

Dickson Despommier is a professor environmental health sciences at University of Columbia, New York and director of *The Vertical Farm Project.*

world agriculture projection

projection changes in global agricultural productivity 2080

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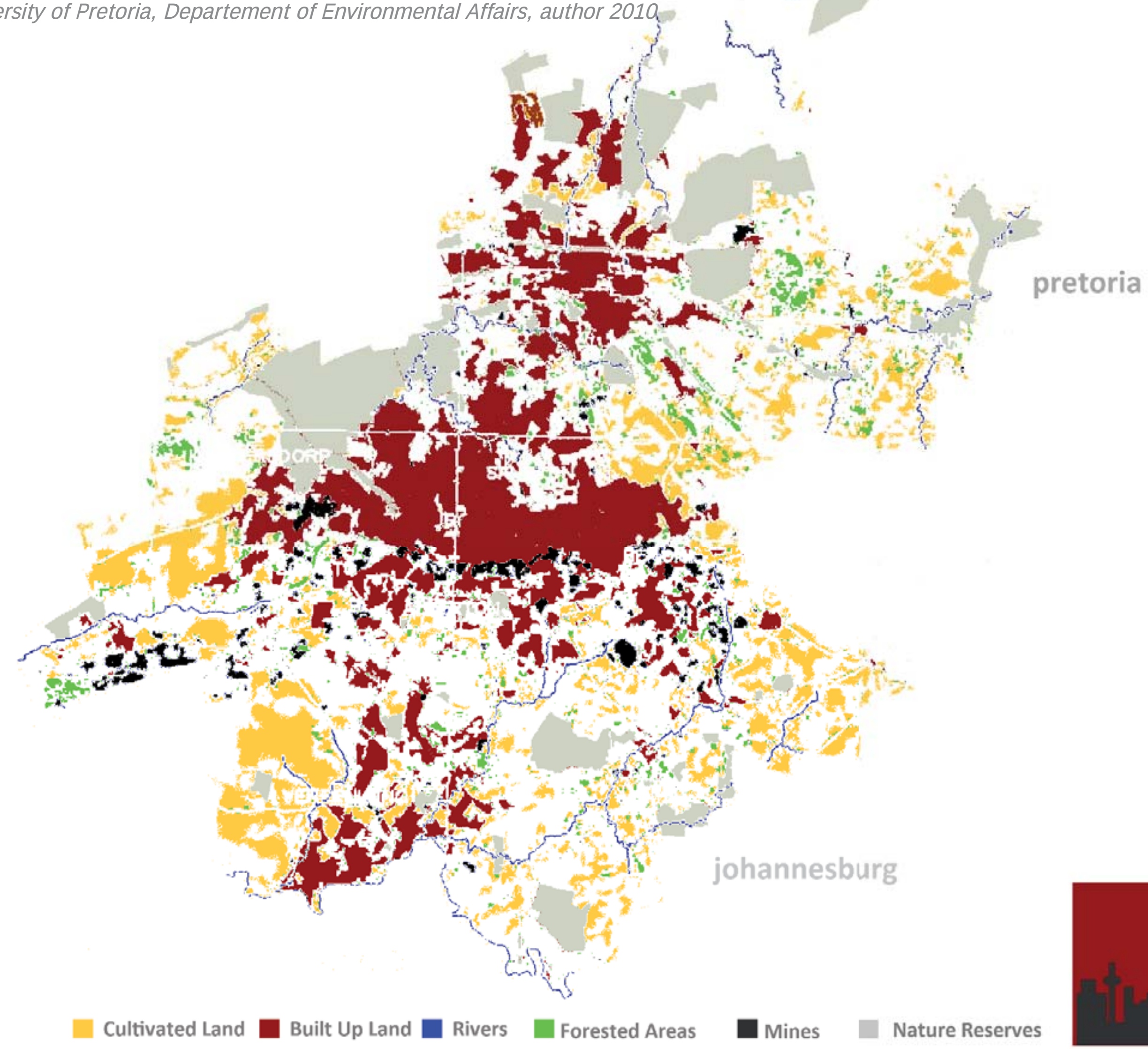
Figure 8: Similarities of global conditions to conditions in Gauteng
adapted from the University of Pretoria, Departement of Environmental Affairs, author 2010



gauteng local symptoms

challenge the integration of urban agriculture in the built environment

land shortage vertical agriculture advantages

Despommier further indicates that 38% of the landmass of the earth is currently used for food production [Despommier, 2008]. Besides the massive consumption of land, there are many draw-backs on land-based commercial agriculture - *urban* land-based agriculture also. Most importantly, it was proven with an experiment conducted by Dickson Despommier and his students in 1999. The experiment calculated how much food can be produced to supply for 50,000 people a daily calory intake of 2,200 calories in the city of New York using land- or soil-based urban agriculture. Using rooftops, parks and vacant land, it was not possible to provide food for even 2% of those 50,000 inhabitants [Cooper, 2009]. There is simply not enough horizontal space for efficient crop production to feed the populations of all our cities. There are many other problems with conventional, land-based agriculture besides requiring space. Crops are completely vulnerable to the elements and conditions of weather and seasons. In countries with droughts, famine or food shortages, these are great tragedies and can set agricultural production back many years. There is considerable uneconomic use of resources in land-based agriculture, including wastage in agriculture run-off, loss of energy resources in the loss of organic wastes of non-edible biomass production, general water mismanagement and losses, and infections of crops with foreign contaminants from adjacent sites and neighbouring crops, or issues of pest and vermin control. Also, the transport, packaging and refrigeration components and the effort to deliver produce to cities nationally or internationally contribute to great consumptions of fossil fuels. Lastly, most cultivated lands, commercially or privately owned, have long-term destructive implications and damage on natural ecosystems that takes years to repair [Despommier, 2008]. These are just a few problems, the list goes on considerably.

It is therefore essential to optimise land for crop production. Especially in urban areas, arable land within in cities that can produce enough commercial crops for the consumption of the inhabitants is extremely limited and will never reach food requirement targets [Despommier, 2008]. Vertical agriculture is a solution to the pressing problem of commercial food production for and within cities. Half a hectare of vertical farming can be an equivalent of traditional soil-based hectares by factors ranging from to 4 or 20, depending on crop types [Despommier, 2008]. In addition, vertical agriculture is an ideal program for the re-use of existing structures or buildings, and can give a new dimension to dilapidated spaces and environments within cities [Buck et al, 2004:5].

It was decided that vertical agriculture is the most suitable program for the thesis as it draws closer the proximities of industry, agriculture and the urban environment in a new field for architecture. It is now possible to explore the new productive role for architecture as it collaborates with agriculture and industry in a local urban environment.

south africa

"South Africa is a nett **importer** of food. even with our rich land and resources, we have a dire food security problem. This problem is real and current. In parallel, alternative methods and new farming technologies are **also real and current.** These systems are viable, productive, sustainable and profitable.

South Africa should lead this productive process and not merely **aid** in food security, but take courageous steps to **solve** food security problems. This pressing problem has a simple solution: intensive urban agriculture."

Morkel Combrink [combrink, 2010].

Continuous, annual crop production - no crop failures due to variations in weather conditions.

Agricultural run-off is minimised and water resources management is maximised.

Massive reduction in the use of fossil fuels (farm machines, transport of crops, long-term refrigeration and packaging et cetera).

Can be developed on abandoned or unused properties.

Provides for local sustainability for urban centres.

Can convert black and/or grey water into potable drinking water.

Contributes energy back to the grid (methane or bio-gas generation).

Provides new urban employment and urban rejuvenation possibilities.

Reduces the infection risks to crops (as found on the traditional agricultural interface).

Returns farmland to a much more natural environment, helping to restore damaged ecosystem operations.

Vermin and pests are eliminated and very easy to control.

Can consume off-site wastes example collecting and using restaurant bio-wastes for methane generation.

the vertical farm project, university of columbia

The Vertical Farm Project was started in 2001 by Dickson Despommier, a professor of environmental health sciences and microbiology at Columbia University, New York. This project has done substantial research on vertical agriculture, focussing its research on the production of food for 50, 000 people by a single building. The research ranges from topics on crop production, energy needs and consumption and possible materials. This project research was applied critically and adapted where needed in order to produce a model and solution for Pretoria and South Africa.

Applying the knowledge gained from the *Vertical Farm Project* and other independent research, the new hydroponic factory aims to be a pilot program for vertical agriculture for South Africa.

However, the urban conditions of Pretoria cannot match the urban conditions of New York City and so do not allow for the scale of the vertical agriculture project in Pretoria to reach the magnitudes of heights or footprints proposed by *The Vertical Farm Project.* Although crop types are similar, the new hydroponic factory in Pretoria will not cater for animal husbandry and this was factored out of *he Vertical Farm Project* model. Also, the vertical agriculture buildings proposed by the *Vertical Farm Project* are almost 30 storeys high and become extremely expensive and unfeasible in local application, and the strategy was changed. Instead of aiming to feed 50,000 people by a single building, it was decided that more buildings of a lower scale should rather be distributed around the city to produced crops commercially.

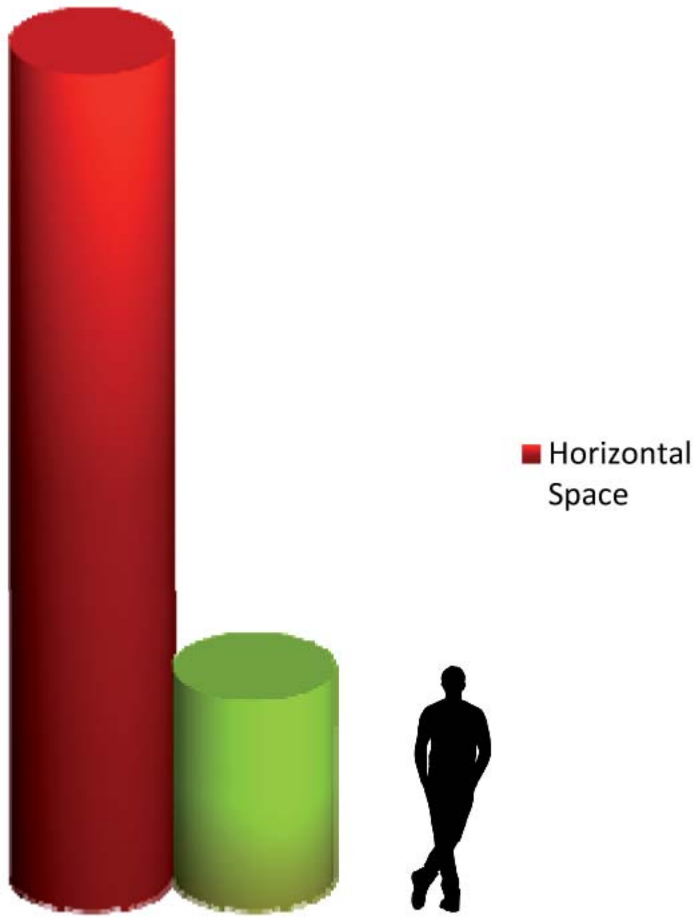


Figure 9: Graphic indicates the land use per capita for crop and food production. It does not even take into account values required for grazing for animal husbandry or fossil fuel consumption. This illustrates the advantages of vertical agriculture as a solution to the optimization of valuable land [author, 2010]

research strategy

From the background study and theory, a research strategy is formulated on critical analysis and applied research strategies.

problem statement

The issues raised from the background studies formulate three problem statements. Firstly, how can architecture aid in the reintroduction of productive processes or industries into an existing urban environment? Secondly, how can architecture aid in the creation of local, resource-efficient, sustainable urban support cells, and lastly how can a building be developed in an idiom of the new role of architecture as a producer of energy and resources?

hypothesis

Architecture can generate a sustainable, resource-efficient, productive society by changing the current culture and perception of urban production.

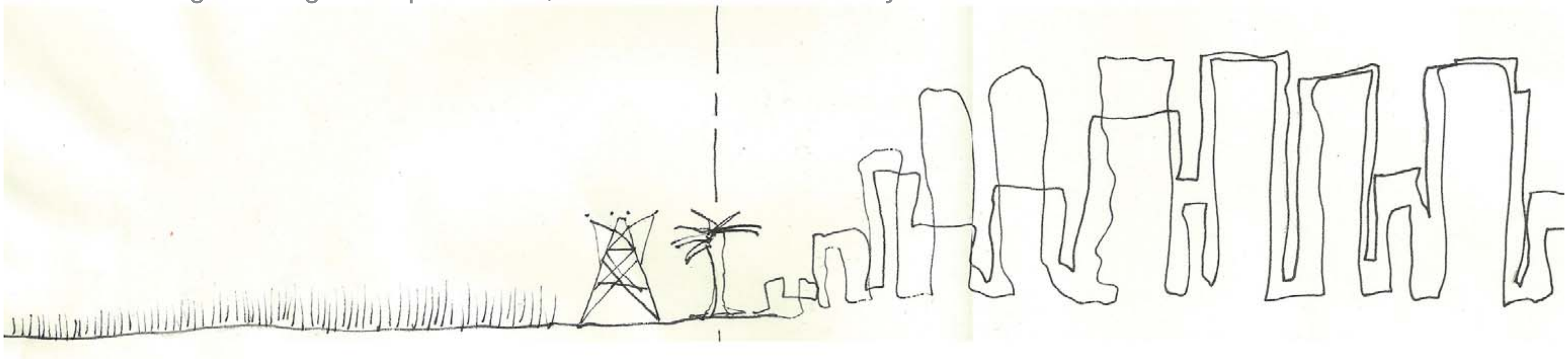
sub-questions

- What is a greater sustainable, continuous productive urban society and how can architecture encourage this within the city of Pretoria, South Africa?
- What type of architecture can be developed for vertical agriculture in South Africa?
- How can industrial heritage be configured to generate a sustainable, resource-efficient, productive culture?

1 **the reintroduction of productive processes into the urban environment**

2 the role of architecture as local support cell within the urban environment

3 the evolutionary role of architecture as a supplier of energy or producer of essential produce to meet contemporary and future challenges of a greater productive, resource-efficient society



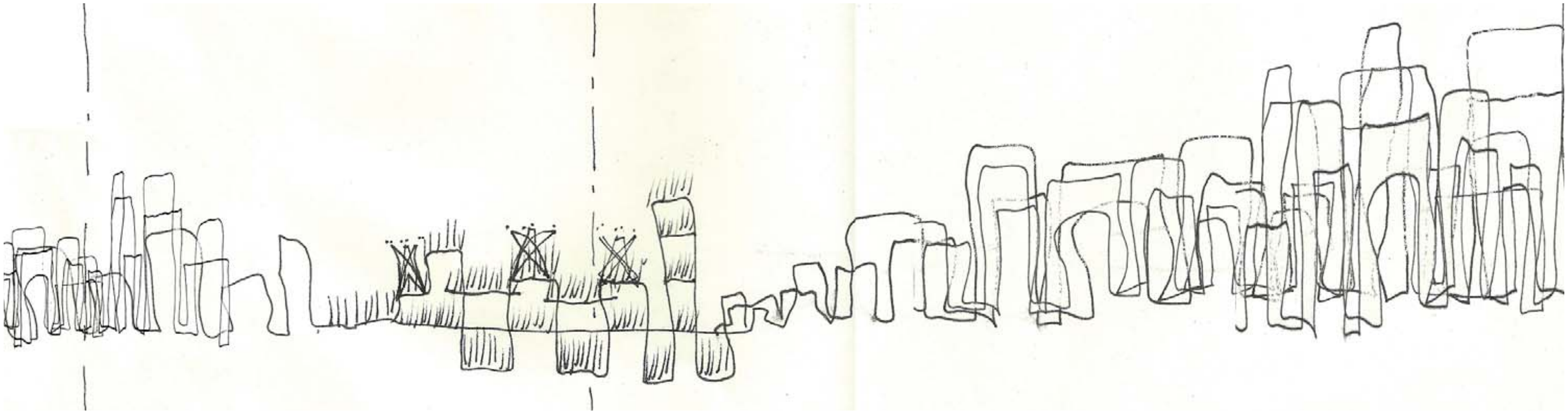
aims of study

The aim of the project is to illustrate that by drawing closer the proximities of food production and the urban environment; by developing the new role of architecture as producer; and by the re-use of industrial heritage, the architecture can generate a sustainable, resource-efficient, productive society by changing the current culture and perception of urban production.

Architecture can do this by bringing closer a tradition of distant commercial agricultural practice into the urban environment to integrate with more intimate social, activities of the city. This is done through vertical agriculture.

The design also aims to generate a new perception and understanding of the value of industry within cities and the potential of industrial heritage to reform dilapidated urban conditions. This will be illustrated by developing on a historic, industrial edge condition within the city of Pretoria.

to generate an architectural model for vertical agriculture for the city of Pretoria, on an existing industrial heritage site



methodology

Research for the project was done through descriptive and applied research methodologies. The following research techniques were applied:

observation

Research through observation was conducted by documenting and forming a greater framework vision for the site through the Pretoria West Framework Group, 2010. The specific site (the Old Pretoria West Power Station) was observed and documented through numerous site visits and on-site interviews. A guided tour of the site was also crucial in understanding its history , processes and development. Further observations were made by visiting local commercial farmers and food packing houses to understand the process involved in food production and transport. Visits to larger and smaller food markets across the city were conducted.

mapping

Observation and mapping within the framework work area and the site informed design decisions. This technique was used to map greater movement patterns around the site, pedestrian patterns across the site, greater and intimate site specific systems, heritage components, production processes, material and energy influx and distribution.

archive

Historic aerial photographs, maps and articles were studied to comprehend the development of the study area. Data from municipal records was also collected.

precedent and case study

The programmatic precedent of vertical agriculture was developed on the research model of *The Vertical Farm Project.* This was adapted and internalised for the new project in Pretoria. Precedent studies in regards to the adaptive re-use of industrial heritage buildings was also investigated.

correspondence

The program of vertical agriculture has limited to no professional correspondents in South Africa. International e-mail correspondence in regards to commercial, urban agriculture and small plot developments, commercial hydroponic culture, vertical agriculture, and other topics had to be conducted. The staff from *The Vertical Farm Project* provided valuable crop data that could be converted for local application.

descriptive interpretation

The data was collected through observations, archival and survey records, precedent, personal interviews and discussions, and finally email correspondence. The information is described and interpreted so that logical, realistic conclusions and models can be made for local application. The research is then further interpreted and configured to develop a solution for local conditions within Pretoria.

applied research

The descriptive research culminates in a site specific, conceptual model. This is developed into in an architectural built form and expression.

interviews discussions

Interviews and discussions were conducted with parties over the entire scope of the project. The most important interviews are mentioned here:

South Africa - The head engineer of the Old Pretoria West Power Station, Mr. Fio Masut, provided incredible amounts of valuable information and historic photographs that could not be sourced from anywhere else. This information was then shared with the University of Pretoria, South Africa, to be archived. He also related information on the current and futures status of the site and its relationship to the city of Pretoria, without which, the project would not be feasible.

South Africa - Mr. Morkel Combrink is an agricultural economist and provided information, guidance and most importantly, a critical professional opinion and motivation for the feasibility of the vertical agriculture for the specific site, for Pretoria and for the greater South Africa. He also guided decisions on crop choices and the project scope.

South Africa - Mr. Deon Brink is an chemical engineer currently completing his PhD in chemical engineering at the University of Pretoria, South Africa. He provided information on the energy production capabilities of the new design and the project as whole through its bio-gas and methane generation and energy potential.

India - Mr. M.C. Mahant is a specialist in bamboo construction technology. He provided guidance and information on the development of bamboo and bamboo technology as a possible structural system for the project.

Other interviews and discussions were informal in nature and were conducted on site or within the greater framework area.

It is clear from the interviews conducted that the project has enormous research potential for South Africa in many specialist fields, and the aim of the project is therefore to be a base for such research. It should be specifically noted that this document provides an *architectural* response and that the design solution aims to provide a platform for further development. The design solution is a *response* on these interviews - a reaction and interpretation on the provided information. Concepts are derived from the various informants to provide an architectural answer to a current and future project. The aim of the project is to determine what such a building would be like for South Africa, to develop a conceptual architectural model of how these systems could coexist, to explore alternative options and ultimately aid in the development of a new 21st century building and program.

Figure 10a (middle) and 10b (top right):
Important interviews [author, 2010].

chapter two

nearer proximities

From the background study, the selected work area of Pretoria West was identified and investigated. The area was studied through observation and mapping. This concludes in choice of a specific site to further meet the project aims.

c o n t e x t
pretoria west, tshwane

The greater proximities study and background research, along with the greater theoretical positions led to an intense search for a site that can address the issues locally. The urban laboratory of Tshwane, more specifically the city of Pretoria, hosts a number of the global symptoms that were listed previously: it has issues of scarcity versus density; it is in a constant state of transition and reformation; and the urban environment deals with many variations in proximities - of time and distance and scale.

Within the city of Pretoria, the area of Pretoria West was identified as an important historic and current industrial sector. Within this study area, a greater framework vision was developed [Pretoria West Group, 2010] and the Old Pretoria West Power Station was identified as the site with the most potential to develop on.

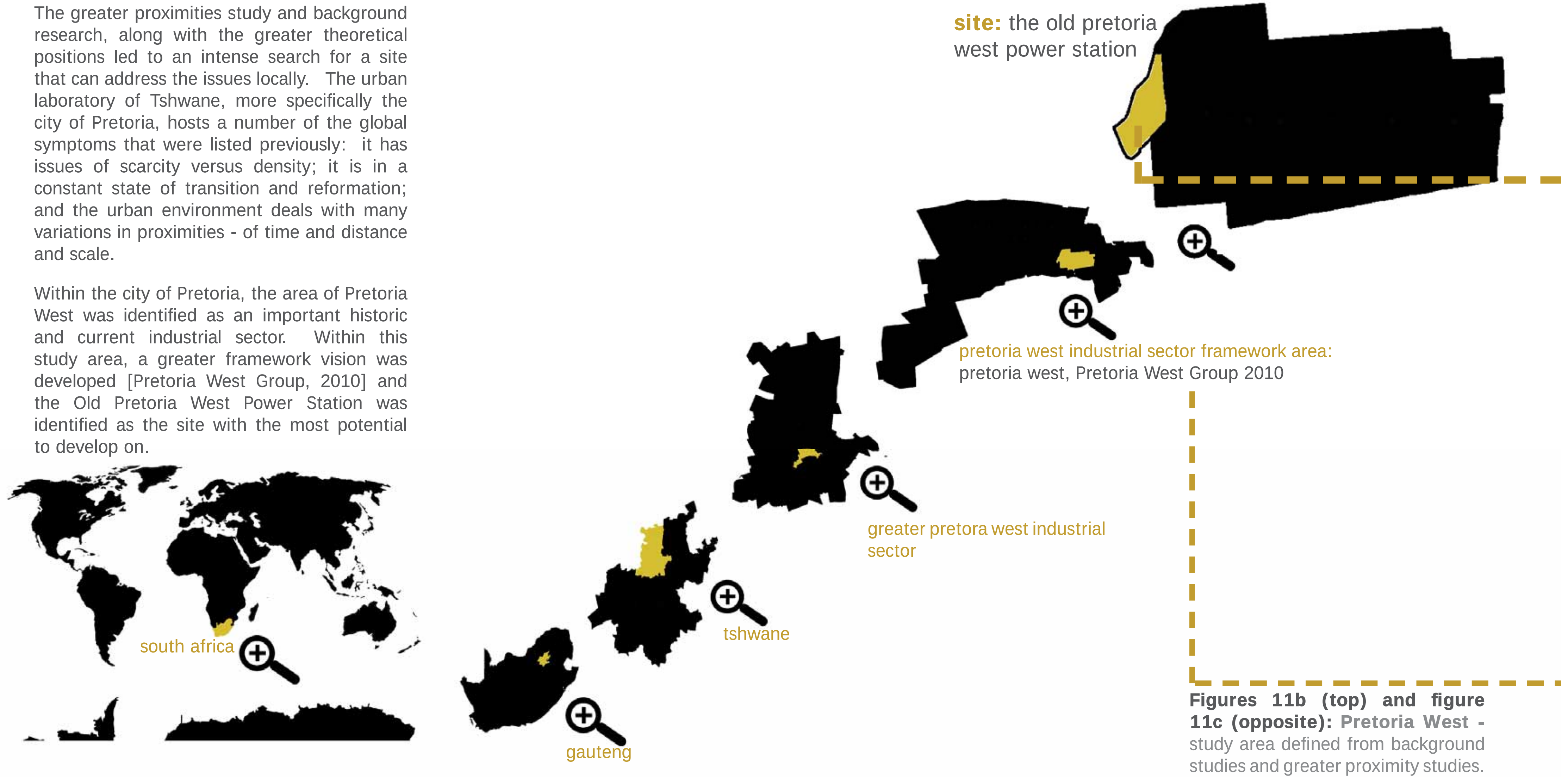


Figure 11a: Site location of the Old Pretoria West Power Station in context to Pretoria, City of Tshwane [author, 2010]

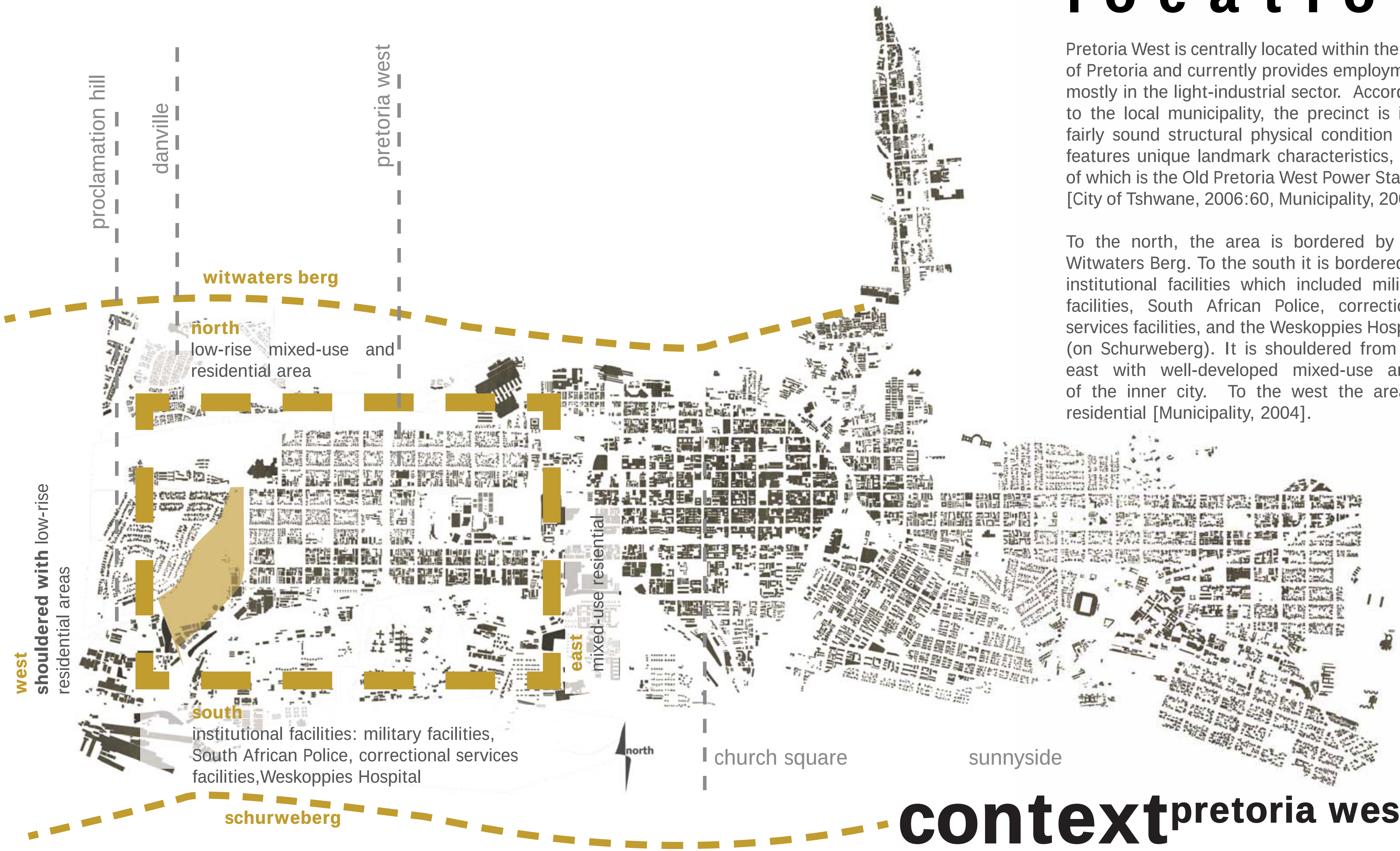
Figures 11b (top) and figure 11c (opposite): **Pretoria West** - study area defined from background studies and greater proximity studies. The focus became the development of Pretoria West and then Pretoria West Power Station as an energy point [Pretoria West Group:2010]


<<<discovery of site
the old pretoria west power station
framework area>>>
urban framework and analysis developed for pretoria west [Pretoria West Group, 2010]
north
church square
sunnyside

location

Pretoria West is centrally located within the city of Pretoria and currently provides employment mostly in the light-industrial sector. According to the local municipality, the precinct is in a fairly sound structural physical condition and features unique landmark characteristics, one of which is the Old Pretoria West Power Station [City of Tshwane, 2006:60, Municipality, 2004].

To the north, the area is bordered by the Witwaters Berg. To the south it is bordered by institutional facilities which included military facilities, South African Police, correctional services facilities, and the Weskoppies Hospital (on Schurweberg). It is shouldered from the east with well-developed mixed-use areas of the inner city. To the west the area is residential [Municipality, 2004].



context pretoria west

Figures 12 and 13 (opposite): Analysis [author, 2010].

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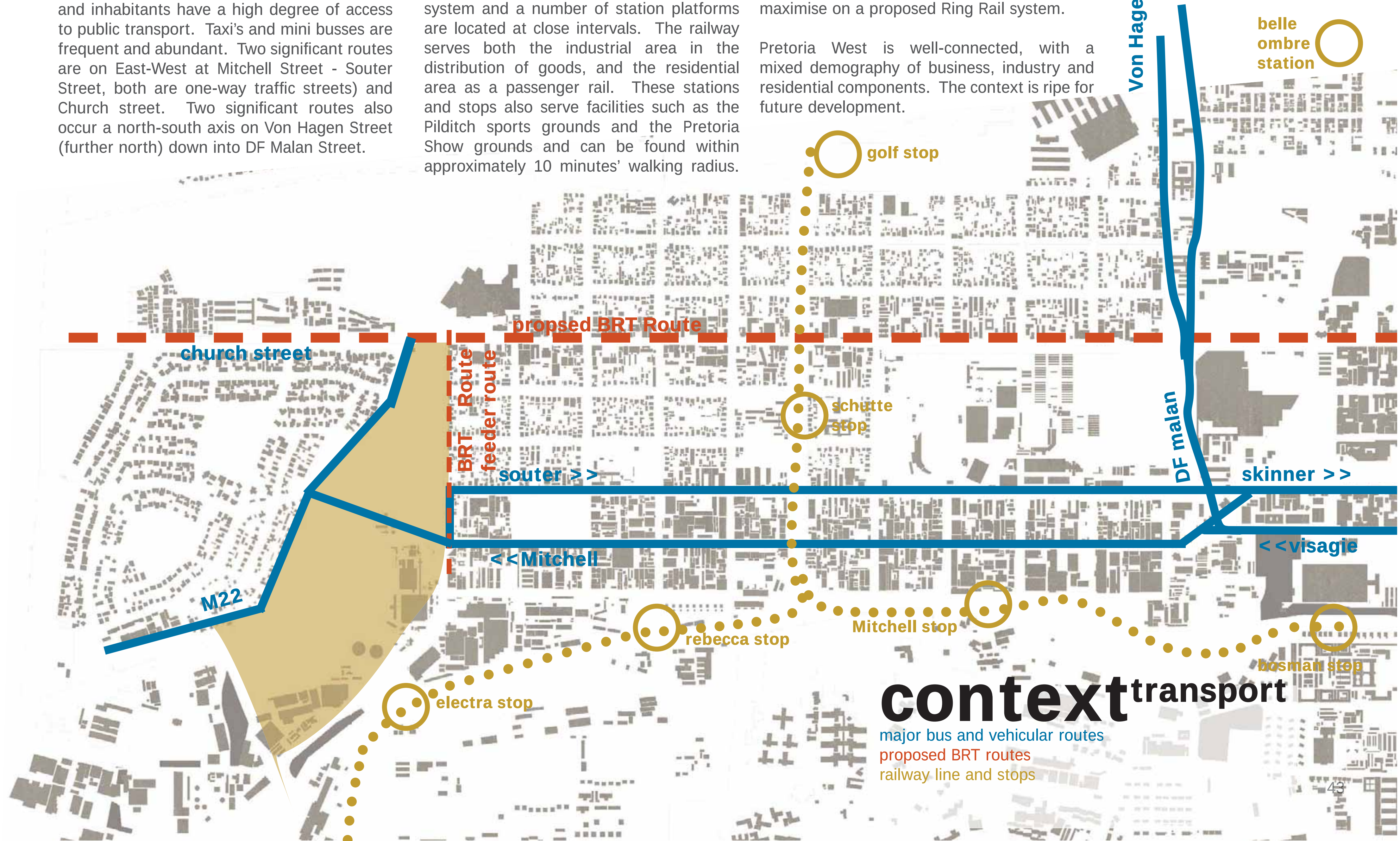
a c c e s s

The road system has bus stops on most blocks and inhabitants have a high degree of access to public transport. Taxi's and mini busses are frequent and abundant. Two significant routes are on East-West at Mitchell Street - Souter Street, both are one-way traffic streets) and Church street. Two significant routes also occur a north-south axis on Von Hagen Street (further north) down into DF Malan Street.

The area is also intertwined with a railway system and a number of station platforms are located at close intervals. The railway serves both the industrial area in the distribution of goods, and the residential area as a passenger rail. These stations and stops also serve facilities such as the Pilditch sports grounds and the Pretoria Show grounds and can be found within approximately 10 minutes' walking radius.

Furthermore, the site is aptly located to maximise on a proposed Ring Rail system.

Pretoria West is well-connected, with a mixed demography of business, industry and residential components. The context is ripe for future development.



context transport

major bus and vehicular routes
proposed BRT routes
railway line and stops

Figure 14a - Passengers - Rebecca train stop

Figure 14b - Passengers - Rebecca train stop

Ample stops from the combined passenger and freight rail provides generous accessibility to public transport.
The power station (in the background) is also connected to this rail, at the Electra Stop, just further south down the track from the Rebecca stop [Pretoria West Group, 2010].

Figure 14c - Freight

Freight, goods and coal is provided by rail also.
Coal is transported all the way from the province of Mpumalanga, and is stored on site in the existing coal bunker [Pretoria West Group, 2010].

context getting into Pretoria West

Figures 14a- 14f: Collection of photographs showing that passenger and freight rail is a very good distributor of residential inhabitants, workers and goods for the Pretoria West sector

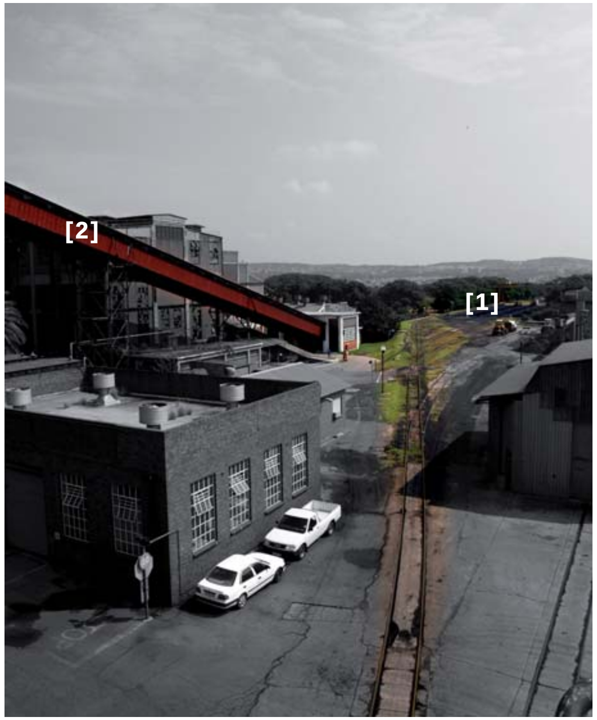


Figure 14d - Coal

Coal is brought in by rail and deposited in the coal bunker [1]. Then the coal is transported via a conveyor belt [2] from the underground bunker to Station-B for combustion [Pretoria West Group, 2010].

Figure 14e - Taxi's on Buitekant street

There is a bustling taxi culture for the workforce of the light industries and local and regional inhabitants. The site is extremely well located for other public transport also. There are many bus stops and a proposed Bus Rapid Transport route is also planned along Church street with a feeder route from Buitekant Steet [author, 2010].

Figure 14f - Access by private car

Pretoria West is extremely accessible by private transport. It is almost always busy on Mitchell Street (above), though traffic loses momentum quickly as one moves away even one block north or south from Mitchell Street [author, 2010].

context getting into Pretoria West

Figure 15a - Mixed-use light industry and residential

Although Pretoria West sector is not a particularly wealthy socio-economic sector, there is a healthy mix of industry, small businesses and residential components just a couple of blocks north of the power station [Pretoria West Group, 2010].

Figure 15b - Mixed-use commercial and residential

There are some residential apartment blocks (background) towards the north, intertwined with light-industry and smaller businesses [Pretoria West Group, 2010].

Figure 15c - Mixed-use rentals

Offices and apartments are available to rent across the entire sector, mixed with light industry and automotive industries [author, 2010].

context working and living in Pretoria West

Figures 15a- 15f: Collection of photographs showing proximity of industry to residential and informal urban activities

Figure 15d - Presence of the power station

Figure 15e - Presence of the power station

Informal urban activities occur right next to larger industrial processes, but without interaction or contact between the two. The power station (background) is completely shut out from the city, but is still has an imposing presence and contribution to the character of the area, the streetscapes and neighbourhoods [author, 2010].

Figure 15f - Presence of the power station

The site of the power station (background) as landmark is even visible from homes that are a couple of blocks away [author, 2010].

Figure 16a - More affluent areas

Just two blocks north of Mitchell street, the light-industry [right] infiltrates into the semi-suburban setting [left] [author, 2010].

Figure 16b - More affluent areas

Proclamation Hill is a well-maintained residential area, not even one kilometre away from the power station. This is a small park within this residential area [author, 2010].

Figure 16c - More affluent areas

Moving closer towards industry, the two programs of urban living and production intermingle [author, 2010].

context working and living in Pretoria West

Figure 16a -16f: Collection of photographs showing proximity of industry to residents and informal urban activities variety of living conditions

Figure 16d - Signs of dilapidation and neglect

The backstreets of the industrial areas however, also have the same scale and potential as the rest of the precinct, but show signs of considerable neglect [author, 2010].

Figure 16e - Potential for great vegetated urban spaces

The old vegetated and urban landscape has potential for great urban experiences, especially along the railway and towards stations [author, 2010].

Figure 16f - Hidden poverty

There are many signs of poverty, especially along the railway tracks, many shacks are hidden away in the rich landscape [author, 2010].

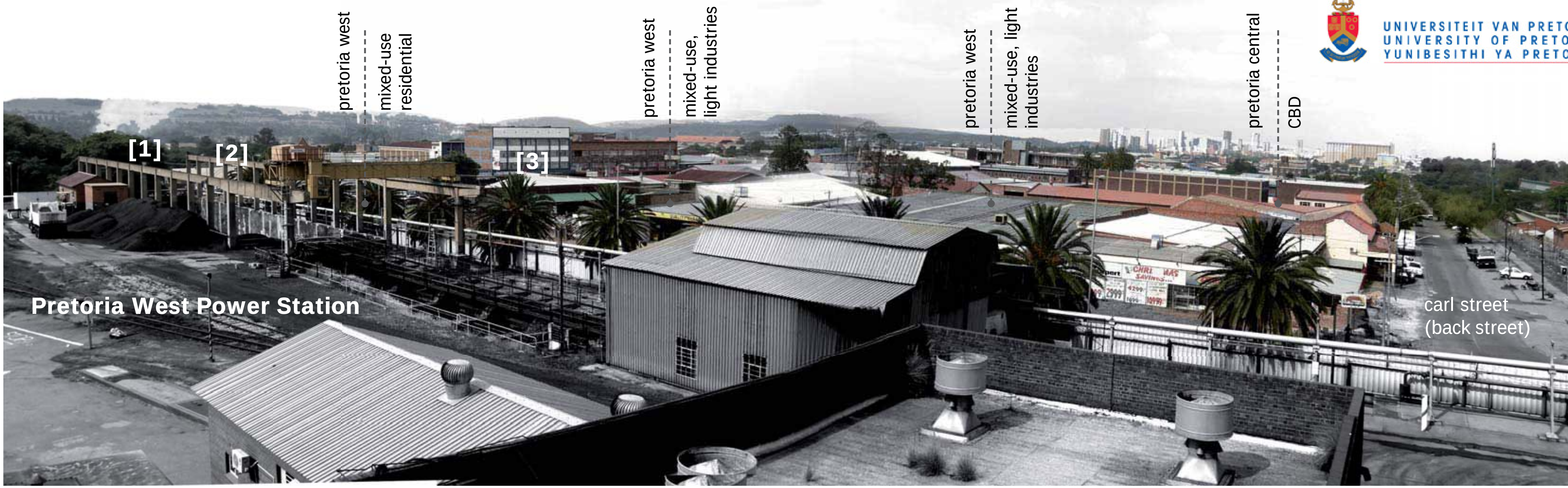


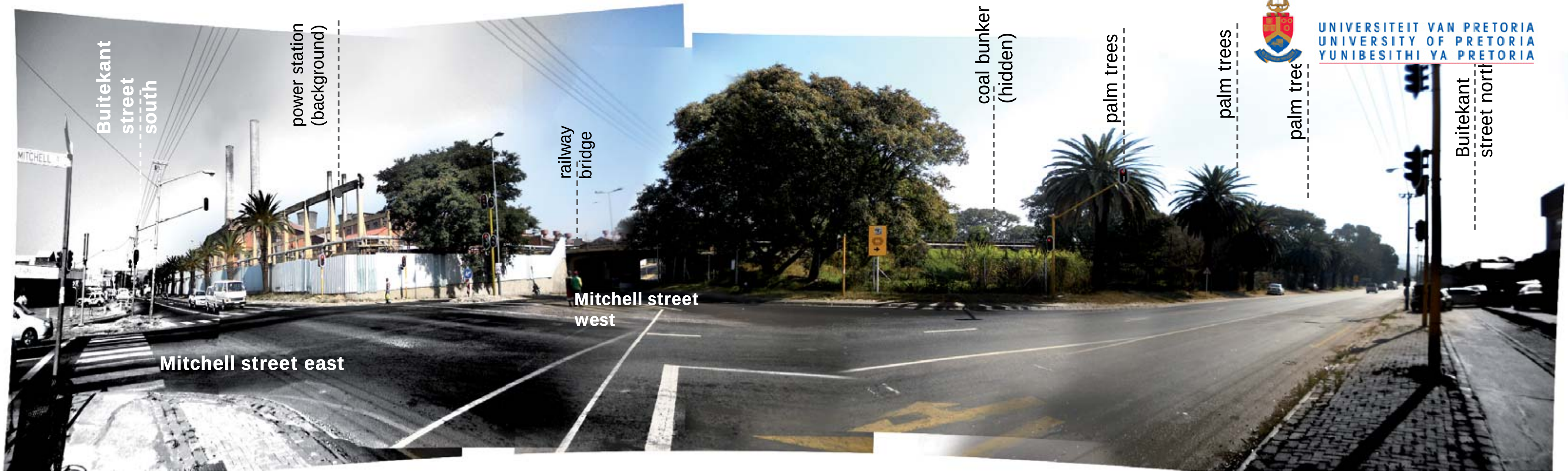
Figure 17: Panoramic view from the power station towards city of Pretoria [author, 2010].

Figure 18 : [1] Looking down Mitchell street towards Pretoria West
Mixed-use, light industrial character [author, 2010].

Figure 19 :[3] Looking down Mitchell street towards Pretoria CBD
the close proximity of the sector to the Pretoria CBD (background) [author, 2010].

context pretoria west

views from the power station towards the east and Pretoria CBD [author, 2010]



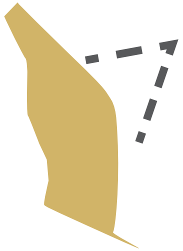


Figure 20 : Panoramic view from the corner of Mitchell Street and Buitekant Street [author, 2010].

Figure 21 : View from the railway bridge towards the east opposite view to the above panorama [author, 2010].

Figure 22 : [2] The corner of Mitchell Street and Buitekant Street Opposite view to the above panorama [author, 2010].

context pretoria west

views from the power station towards the east and Pretoria CBD [author2010]

c o n t e x t
pretoria west, tshwane

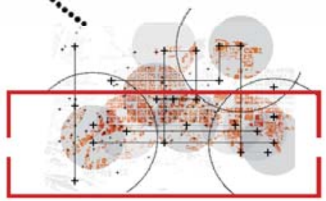
An urban framework study was conducted. Through observation and mapping, the framework concluded that among other urban problems of safety, vacant lots, abandoned sites and poor cross-programming, the Pretoria CBD is experiencing urban sprawl and emtying Pretoria West is suffering from this the most.

The framework vision for Pretoria West is to become and urban support cell to encourage a greater urban renewal for the inner city of Pretoria and counteracting urban sprawl. Having this support cell on the periphery of Pretoria CBD could aid in such an urban reform. The general negative perceptions on Pretoria West and industrial sectors dilutes the development potential of the site. The framework analysis revealed valuable properties and interests specific to the study area.

This sector is filled with hybrid programming that needs to be built on and enhanced. Stabke urban infrastructure is already in place, making it easy to develop the site into a walkable, live-work sector of the city. The area can support a wide range of programmes as it is directly connected to provincial and national systems of production, trade and transport. The city grid block sizes are also the same as inner-city of Pretoria and this indicates that the entire area can exceed its current densities. Lastly, this area has a very rich heritage value as it is more than a the century old and contributed not only to local history, but also national history.

These issues are investigated further.

Figure 23 (top) : Density and distance mapping
Understanding the potential of the work area by connecting proximities - places of importance, routes of importance and residential densities [Pretoria West Group 2010]



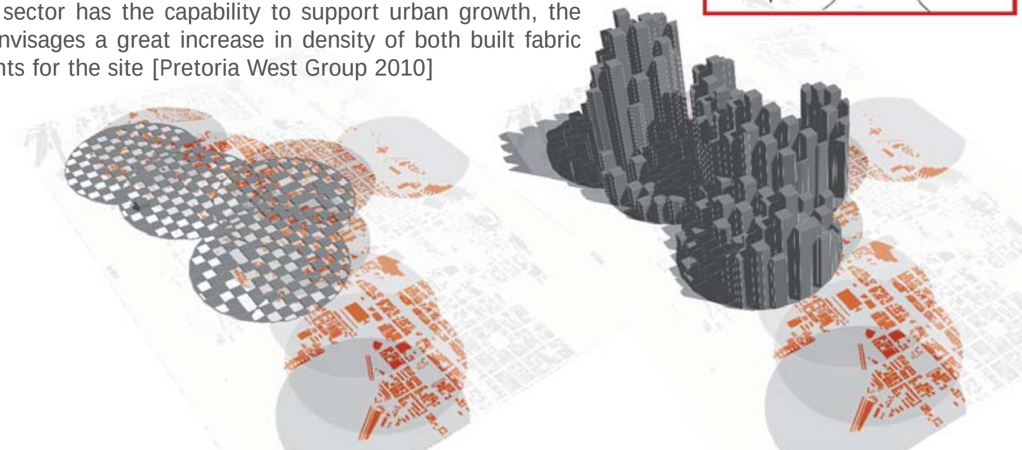


Figure 24 (below) : result and vision
because the sector has the capability to support urban growth, the framework envisages a great increase in density of both built fabric and inhabitants for the site [Pretoria West Group 2010]

context pretoria west densities
work area density studies

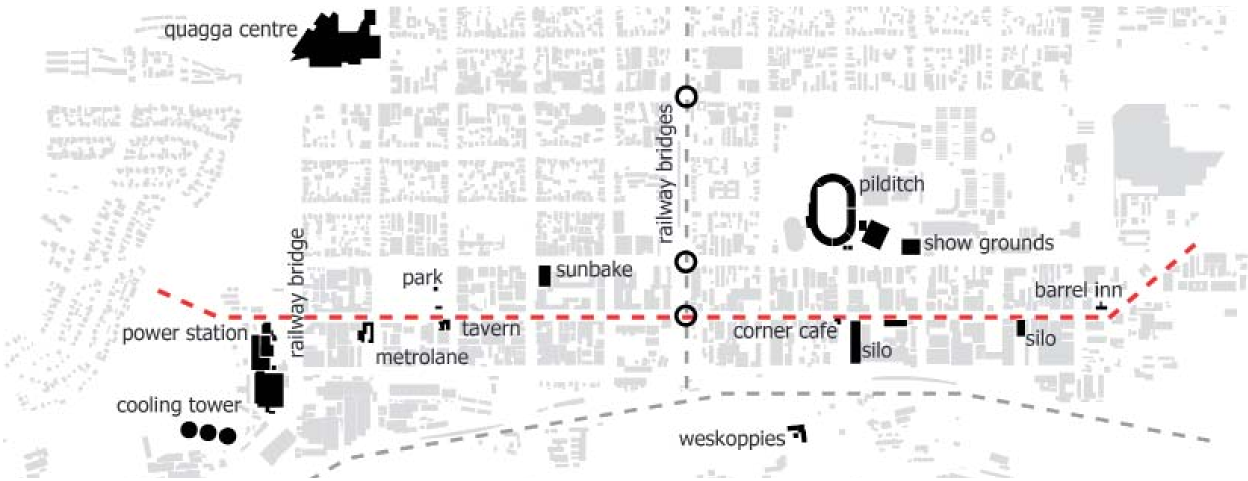


Figure x: Key landmarks
[Pretoria West Group 2010].

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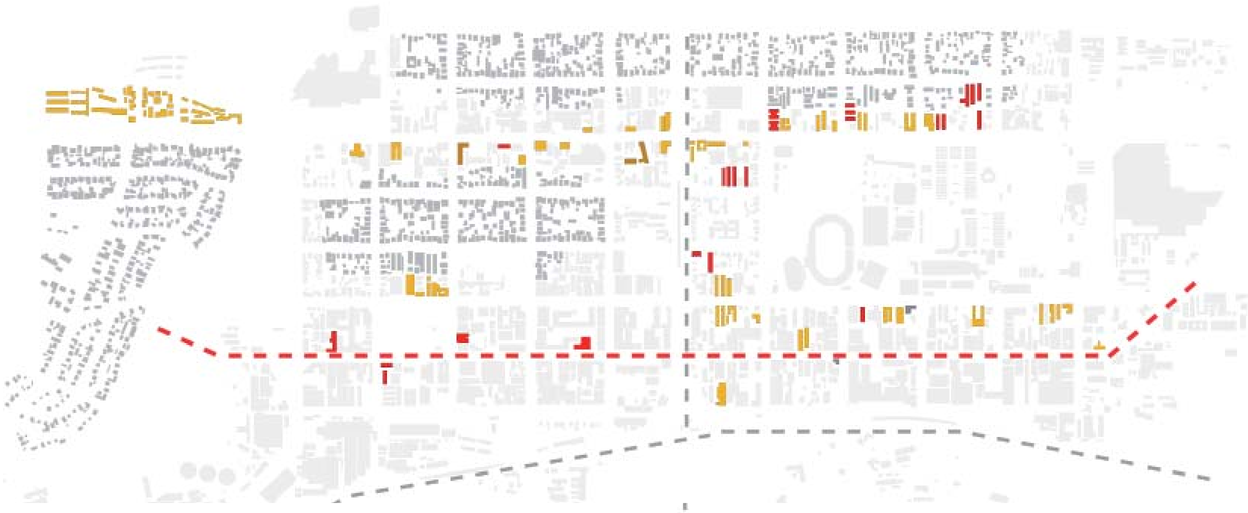


Figure 25 : Housing mapping
understanding the density of housing in the sector and Mitchell Street [Pretoria West Group 2010].

higher density
medium density
low density

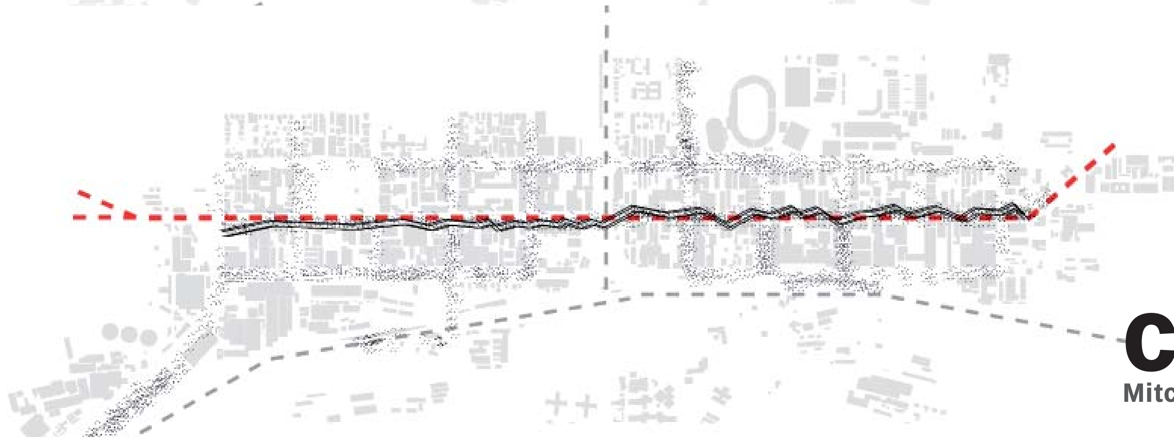


Figure 26: Pedestrian movement across Mitchell street towards the power station [Pretoria West Group 2010].

context Mitchell street

Mitchell street housing, movement and landmarks around Mitchell street

Current built fabric

Most existing built fabric towards the north is low-rise mixed-use. The existing built fabric towards the south has mostly industrial buildings.

Existing heritage buildings

Remaining heritage buildings of the area. The power station as a whole is a heritage site.

Lost heritage

Buildings that were destroyed or demolished.

context heritage mapping

Figure 27: Work area, understanding the heritage value of Pretoria West [Pretoria West Framework, 2010].

work area

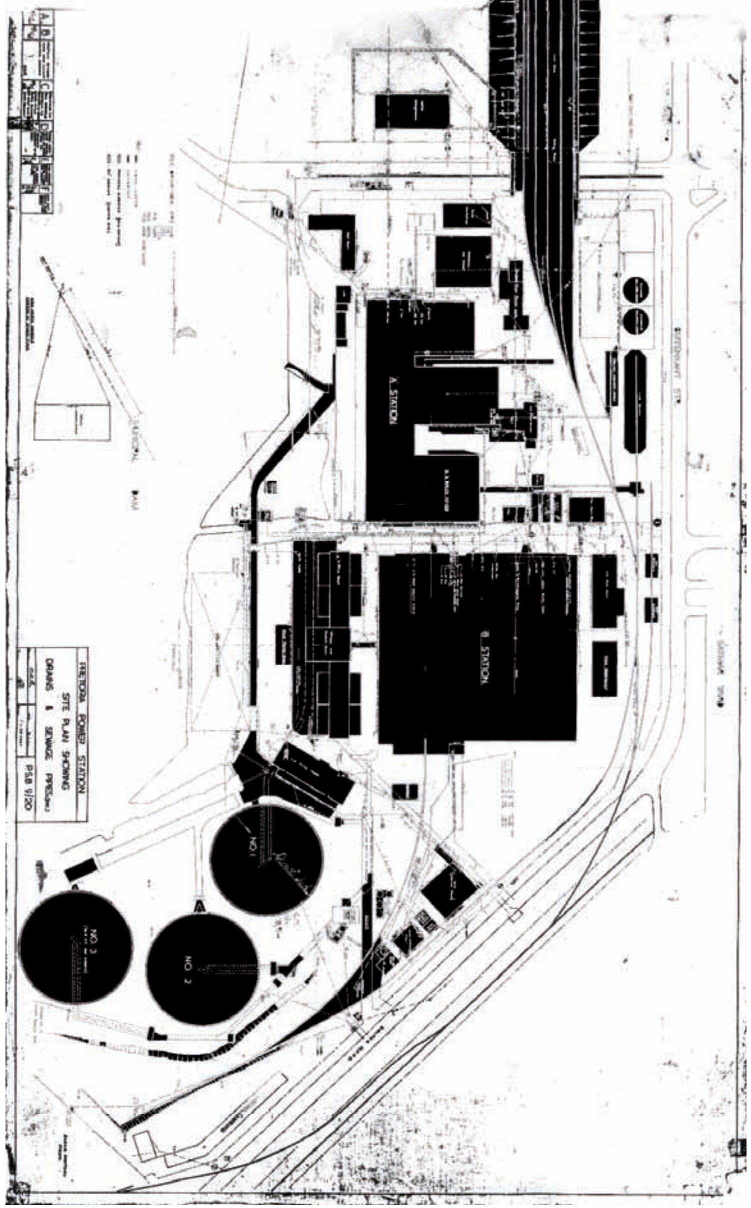
The Old Pretoria West Power Station has the most potential for development. The vision for the Power Station site is to aid in the creation of a light-industrial productive precinct - a continuous productive urban landscape for Pretoria city. The site aims to build on its industrial heritage as a place of production and distribution. It can also distribute its goods and produce not only locally, but also nationally because of its in-place, on-site infrastructure of a freight rail.

The new programs proposed for the site and its precinct must therefore focus on energy influxes and distribution. Energy, not only in the form of produce, but also in the development of skills and knowledge.

The Old Pretoria West Power Station has the potential of becoming a small city in itself - the existing built fabric has a positive urban scale (4-6 storeys) and the buildings are robust and in good structural condition. Furthermore, investigation has proven that the site will be decommissioned in the near future [Masut, 2010]. The character and quality of the site is valuable and must be retained, not only because of its heritage in building stock, but because it is a landmark for Pretoria, and South Africa also. Further development of this site makes it possible to become an exciting gateway for the west of Pretoria.

A specific work area is investigated further.

Figure 28 (left): Site drawing
The site of the Old Pretoria West Power Station [author, 2010].
Figure 29 (right): Site figure ground
Built fabric and footprints on the site [author, 2010].



context conditions on site

Figure 30: Rich vegetated landscapes around the ash ponds [author, 2010].

The Pretoria West Power Station is doomed for desertion and abandonment unless intervention occurs. As a power station, it cannot continue in its current form as coal-fired power generator and it cannot evolve into a new contemporary form for power generation. It cannot be demolished as it has measurable physical value (it is still perfectly operable and on grid, the buildings are robust and all infrastructure systems are in working order) and it has historic industrial heritage value. It cannot be kept, it cannot be destroyed: the site is stuck in time, illustrating a proximity of the past to the present to the future in a single environment.

The site is also not unique - there are thousands of sites in similar conditions nationally and also globally, yet currently the reappropriation is always different and equally unsustainable [www.nbi.org.za, 2010]. Via site and program choice, the new project illustrates the relationship between global and local proximities.

From the urban framework vision, the new intervention must be productive, provide employment and integrate industry into the urban environment. Urban agriculture meets this requirement as it not only provides an accessible interface for the public to industrial environments, but also aids in the rehabilitation of the landscape of the site. Furthermore, the high-content coal and ash in the landscape is especially beneficial for growing plants. This is evident in the lush vegetation on site, especially around the ash ponds (opposite).

The project will establishing the Old Pretoria Power Station as a foothold for urban agriculture for the city of Pretoria.

Council Minutes: City of Tshwane Metropolitan Municipality, 27 March 2008

- National Energy Regulator of SA (NERSA) will not support any major curtailment of mothballed generation units country-wide
- Grid price does not effectively compensate for running the Pretoria West Power Station
- Spoornet is not supporting the process of coal delivery for the Pretoria West Power Station
- A study on the conversion of gas into electricity was undertaken at the station (no reports on results found to date)

Figure 31, 32: Abandoned buildings overtaken by nature
During its lifetime, numerous upgrades for the station caused the commissioning of new buildings on site, leaving older structures useless and ultimately abandoned. Vegetation starts to infiltrate into the dilapidated buildings [author, 2010].

Interview: Mr. Fio Masut
station engineer
25 February 2010

- the buildings are unable to expand or be adapted for larger scale coal-fired electric power generation and in all probability need to be abandoned when upgrading the station
- no reports or results indicated the conversion of the existing coal-fired system to a any new alternative energy system
- The station currently has no positive outlooks and will in all probability be shut down in the next 10 to 15 years, the site will be abandoned and/or demolished completely.

"Only the consciousness of context, the knowledge of the milieu in which he constructs, can permit him (the architect) to find a real sense. That is to say, a physical, historical knowledge of this milieu - the consciousness of the possibility of evolution during the life expectancy of the proposed building - and a human knowledge - how the milieu is felt by those who live in it, what is expected of the building to be created, whether there is a suitable balance between the program and its social vocation...."

jean nouvel
selections from *Doctrines and Uncertainty Questions for Contemporary Architecture: Lectures at the Centre Pompidou,* 1997:56

"...a conviction that the structural and conceptual framework of modern architecture has the potential for environmental benefit, that architectural progress is not about re-styling. The main issue is how technology is used, who controls it, and to what end."

richard rogers
at the *World Sustainable Building Conference, Tokyo,* 2005

context prevent abandonment

the project aims to prevent the abandonment of such a valuable resource such as the Old Pretoria West Power Station

Figure 33a - Building stock

Figure 33b - Building stock

The building stock has a positive urban scale and the built structure and infrastructure is in place and sound.

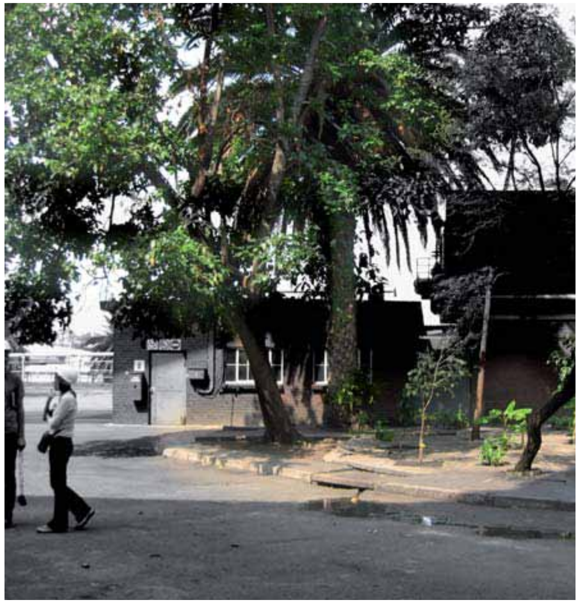


Figure 33c - Spaces

Spaces between buildings and under the conveyors or hoppers are vegetated with large trees and other plants.

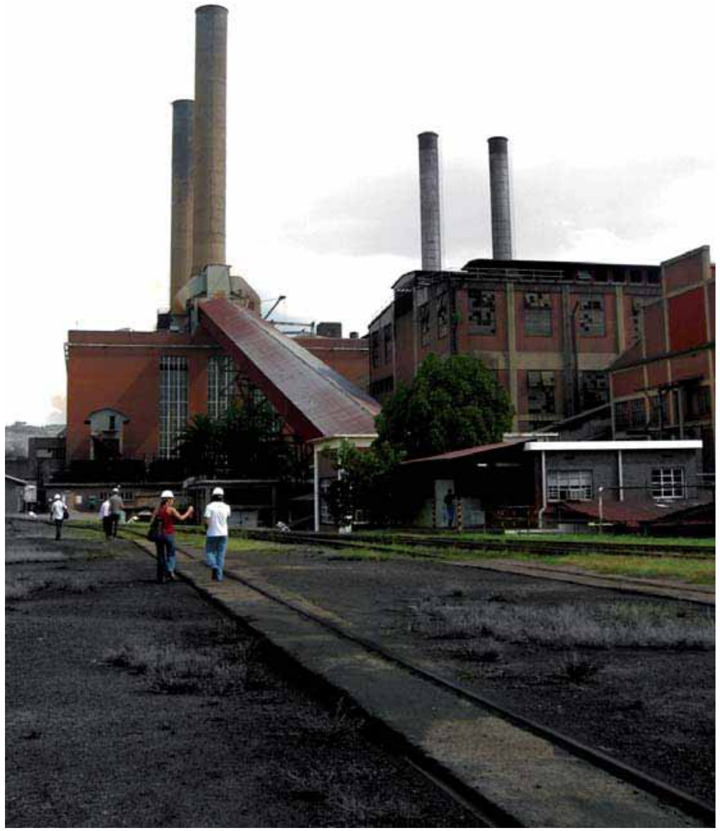


Figure 33d - Station-B and the conveyor

Coal is conveyed from the underground coal bunker to Station-B for combustion. Many other buildings are vacant.

context the buildings

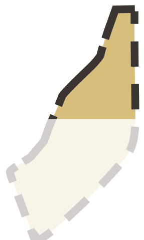
Figure 33a - 33d: collection of photograpsh showing buildings stock is on the southern half of the site [author, 2010]

Figure 33e - Thriving landscape

Figure 33f - Thriving landscape

Figure 33g - Thriving landscape

The high coal content in the soil and water is beneficial for plants. Vegetation around ash ponds are especially lush and prosperous.



context the land

Figures 33e - 33g: Flourishing vegetation and a dramatic landscape on the northern half of the site [author, 2010].

proximities

The framework research indicated that the site deals with the following proximities:

1 biophysical proximities

i. the proximity of human individuals to physical objects as both are ever-increasing in density within the urban environment

ii. the proximity of product to consumer

iii. the proximity of the local to the global

iv. the proximity of varying programs towards each other and at what point multiple programs are perceived as a single holistic program

v. the proximity of heritage building stock to the changing needs of the current and future urban conditions

vi. our proximity to the “natural” and to the “man-made” environments

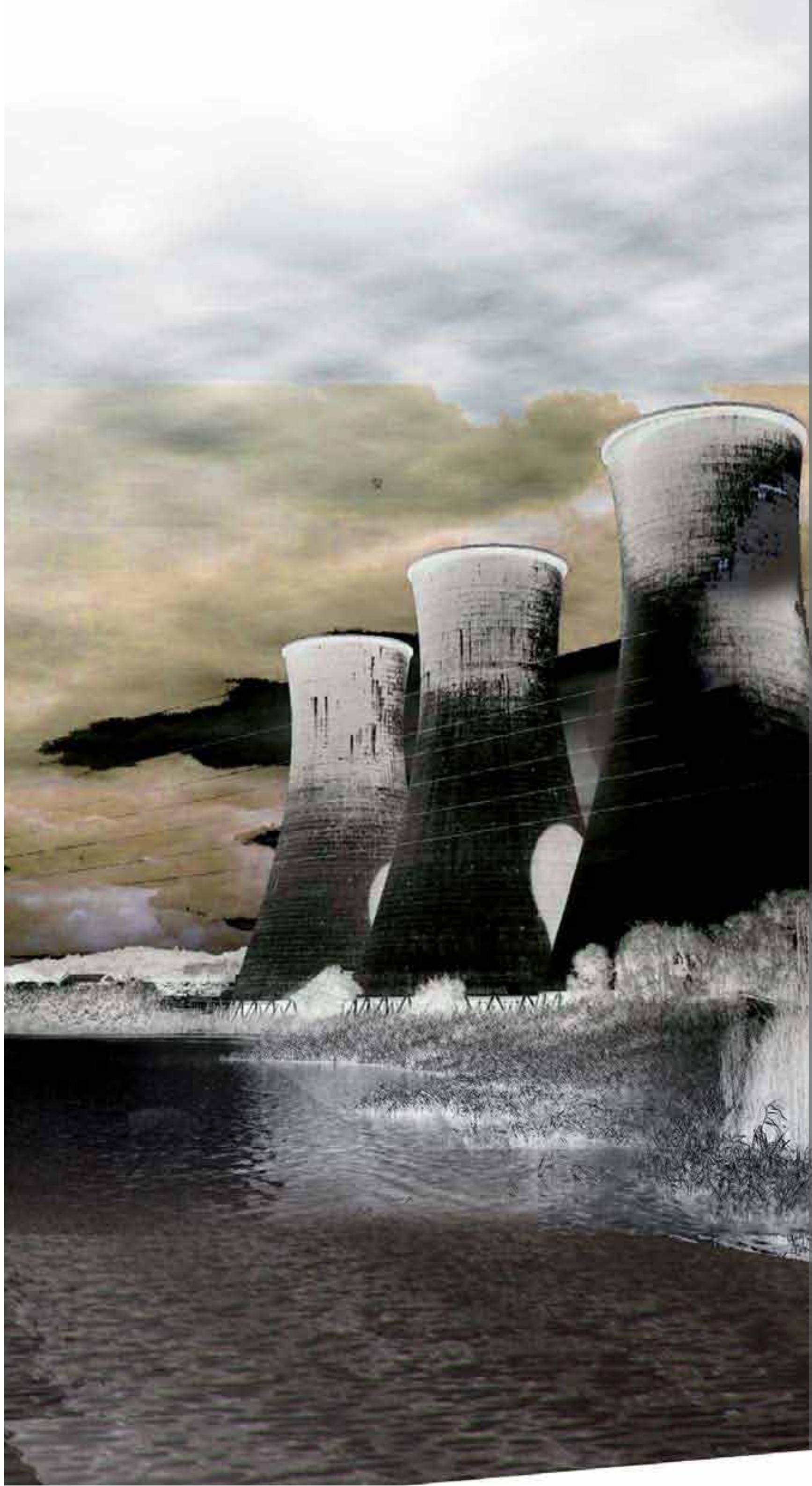
2 metaphysical proximities

i. our proximity to both the past and the future in a single environment

ii. our proximity to invisible environments and processes and visible environments and processes

iii. our proximity to circumstantial evolution and evolutionary directions made by our own conscious conduct

iv. our proximity to global problems that demand real-time local solutions



investigation

The specific site of the century old site of the Old Pretoria West Power Station illustrates:

Proximities of singular objects

i. The site is an urban fringe condition, an environment both isolated from and integral to the current urban condition. The site is also isolated and integral to the future of that same urban environment that it fringes upon

Proximities of points of produce to points of consumption

ii. The site and current program has visible and invisible interchanges of multiple energies. Both local and regional energy inputs and outputs can be found and these energies range from people (residential inhabitants to industrial workforce), vehicles (cars, trucks, trains) and visible and invisible products (coal, ash, electricity).

Proximities of "beginning" to "end"

iii. The site is a paradox: the same initial scale of buildings required for the station to be operable is now also its limitations, the cause of its desertion and abandonment.

Proximities of time and history

iv. The site is a landmark not only as a physical object, but it indicates to a point in time of human development [20th century past]; reflects a global condition [present] and asks for a future-orientated local solution [21st century future].

synthesis

The site is representative of theses constructs and also provides opportunity to express many of them further. The program was developed along the same thinking and together the architecture is developed so that site and its new program will be perceived as one. In the same way that the site and program were one thing when it still was a power station, so should the new program also reflect this character of the site.

The site is further investigated.

discovery

pretoria west power station

Figure 34: View from west, looking across the lake. First site visit, 2 February 2010 [author, 2010].

a site where the physical and the metaphysical meet

chapter three

immediate proximities

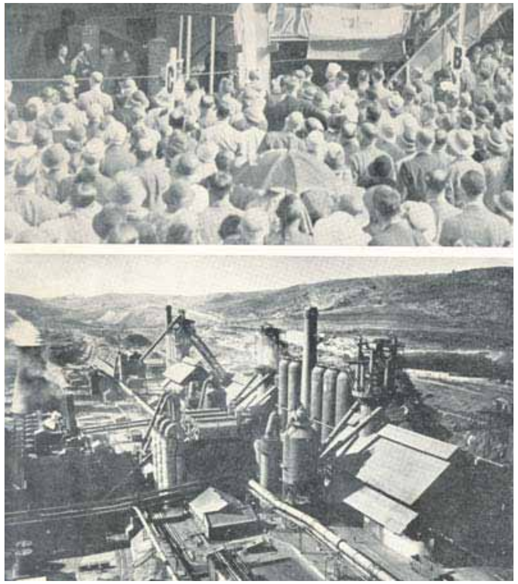
From the background study and urban framework vision, the site of the Old Pretoria West Power Station was selected as a work area. A general site investigation was conducted to understand the proximities within a more specific site. From the history of the site, the investigations into its operations and a mapping of the systems and qualities of the site, a specific work area was demarcated on the northern part of the site, namely the old coal bunker.

a n a l y s i s
history of pretoria west

In 1892, Pretoria was supplied with electric energy by a power station situated in Schoeman Street, east of the current site. As energy requirements increased, the station had to move out of the city onto its larger premisses and its present location. A new station was built in 1922 [Masut, 2010]. In 1928 the South African Parliament established Iscor - the South African Iron and Steel Corporation Limited. Iscor is still situated south of the power station. The construction boom during the 1920's caused by these two industrial giants alleviated much of the poverty and unemployment pressures during the Great Depression. Iscor generated a booming steel industry that not only benefited Pretoria and its industries enormously [Stark, 1952:105], but also contributed massively to the industrial prosperity of the greater South Africa. The by-products of the steel industry were also incorporated in a variety of sub-industries into the industrial sector of Pretoria West [Engelbrecht et al, 1952:103].

However, today Iscor is in the process of closing shop and moving out. This is beneficial for the greater urban environment as the steel giant is responsible for large quantities of air, ecological and water pollution. Its monopoly and presence also made it difficult for other industries to integrate into the west and it limited the development potential for the precinct. This caused the urban environment of Pretoria West to slowly dilapidate into an monotonous, undesirable urban sector. However, with the exodus of Iscor, and the inevitable decommission of the power station, Pretoria West has significant new potential for progression. The land that Iscor occupied and its immediate is considered prime property for the development of educational facilities, new industrial or other commercial enterprises [Municipality, 2004].

Together Iscor an the Old Pretoria West Power Station helped to established and define the western boundary of the city centre of Pretoria on the aptly named Buitekant street ("outside", "outskirts" - street). This condition was enhanced by the municipality by the planting of a long row g Buitekant street circa 1950. It was the a tradition at the time to very clearly indicate the edges of cities with rows of trees, and a similar situation can be found on the historic Buitekant Street in Cape Town. The station itself expanded and additional structures were built in the forms of coal bunkers and coal stores. Buitekant Street slowly became a dead-end destination.



1925 Iscor

Figure 35: Industry boom
In 1925, Iscor and other industries brought prosperity and promise of progress for Pretoria and larger South Africa [Engelbrecht et al, 1952:103].

Iscor to the south-west of the power station

Construction and completion of the second power station of Pretoria, now on Mitchell Street

1925 power & industry

Figures 36: 100 years of landscape and urban changes
By 1925, the Pretoria West Power Station A was almost completed, and the sited demarcated the edge of the city of Pretoria. Sporadic houses and residencies can be seen towards both the west and the east. The site is in effect a large, noisy construction and industrial area.

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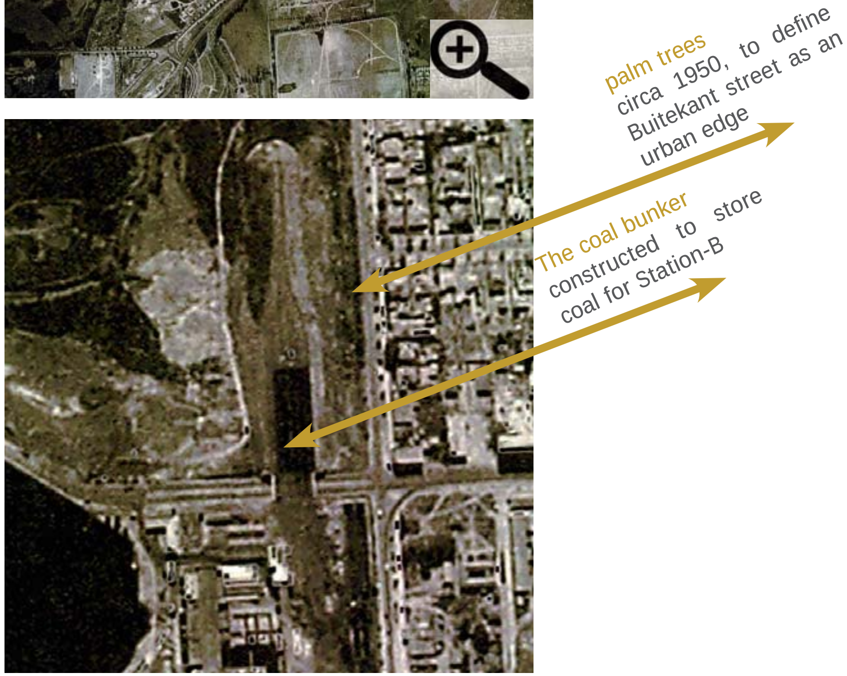
a n a l y s i s
history of power station

After the second 1928 station reached its limits on electric production capabilities, the next set of buildings were commissioned. A somewhat larger station, Station-A, expanded from one of the boiler buildings but soon also reached its peak production capacities. Station-A to this date provided 54MW of energy, selling over 400 000 000 units annually and lighting over 10 0000 street lamps for the city of Pretoria. Still, it reached production capacity and Station-B was commissioned and completed in 1954. Station-A was decommissioned and virtually abandoned, used for storage of unused machinery.

During the 1990's, new health and safety acts on asbestos demanded that asbestos material be removed from all buildings and so much of the older buildings were left totally scarred. Also, funds were tight and the municipality decided to strip the older buildings bare to the bone of all metal fittings and components found in walls, floors and machinery. The collected metal was sold as scrap to smelters and the profits made paid for the removal of the asbestos. Any building on site that cannot be used for the process of power generation, is simply abandoned, and the process will in all probably repeat itself if the power station needs to face another upgrade or change [Masut, 2010].

Figures 36-39: Images obtained from the University of Pretoria, The Van Der Waal Collection, images enhanced by author, 2010.



1948 operations of Station A

Figures 37: 100 years of landscape and urban changes
In over 20 years, the site and urban conditions hardly change. Residential areas are extended somewhat westwards, beyond Buitekant street.

1954 completion of Station B

Figures 38: 100 years of landscape and urban changes
During the 4-5 years of construction of Station-B, the city develops considerably around the site. The coal bunker is constructed along Buitekant street - it enforces the barrier conditions on the street edge (it is estimated that the rows of palm trees are also planted during this time).

1969 intensify

Figure 39: The edge condition is enforced, prohibiting access onto the site. However, the city now almost completely surrounds the site. The site is still relatively barren of vegetation and the new palm trees are clearly visible to the east.

engulfed
the site becomes engulfed by urban development

edge condition
palm trees (circa 1950) defines Buitekant street as an urban edge

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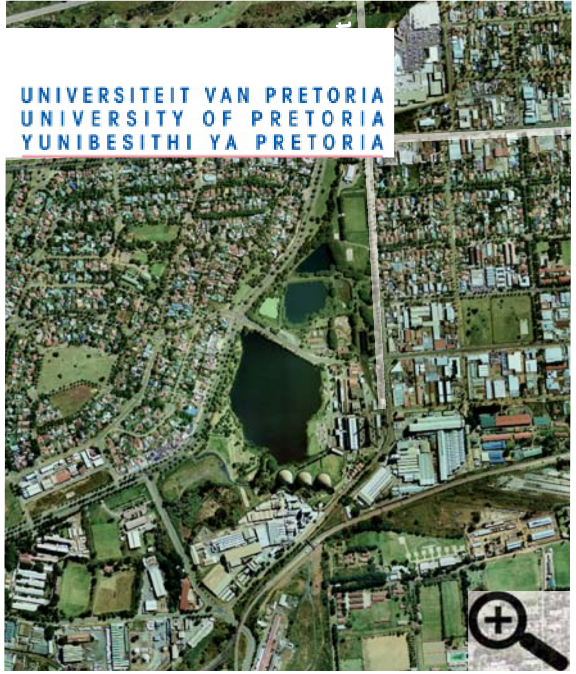
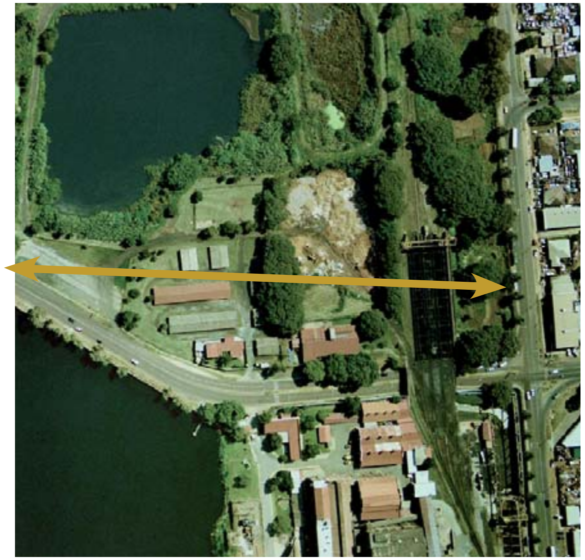




2010 effects

Figure 40: The edge condition is still there today, but the city totally engulfs the site. The effects of the coal and ash ponds, and the nutrients in the water is clearly noticeable in the lush and healthy vegetated landscape. The site is now a hidden landscape, its heritage physically obscured from the public. It's intensely close proximity to an urban streetscape creates an opportunity for development [University of Pretoria, Dep of Geography, images enhanced by author, 2010].

Figure 41a - Current Power station

the railway bridge

Figure 41b - Urban byway

Figure 41c - The historic city edge

the edge buitekant street

Figure 41a - 41c: Collection of photographs showing Buitekant street as the historic edge for the city of Pretoria [author, 2010].

1. portuguese sports club
2. the coal bunker
3. ash ponds
4. power station training facilities
5. 1924 station
6. 1937 station (station A)
7. coal surplus store
8. administration block
9. 1952 station (station B)
10. evaporation lake
11. cooling towers
12. glass factory
13. proclamation hill (residential)
14. iscor (industrial)
15. pretoria west (mixed-use and residential)
16. pretoria west (mixed-use and light industry)
17. quagga centre (retail shopping centre)
18. police college and training
19. city park

analysis
choice of specific site

A site investigation was conducted through numerous site visits, documentation, mapping and interviews with Mr Masut, the station head engineer. From the knowledge gained on the landscape and infrastructure of the site, it became clear that the existing coal bunker [2] is the most suited in order to address key issues of the project:

- Vertical agriculture: there are site processes and systems in place that encourage agriculture as a new productive program for the old coal bunker (greater water system, existing conveyor and distribution system, and vast scale of the bunker volume)
- Urban fringe condition: the coal bunker demonstrates the influence of industry and its processes on the natural and urban landscape. It physically separates, isolates and hides the industrial process from the interactions of a mixed-use urban environment.
- New productive landscape: there is great development potential on this north-eastern part of the site that can encourage interaction between the existing urban fabric, on-site processes and the vegetated landscape of the site.
- The new building can express the closing proximities of vegetated landscapes and built urban fabric.
- The new building can express the closing proximities of industry to social urban environment as an edgeless condition of the 21st century.
- The new building can express the closing proximities of heritage and infrastructure that must be reconfigured for contemporary needs.

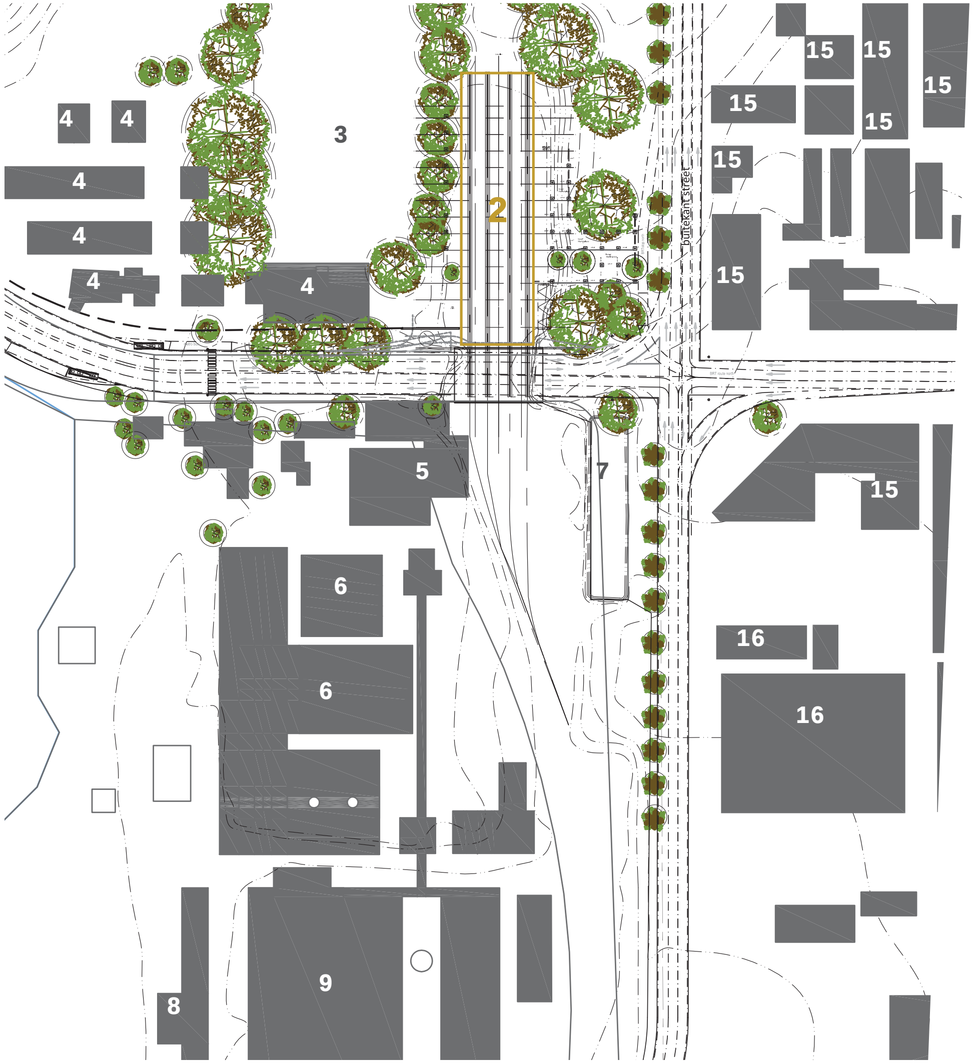
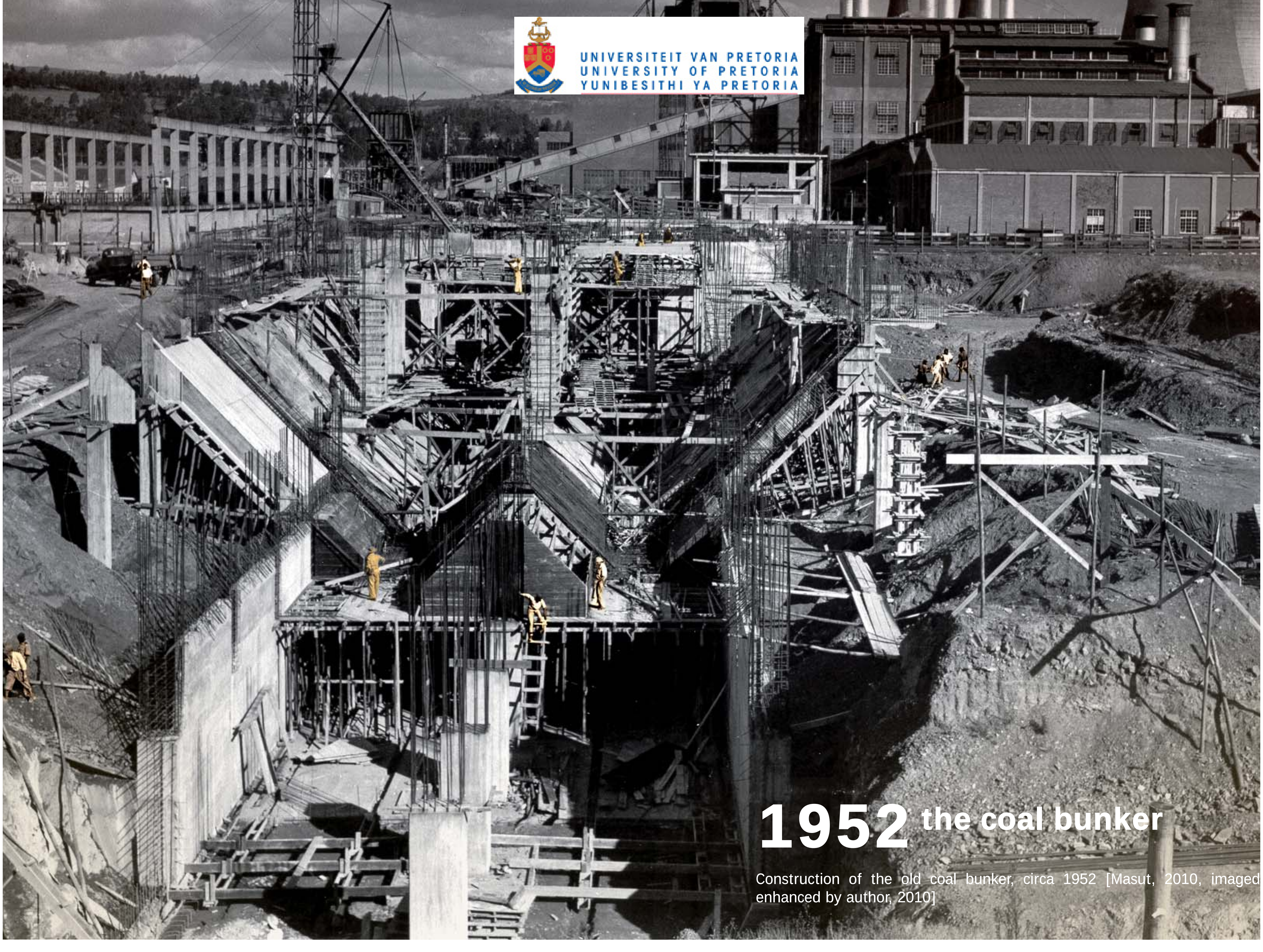


Figure 42 (opposite): Pretoria West Power Station [9] [author, 2010].
Figure 43 (top): Site context plan [author 2010].
Figure 44 (right): Site context aerial [author 2010].



1952 the coal bunker

Construction of the old coal bunker, circa 1952 [Masut, 2010, imaged enhanced by author, 2010]

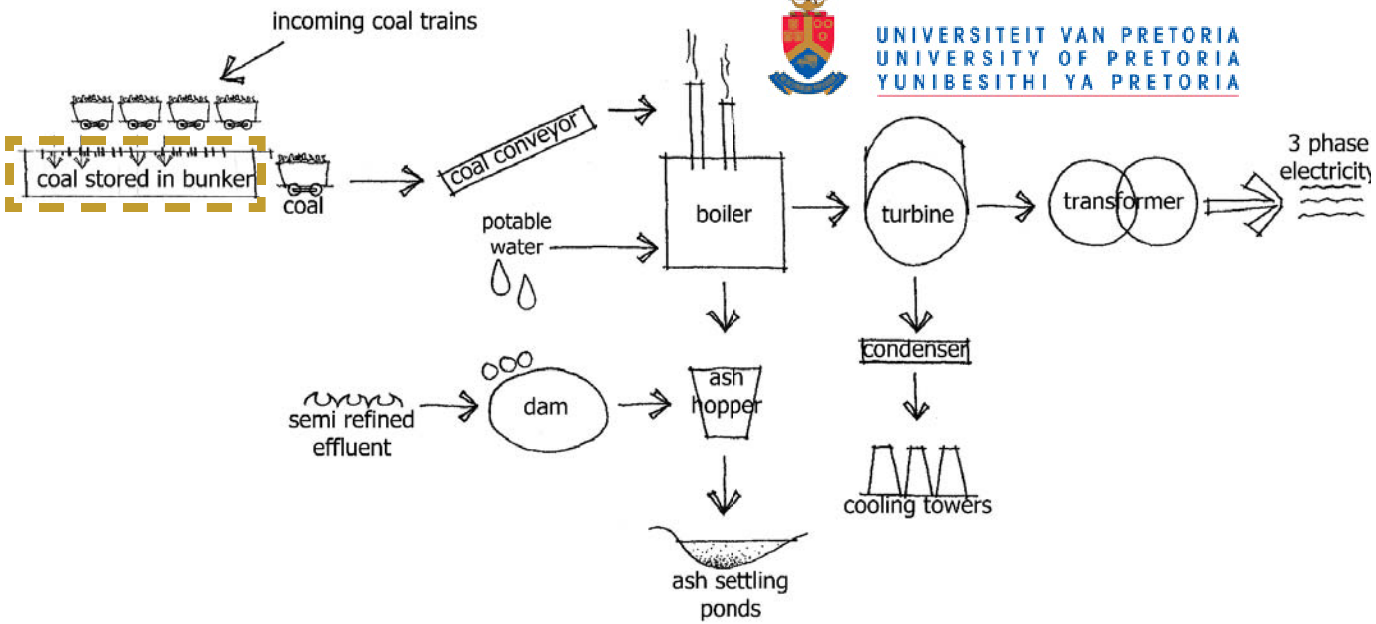


Figure 48 : The power process

Coal comes in by rail and is stored in the underground coal bunker. From there the coal is conveyed to Station-B for combustion [Pretoria West Group,2010].

Figure 45 : On top of the bunker

Coal trains arrive and coal is manually shoved from the coaches, down the steel grill and into the submerged concrete bunker [author, 2010].

Figure 46,47 : Steel steps down to Buitekant Street

Steps down the bunker towards the street [author, 2010].

Figure 49: The bunker hidden by the landscape

The semi-submerged bunker is covered by the landscape [author, 2010].

heritage position

The old coal bunker is literally hidden in the current urban fabric of Pretoria West. If it is not used for its original purpose of storing coal, it runs a risk of becoming a lost heritage. It was decided to introduce this structure to the city. By giving the structure a contemporary, future-orientated productive program, the proximity of its past to its future is drawn closer. The bunker is a completely internalised structure and this characteristic isolates it even further from the city and its inhabitants. By opening up this object, it is possible to explain its heritage and its role in the greater process of the power station. The old coal bunker is classified as a heritage site as it has buildings, structures or other site elements older than 60 years [SAHRA, 1999:4]. Two issues are important in understanding the inherited and potential significance of the site for the city:

- Inherited: the landscape features are unique to the City of Tshwane. The cooling dam, ash ponds, dramatic vegetated landscape, valuable building stock has qualified it as a landmark site [City of Tshwane, 2006:60].
- Potential: currently the site functions as an isolated unit in relation to the city. It has potential to retain its industrial character and still be integrated with the urban environment. The group framework vision for the site [Pretoria West Group, 2010] proposes a productive environment as the heritage position as it aims to use the site as a catalyst for urban rejuvenation for Pretoria West and the western edge of the Pretoria CBD.

From all the various heritage charters, the SAHRA, ICOMOS and UNESCO position papers, Xi'an Declaration, Ename Charter and the Burra Charter were selected as the most applicable to the current bunker and the aims of the project. These charters encourage new, contemporary developments on heritage buildings so to enrich the cultural value of the heritage site for the community by integrating the heritage structure with contemporary urban life. A heritage position for the coal bunker was drafted on the combined principles of these charters. These now present a steady heritage framework to work from, and the following principles are the position for the new design:

- The new architecture and program must illustrate and retain the use of the heritage site and place.
- The architecture must be compatible, enhance and respect the heritage in its entirety as a heritage site. This implies not only objects, but the spatial quality of the landscape and site.
- The architectural developments and interventions in regards to heritage buildings and sites must address issues of urban identity; urban core and periphery.
- The architecture for the heritage site should reflect the development in contemporary urban culture.
- The new architecture and program should address the issue of how historic centres and heritage landscapes move towards modernity and the future.
- In the case of the Old Pretoria West Power Station, inherent existing systems (greater water system, on-site process or distribution of products, the purpose of the site as a generator of energy) are also accepted as heritage components of the site and must be referred to or be integrated with the new design

The coal bunker will now be introduced into the existing urban environment. It is a demonstration of the reintroduction of productive processes into the urban environment and aids in a new understanding of the role of industry and production within the urban environment for the 21st century.

Figure 50: The old coal bunker is buried by vegetation [author, 2010].

Figure 51: The area in front of the bunker has already been cultivated informally with a bunch of small crops, but the person responsible for the plants could not be found. Maize and other edible plants were also found along the railway tracks beyond the immediate site [author, 2010].

precedent
a c k n o w l e d g e

heritage as object - new design floating above heritage building

Elbe Philharmonic
Hamburg, Germany
Herzog & De Meuron
under construction

- isolated industrial heritage building
- original building and structure retained
- new design mimics heritage footprint
- new design elevated from old building
- new facade contrasts from heritage building
- definitive contrasting materials

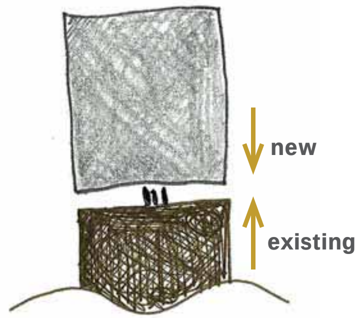


Figure 52: Acknowledging the existing [author, 2010].
Figure 53: Elbe Philharmonic Hall, Germany [http://cubeme.com]

precedent
e x t e n d

new structure extruded from within heritage building

Lyons Opera House
Lyons, France
Jean Nouvel
completed 1993

- heritage building in dense urban setting
- new design element - half cylinder roof
- new design rests within old building and completely replaces interior structure, only facade remains
- new materials sympathetic to old building

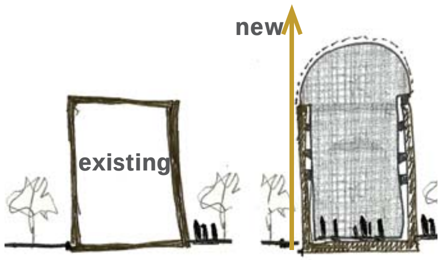


Figure 55: Extension on the existing [author, 2010].
Figure 56: Lyons Opera House, France [Bonet, 2002:24]

precedent
i n v i t e

draw in streetscape - introduction of interior program to the street

St Jobsveem
Rotterdam, Netherlands
Wessel de Jonge
completed 2008

- the conversion of old packing house into residential
- interior punches through to streetscape
- parts of facade removed
- new materials in relationship to old structure
- new scale introduced to building interior

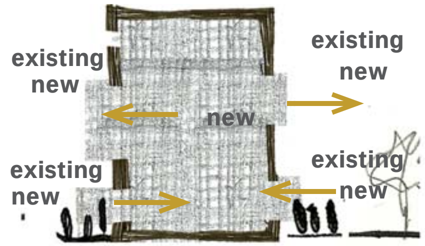


Figure 57: Inviting streetscape into building [author, 2010].
Figure 58: St Jobsveem, Netherlands [http//:www.worldarchitecturenews.com]

precedent
i n s e r t

off-set incisions - old structure pierced and new structure envelopes street

St Caterina market
Barcelona, Spain
Enric Miralles & Benedetta Tagliabue
completed 2004

- existing market revived in heritage building in dense urban setting
- additional contrasting insertions
- new design element - iconic roof
- new materials vividly contrasted to old building

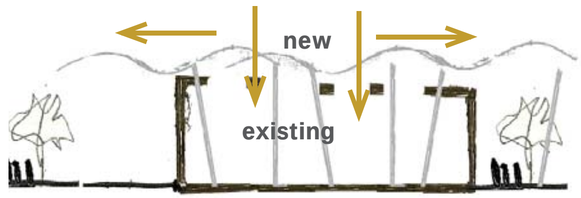


Figure 59: Pierce with new & envelope streetscape [author, 2010].
Figure 60,61: St Caterina, Spain [http://www.flickr.com/]


1952

Figure 62: Circa 1952 hidden historic edge [Masut, 2010].

view from Station-B

2010

Figure 63: Hidden production industry inaccessible and hidden from the urban environment [author, 2010]

view from Station-B

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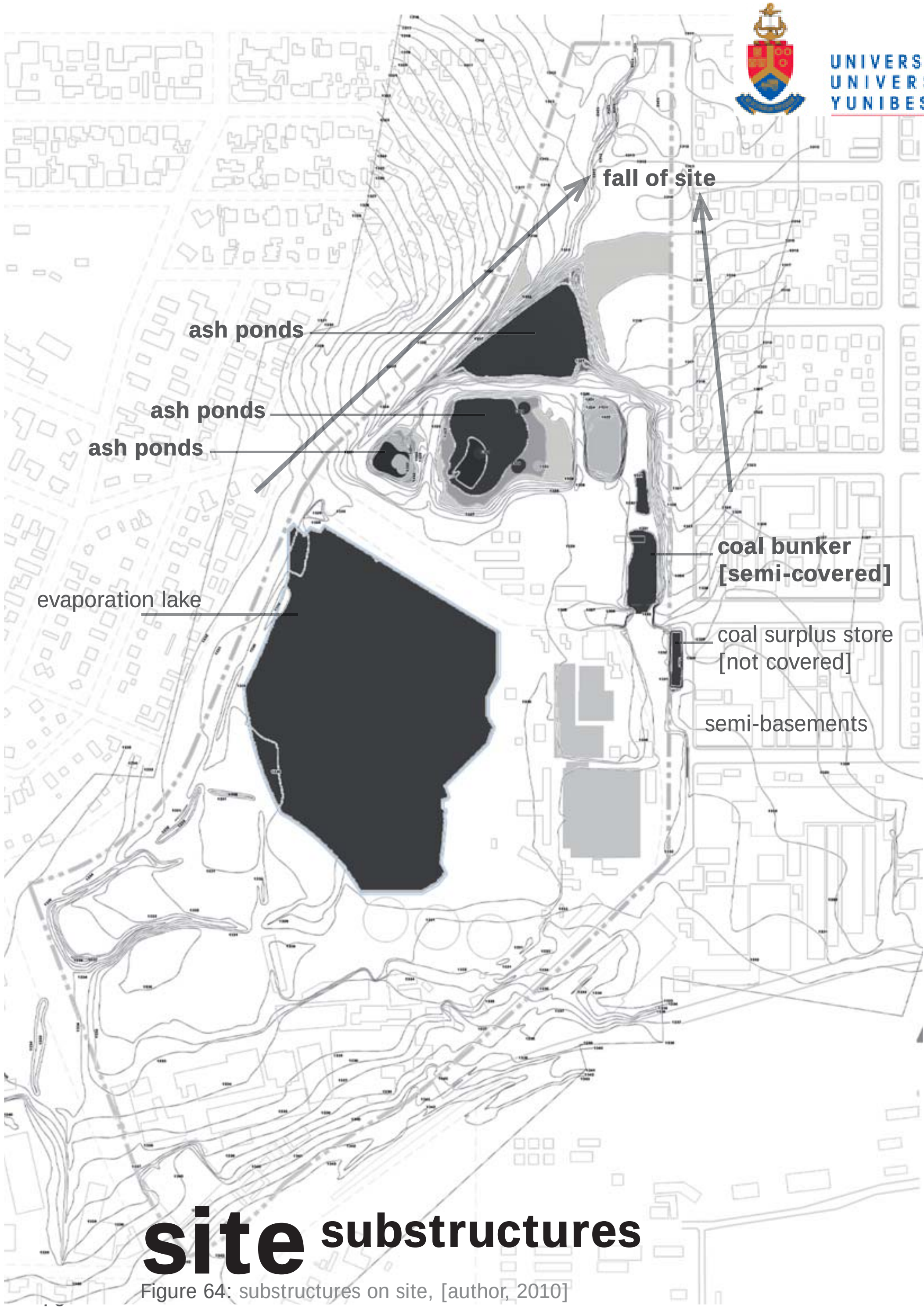
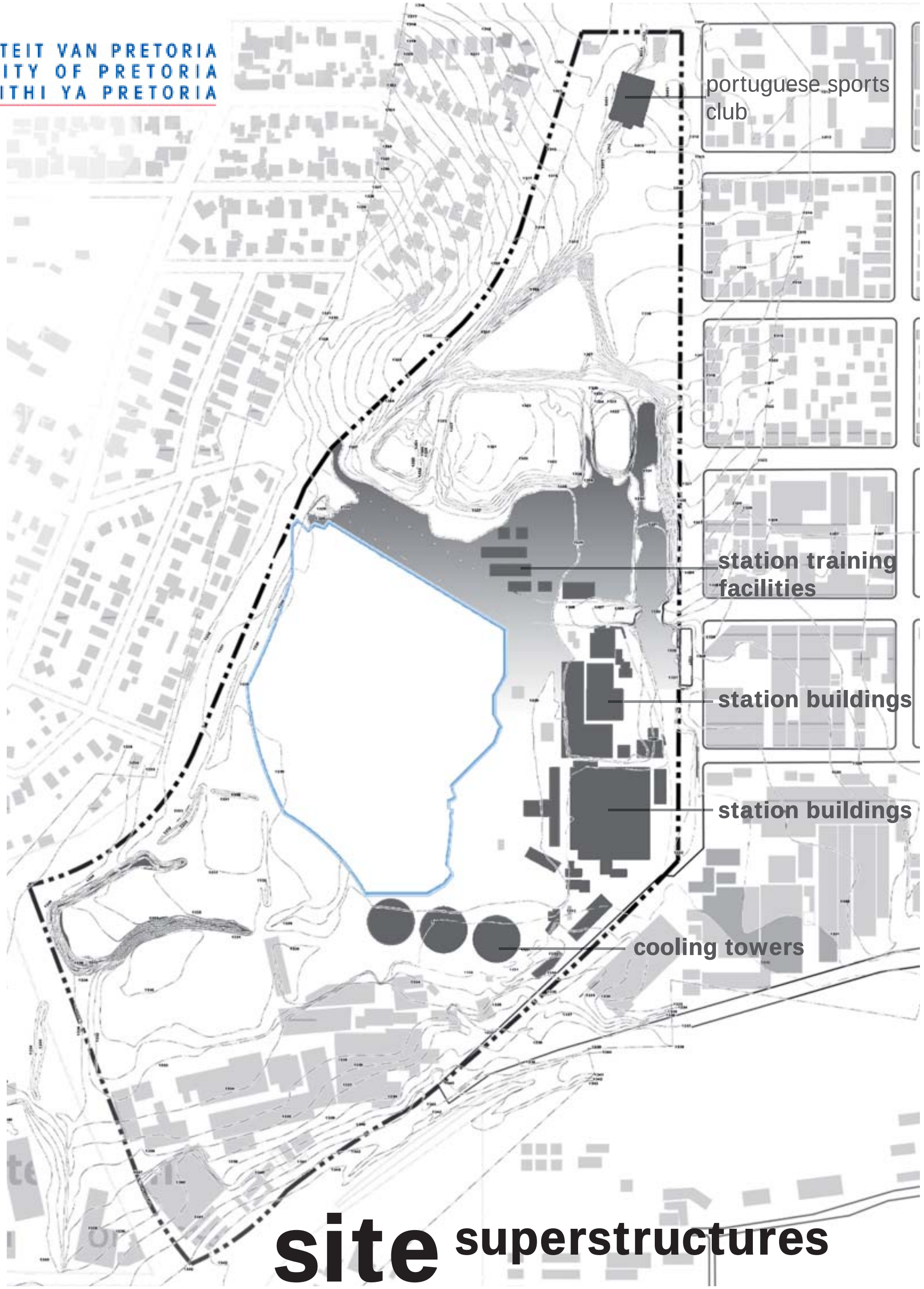


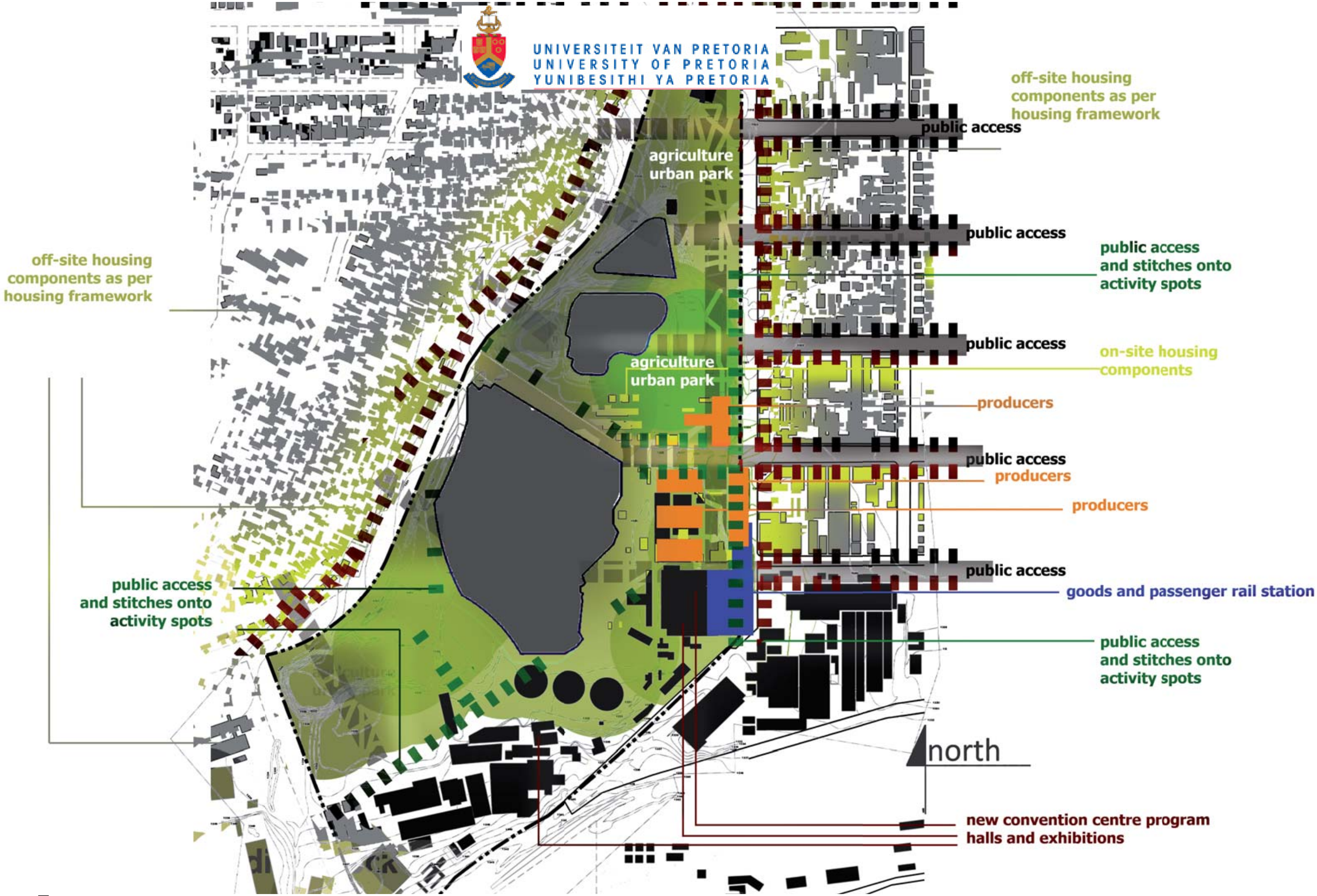
site substructures

Figure 64: substructures on site, [author, 2010]



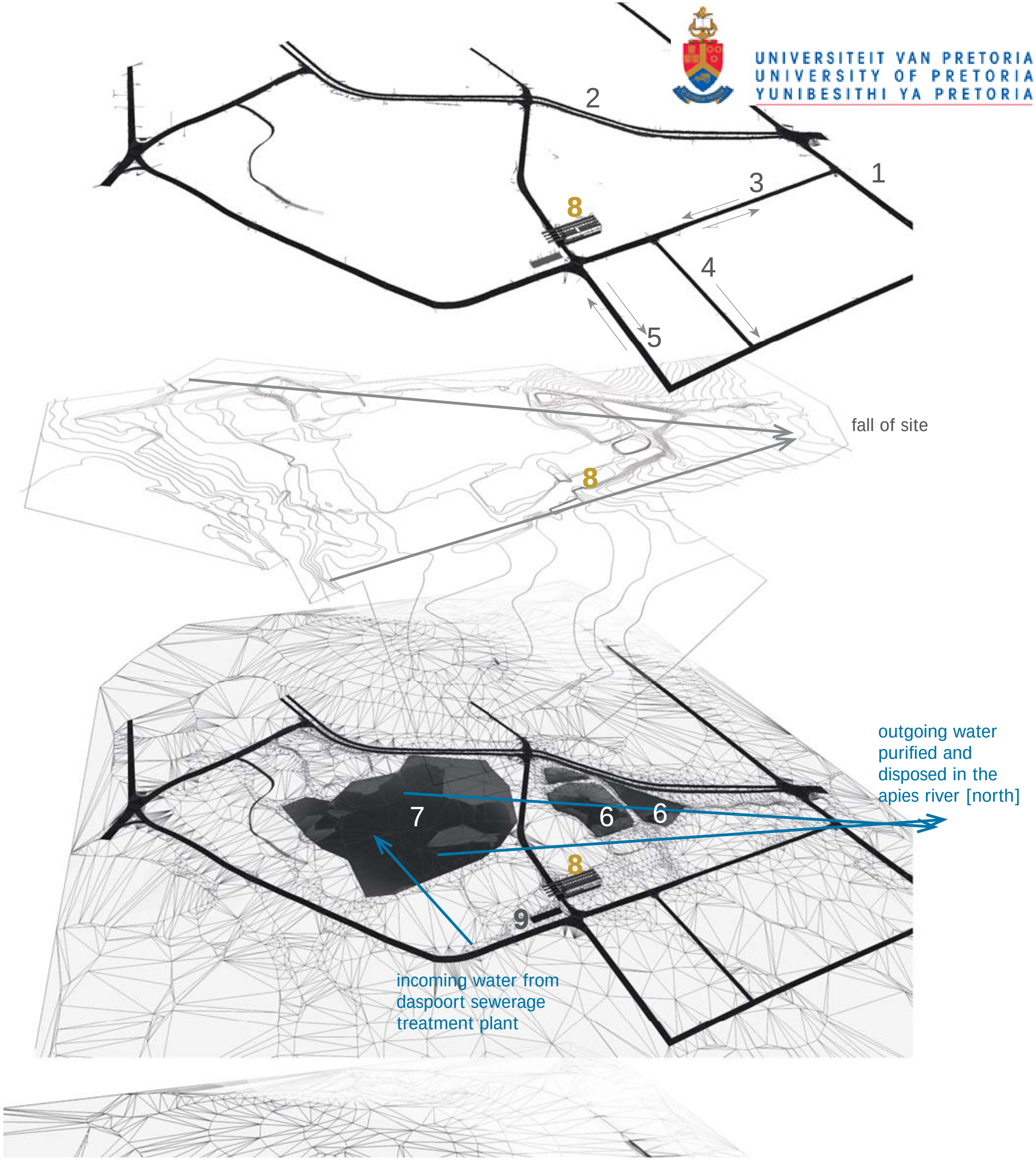
site superstructures

Figure 65: superstructures on site, [author, 2010].



site framework proposal

Figure 66: Basic framework proposal for the site [Pretoria West Framework Group, 2010].



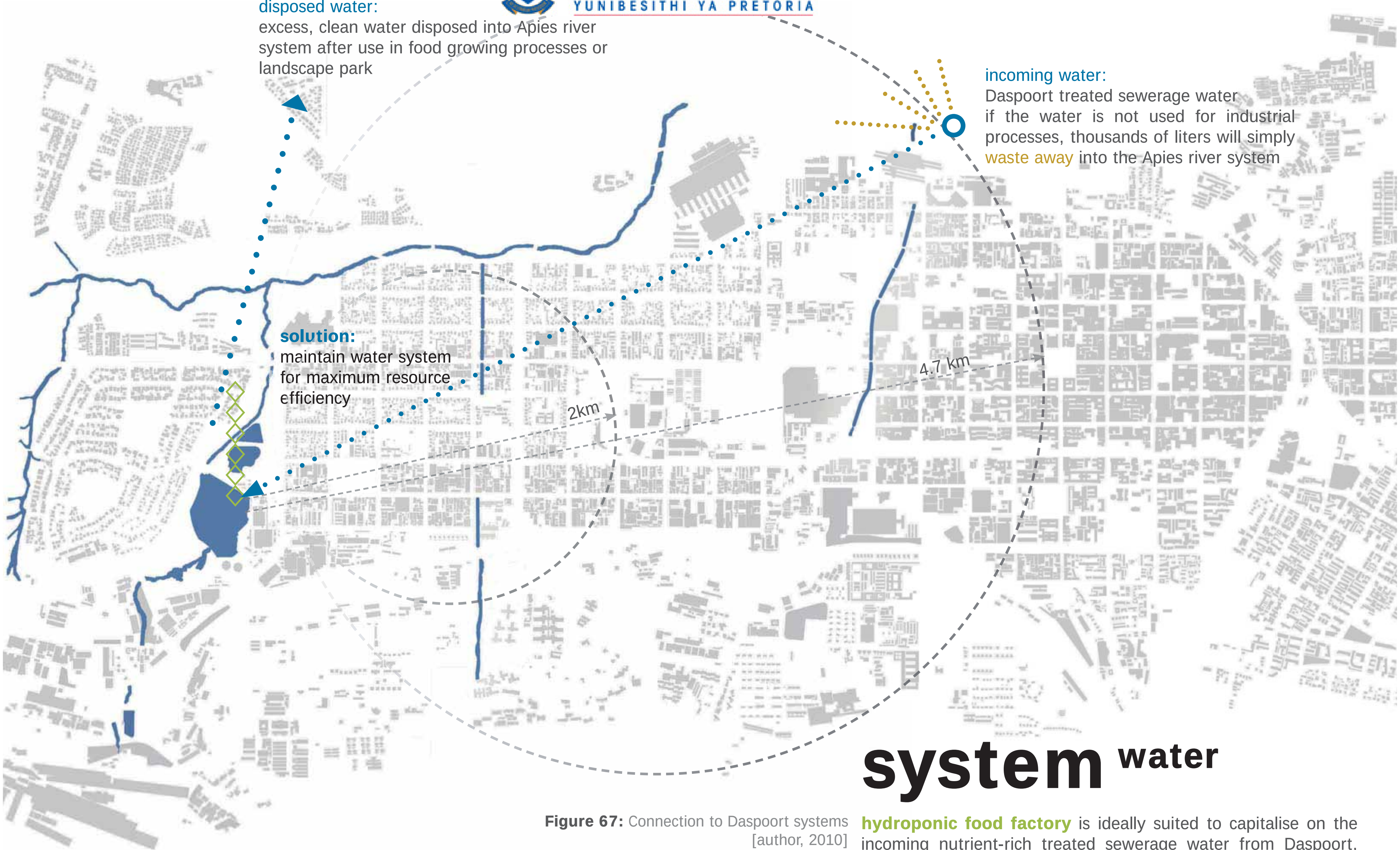
water supply

The existing water system is primarily used to slurry coal (and other by-products created by the coal-fired processes) around the site. The station receives excessive amounts of refined sewerage water from the **Daspoort Sewerage Treatment plant.** Although not used as potable drinking water, this water is clean and safe as it has to comply with Tshwane health regulations [Masut, 2010]. In fact, there have been many triathlon's and other sporting events around the site which utilised the dam and water and it was reported that the water is perfectly clean and manageable for public use [Masut, 2010]. The system on site currently disposes of the water through another purifying station and finally, into the Apies River (north). When the plant closes down, the water and pipe system will be redundant unless applied in another industrial application. The Daspoort Sewerage Treatment Plant will dispose of this water into the Apies directly, causing a massive resource waste as thousands of litres of water will go unused [Masut, 2010]. Because the water has high nutrient values especially for vegetation, it is proposed to maintain and extend this system into the coal bunker as it is an invaluable resource specifically for a landscape application and the hydroponic food factory.

1. Church street [east - west]
2. Quagga street [north -south]
3. **Buitekant street** [north south]
4. Souter street [east-west, one -way traffic eastwards]
5. **Mitchell street** [north-south, two-way traffic]

Topography
fall from south to north
[from ridge towards church street]

Subsurfaces
6. existing ash ponds
7. main water body [cooling dam]
non-potable, high nutrient value water fed from Daspoort Sewerage Plant
8. **existing coal bunker** [16 meters deep, sunken]
9. existing coal store [4 meters deep, sunken]



system water

Figure 67: Connection to Daspoort systems [author, 2010]
Figure 68 (opposite): Fall and topography [author, 2010]

hydroponic food factory is ideally suited to capitalise on the incoming nutrient-rich treated sewerage water from Daspoort, that would otherwise be a wasted resource.

chapter four

culture and industry

From the background study, urban framework and site investigation, research was conducted to meet the project aims of creating an architecture that helps generate productive urban landscapes and societies.

The investigation first led to an understanding of what such a society would be and on what scales the building can facilitate this.

Next, the potential and feasibility of the program was investigated and a model for vertical agriculture (in the form of a hydroponic factory) was developed for the old coal bunker. Suitable clients are proposed to approach with the project.

Lastly, the heritage status of the site together with the project aims and the heritage position, the design demanded that an adaptive re-use strategy be taken.

The knowledge collected on vertical agriculture, methods, requirements and energy systems together with heritage position and the greater project aims directed the design development further.

productive landscape

key concept: CPUL city

The vertical agriculture project is a catalyst for a greater Continuous Productive Urban Landscape (CPUL). This involves a network of urban landscapes and open spaces that are environmentally and also economically productive. According to architect and author Andre Viljoen in *CPULs: Continuous Productive Urban Landscape*, CPULs do not require the complete rebuilding or demolition of cities, instead they suggest reconfiguring the city so that it can operate within the envelope of its own environmental capacity and as far as possible make its own ecological footprint a constructive one [Bohn et al, 2005:266]. In Pretoria, the current green landscape is limited, scattered and unconnected. The project will be an important link in closing the loop within the city and uniting this landscape into a CPUL. It becomes the platform for further development on an urban agriculture CPUL for the Pretoria cityscape.

Figure 69 (right): Forming part of the greater landscape system and closing resource loops [author, 2010].
Figure 70 (below): Reconfiguring into an agriculture CPUL and becoming major linkage in the connecting the green landscapes of Pretoria [author, 2010].

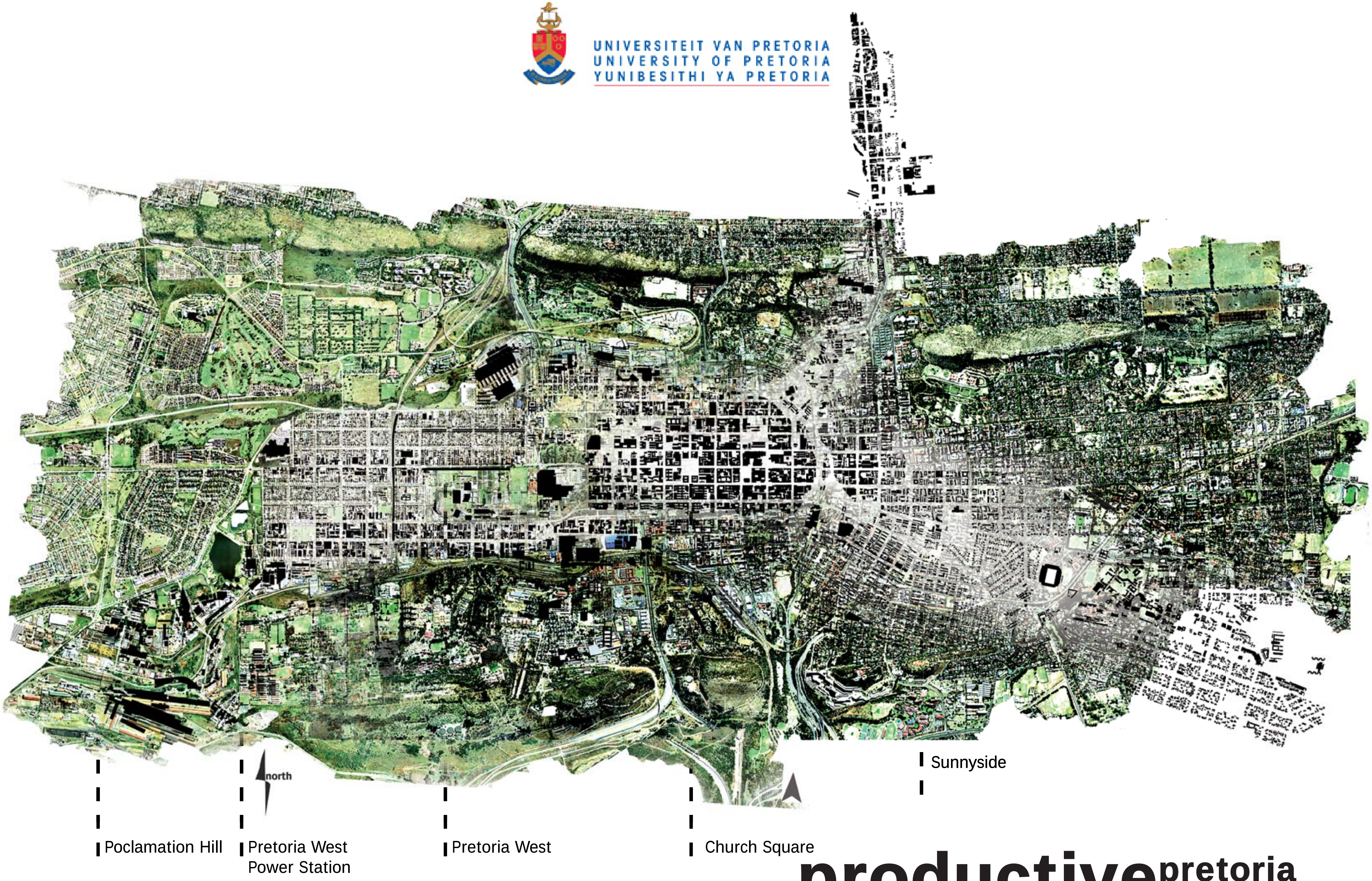
existing highly disturbed areas
brownfield sites - areas disturbed and damaged from industrial processes
adapted from Pretoria West Group 2010 [author, 2010].

existing medium disturbed areas
brownfield sites - indication that proper intervention can bring together the separated industrial and urban proximities
adapted from Pretoria West Group 2010 [author, 2010].

potential CPUL development
the site's potential to reunite underdeveloped and hidden greenfield conditions through urban agriculture
adapted from Pretoria West Group 2010 [author, 2010].

productive landscape

vertical agriculture closing proximities between damaged landscapes for new urban form within the Pretoria urban core.



productive pretoria

Figure 71 (top): Potential and vision [author, 2010]. Local green and urban agricultural potential that the Old Pretoria West Power Station agriculture cell can catalyse.

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productive community society

With the birth and growth of a global industrial era over two centuries ago, urbanisation intensified dramatically [Byrne, 2002:261]. Industry became a system that acted beyond its initial economic goals and moulded entire industrial cities and cultures. Currently, most cities today are in the process of deindustrialisation and negative reputation of production and reproduction processes of industrial culture is perceived to be working against the goals of contemporary society and innovation, especially on issues of sustainability and resource-efficiency. When industry is completely removed from an area, large communities (mostly skilled workers) are left behind [Byrne, 2002:280]. These communities usually have multiple generations of experience and in an industrial lifestyle and cannot blindly follow the exodus of industry. The area of Proclamation Hill, Danville and Pretoria West is such an industrial community. When large industries move out (Iscor and the power station), there is a risk that sector will not only lose its identity, but also its livelihood.

It is therefore important to cultivate a new sustainable industrial culture for Pretoria West as it is not only its inherent legacy, but also its unique future. This implies that the new sustainable industrial society must have sense of ownership of this new industry. The aim of the design is to create this sense of belonging and sense of place for a greater urban community within this new industry to aid in the creation of sustainable industrial culture. This belonging, according the British urban historian David Byrne, is achieved by creating a greater feeling and experience of the industry as a culture, cultivating sentiments which guide and form ways of life for a community. Sociologist Inger Birkeland agrees and goes on to say that this cultural energy and vitality is as important for sustainable development within communities as other issues of social equity, economic viability and environmental responsibilities [Birkeland, 2008:283].

productive landscape society

The project aim is to close the proximity between an urban environment and a productive environment and create a culture of a productive society. A healthy urban interface is required.

According to urbanist Jan Gehl, merely grouping functions or buildings of various programs together is not enough to stimulate the growth of a healthy urban space. The important factor is whether and how the people who work and live in an urban area use the same public space to connect on a daily basis [Gehl, 2006:101]. The French landscape designer Gilles Clement names this space where free and informal public activities or events occur a *Third Landscape* [Clement, 2006:90]. Since the aim of the project is to have an architecture that aids in the development of a productive urban society, it is essential for this quality of space to exist within the design project.

Gehl further explains that public activities are either necessary, optional or social [Gehl, 2006]. The interplay between them are not just created by the physicality of buildings and architecture, but also by the activities and interpretation of the spaces linking buildings.

A human being is sensitive to physical and metaphysical proximities. Physical proximities include the liberty of movement, scale of spaces or structures, materiality, and the practicality in the use of places. Metaphysical proximities include the level of spontaneous social stimulation, freedom of public activity, ownership, sense of place and sense of security. The *Third Landscape* is created where there is a close proximity between physical and metaphysical environments.

The hydroponic factory must form part of a *Third Landscape* in order to meet the project aims of creating of a productive society.

productive culture

vertical agriculture closing proximities between industry and urban living

productive society

A *Third Landscape* space is a virtual space - a place that connects physical and metaphysical proximities for a human experience. This virtuality of the *Third Landscape* implies that the physical boundaries of a building or space does not limit the experience of the building or space as a *place.*

In order to maximise a human experience of *place*, the building must extend its presence beyond its own physical built fabric. The following strategies were developed to do this:

[1] Layered and crossing interactions

Layering the public interactions with the production program narrows the proximity between an urban inhabitant and the productive process. Layering happens both horizontally (on plan) and vertically (in section). The experience of change in scale is also part of the layering strategy.

[2] Extensions

The building physically extends beyond its formal boundaries and into a streetscape and landscape. Simultaneously, street activities are pulled into the building, closing the proximity between a informal street experience and a formal industrial experience.

[3] Centrepoint

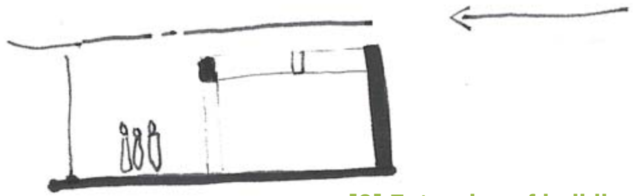
To generate a healthy public space, the interplay between the necessary, optional or social public activities should be encouraged. Considering this, the public program is developed to give gravity and a purpose to the public space. Considering the urban framework in the regards that new buildings and programs must provide ample employment [Pretoria West Group, 2010], it was decided to introduce a public food and farmers' market as the primary public program. This does not only meet the aims of the urban framework, but it also encourages entrepreneurship and matches the inherit spirit of the vertical farm in local food growth and distribution.

[4] Magnetism (below and next page)

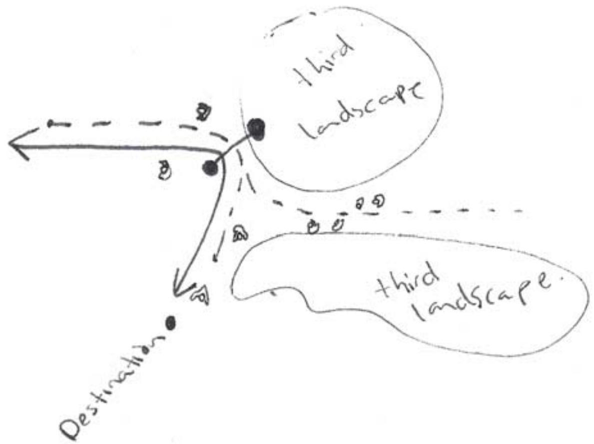
The building seduces and lures public curiosity by having different interests and activities aimed at different users within its public space. This is done through cross-programming the public space with both formal production activities and informal urban activities. This draws closer the proximity between formal users and informal users.

With this specific, active public program - a public market - a balance can be formed between the necessary, optional and social activities of the public space. Through the program of a public market, the proximity of point of production and point of consumption is illustrated literally and proximities are drawn closer.

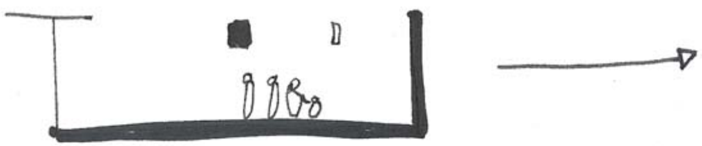
[1] Layered and crossing interactions



[2] Extension of building onto street



[3 + 4] Centre point and magnetism



[3] Extension of street into building

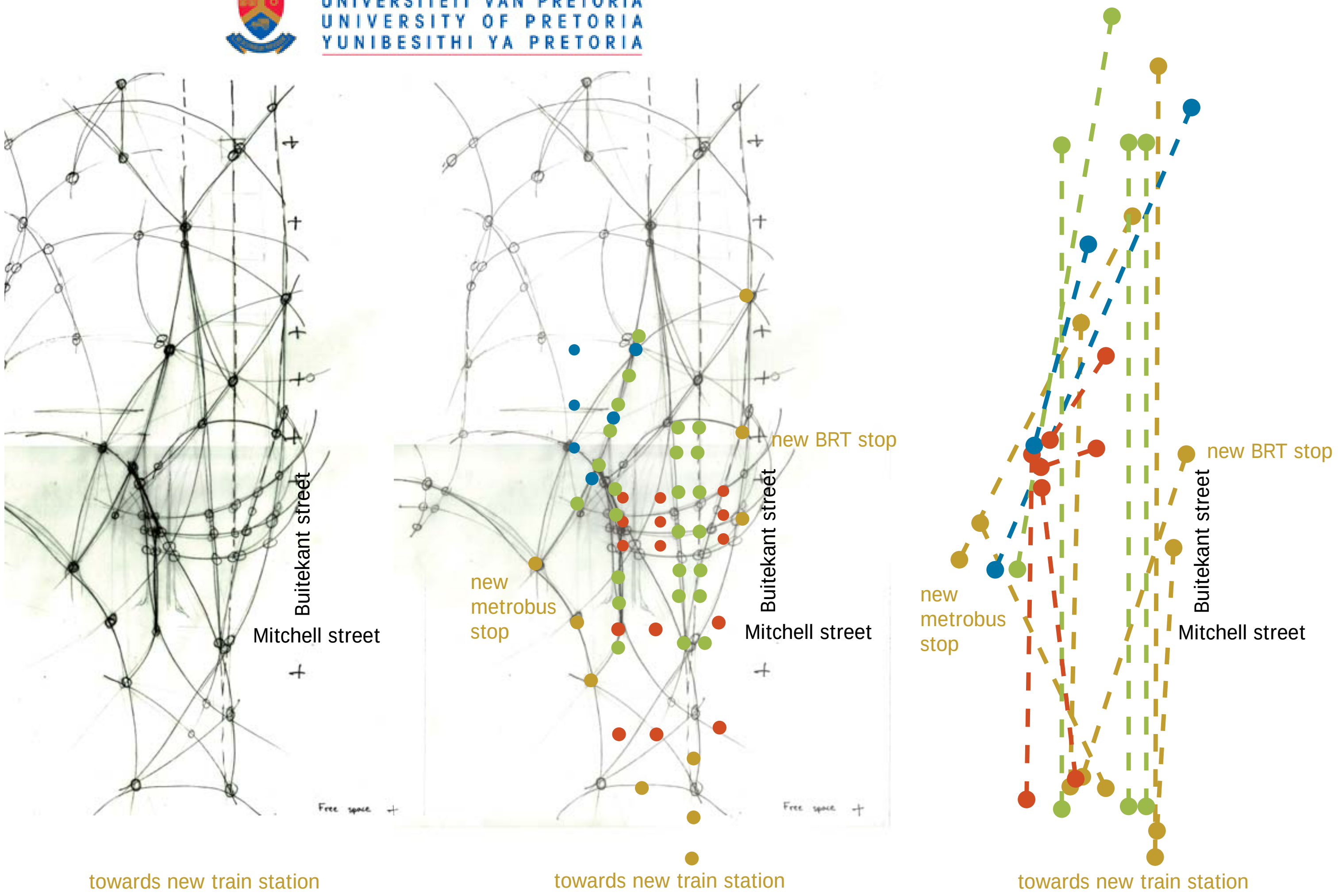
Figure 72: Diagrams and strategies to create a third landscape [author, 2010].

productive society

The design encourages movement through and across the bunker and onto the landscape by ensuring that the production process is either part of a public process or en route to an important transport node.

- **transport**
The introduction of Metro Bus and BRT stops as well as the new proposed passenger rail links.
- **education**
Public and staff hydroponic training and education.
- **industry**
The hydroponic food factory.
- **commercial**
The farrmers' market public space and informal trade along Buitekant street.

In this way, the programmatic heritage of the streetscape (mixed-use) and the character of the light industrial environment will still be maintained. Through cross-programming the site becomes more permeable and accessible for the public and aids in closing proximities between the surrounding landscape, the production program and urban activities.



new movement flows and routes on site determined by current and historic site conditions and routes

programming to encourage more flow across the bunker and movement across the site

induced flow of various participants across the bunker onto and through the building and the landscape

Figure 73 (right): Cross-programming on plan [author, 2010].
Figure 74 (opposite): Cross-programming on section [author, 2010].

proximtiy programming

plan drawings creating movement by closing proximities between urban programs with an industrial /production program

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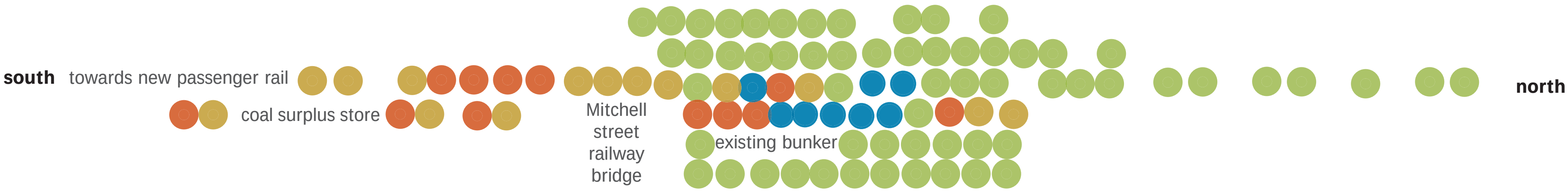
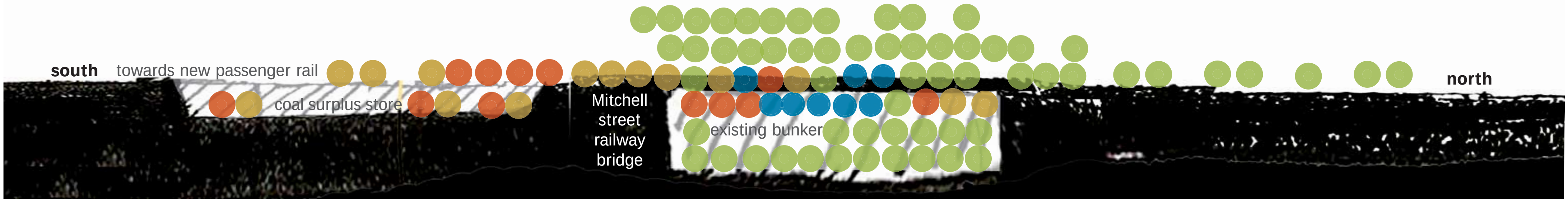
section north-south



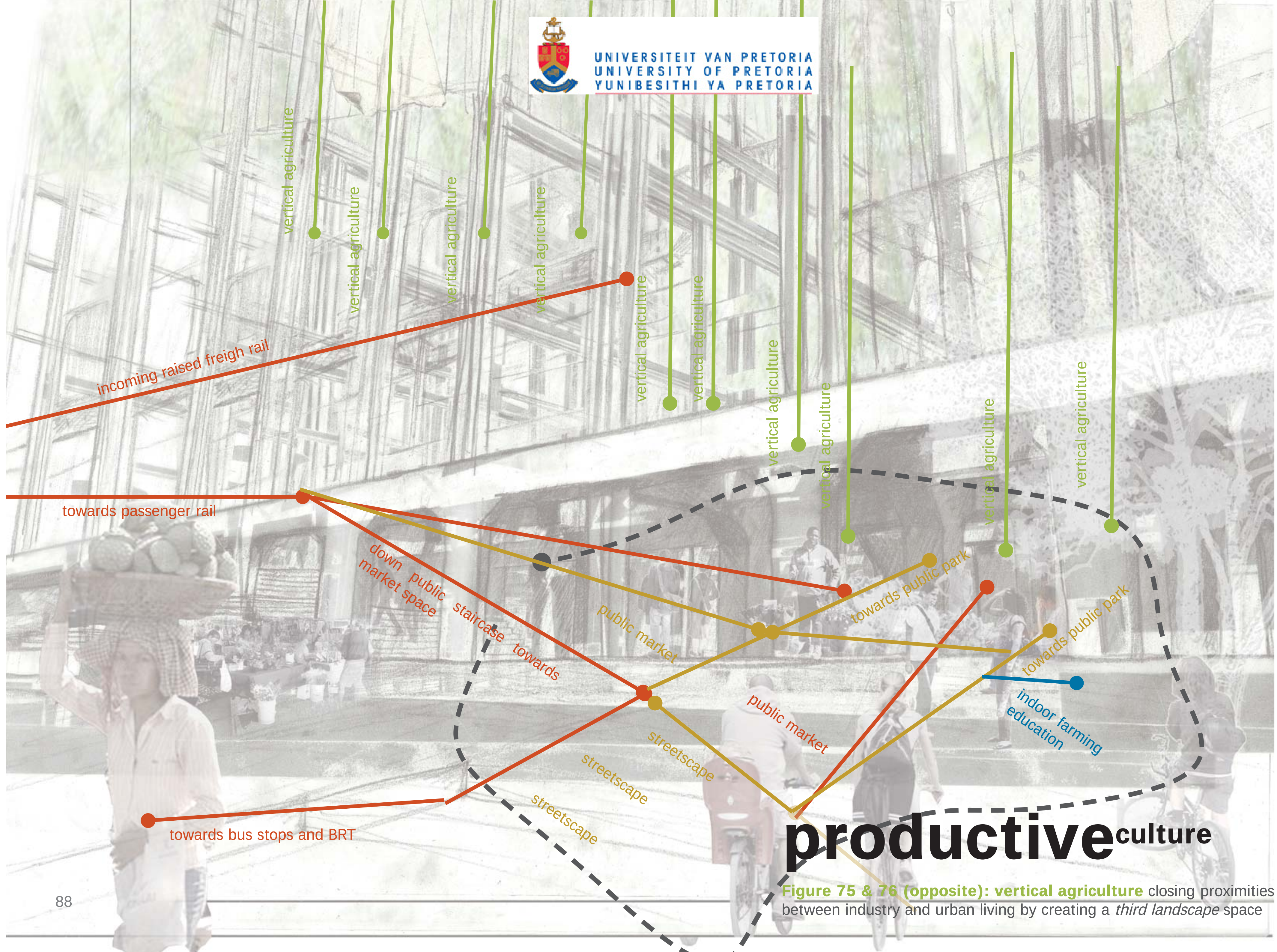
section north-south



section north-south

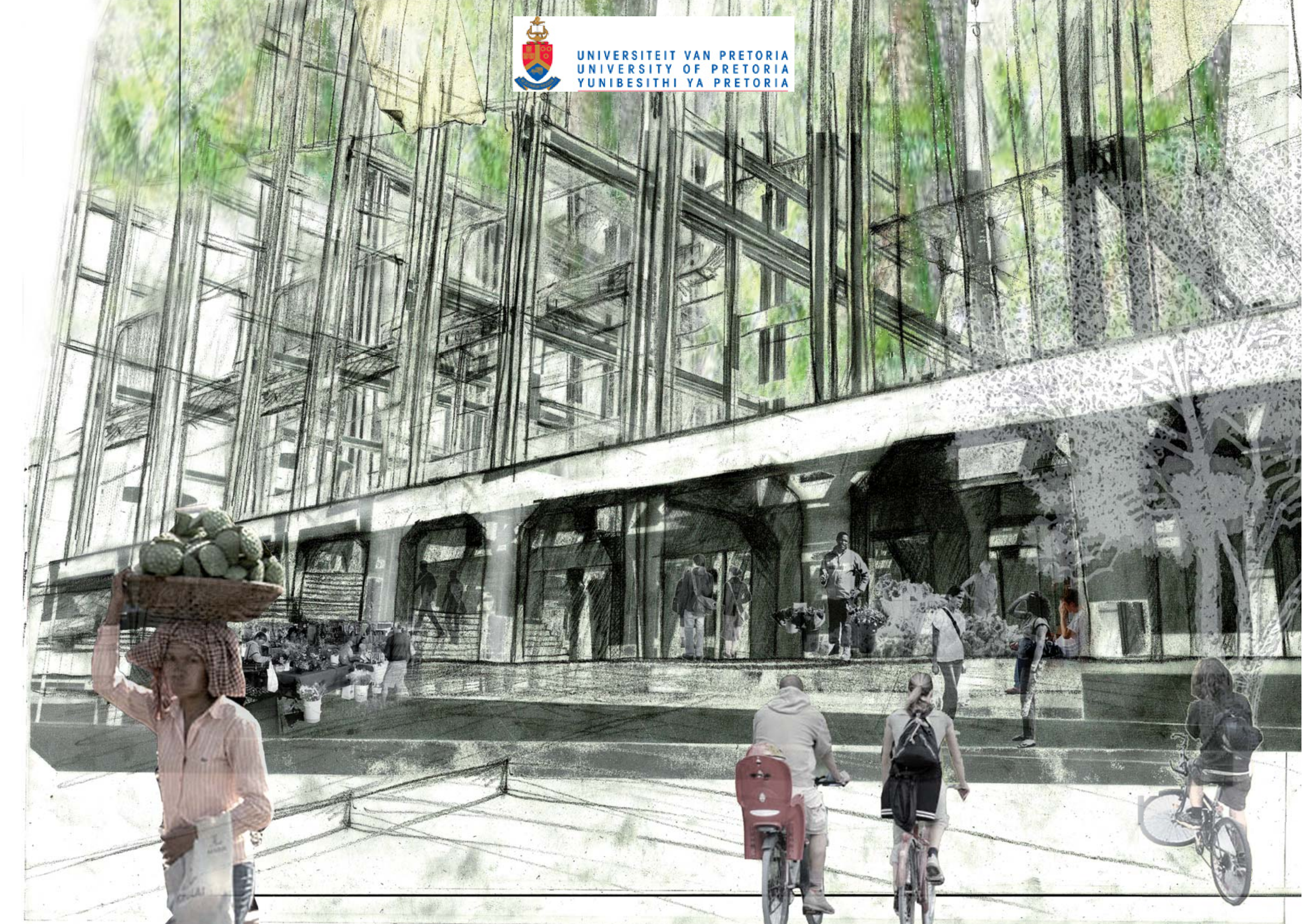
proximtiy programming

section drawings creating movement by closing proximities between urban programs with an industrial /production program.



productive culture

Figure 75 & 76 (opposite): vertical agriculture closing proximities between industry and urban living by creating a *third landscape* space

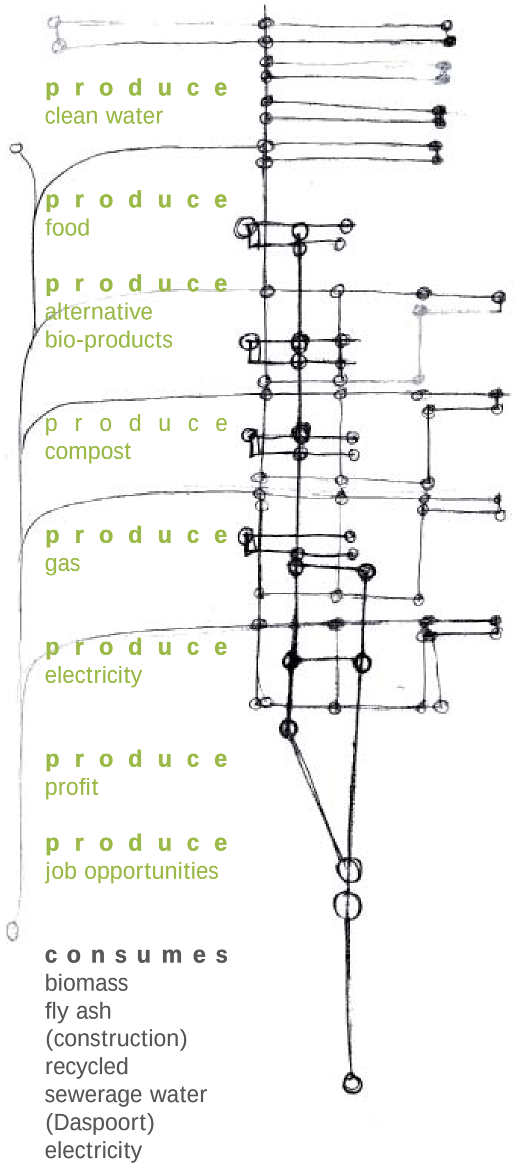


productive building

key concept:
integrated design approach

The vertical agriculture is modelled for the old coal bunker at the Old Pretoria West Power Station. Bearing in mind that the project aims to develop a sustainable urban landscape and society, a similar strategy for a productive building was adopted for the design. Vertical agriculture is ecosystemic in principle - as illustrated with the *Vertical Farm* project by Despommier and his students [Fitzpatric et al:2006:4]. Such an ecosystemic approach requires that the site must be understood as both a consumer of resources and as a producer of resources. The building closes the proximities between industry and the urban landscape on both a greater urban scale and an immediate building scale. The design actively participates with greater systems and on-site materials and resources. These resources are often overlooked through poor understanding of the potential of the site and as result go to waste. However, these resources form part of the hidden heritage of the site, especially in the case of the Power Station. For instance, there lies great potential in reconfiguring the existing nutrient-rich water resource from the Daspoort Sewerage Treatment Plant for the use on plants or the re-use of abundant coal fly ash from the existing ash ponds in new building materials.

Figure 77 (top) : Catalytic potential of the vertical farm to aid in the development of CPUL cities in sustainable, resource-efficient urban cells [author, 2010]
Figure 78 (right) : Closing resource loops within the building as part of whole building design strategy [author, 2010].



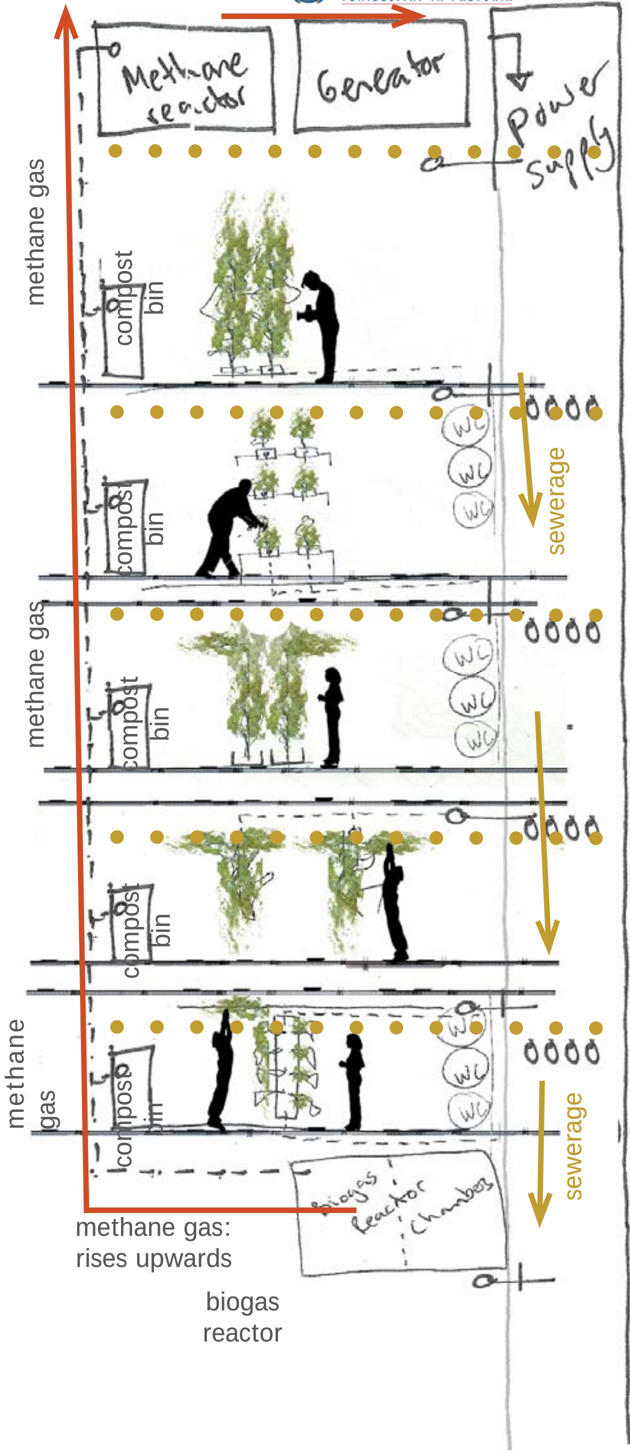
hydroponic food factory

key concept:
inputs and outputs

The building aims to be part of a Whole Building Design strategy [Prowler, 2008]. Internally, the new hydroponic food factory building has a closed-loop strategy in regards to its own resource use, especially with water, electric energy and biomass.

The building has some biomass consumption through composting requirements (most crops are hydroponic and soil-less and will be explained shortly), and leaves a surplus of biomass and other organic crop by-products. Other consumptions of the building include recycled sewerage water (Daspoort); rainwater; fly-ash from the on-site ash ponds (provide ash as aggregate in concrete and masonry); and electricity. The building, however, also produces clean, potable water; food crops; alternative bio-produce and materials; excessive amounts of compost; gas; electricity; profits and job opportunities.

An investigation into indoor farming techniques and systems was carried out. The requirements for vertical agriculture later informs not only building organisation, but also a building form.



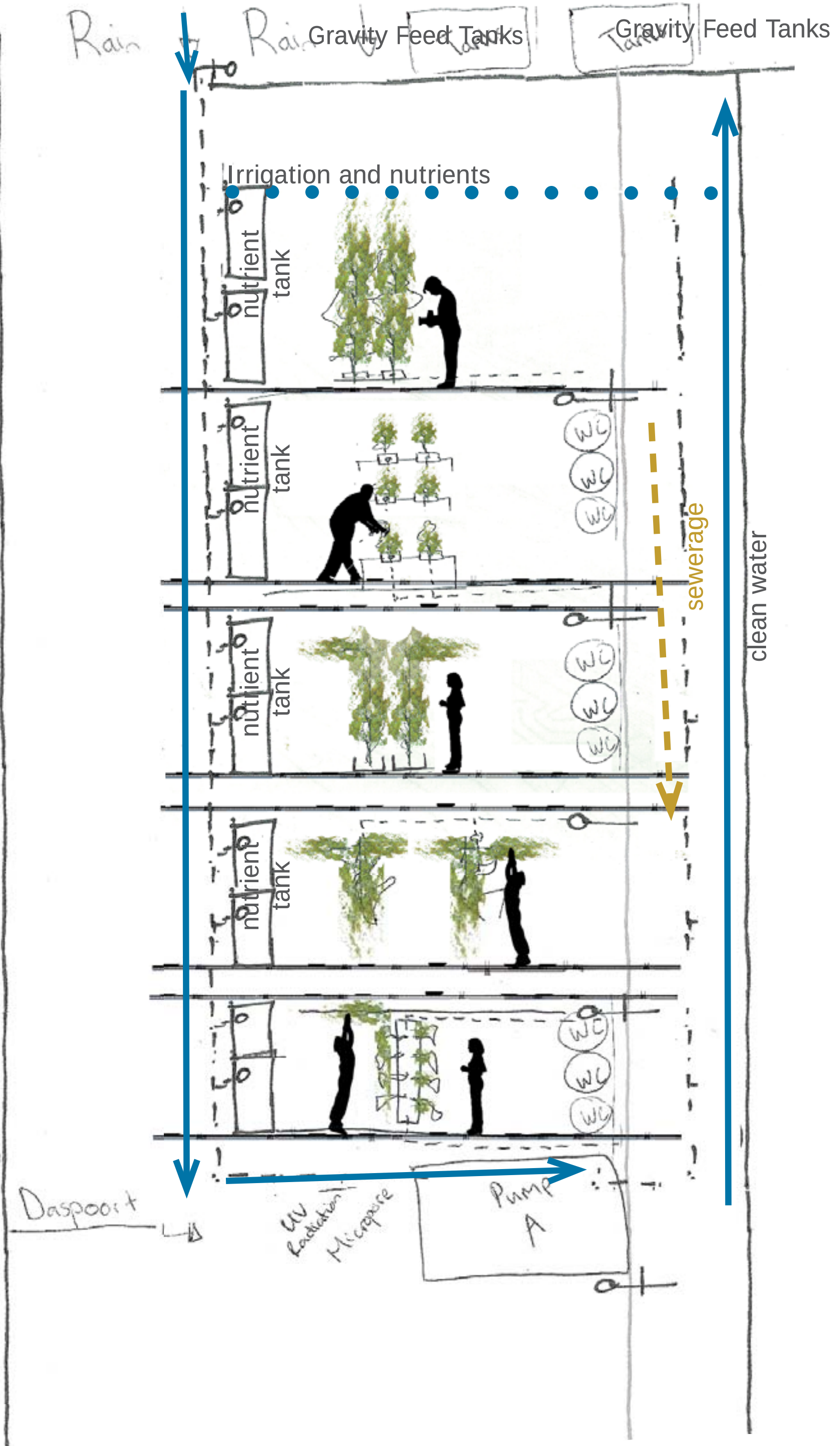


Figure 79 (right) : Building system illustrating the bio-gas created from the excess bio-wastes, converted into electricity [author, 2010].
Figure 80 (far right) : Building rainwater system [author, 2010].

hydroponic food factory

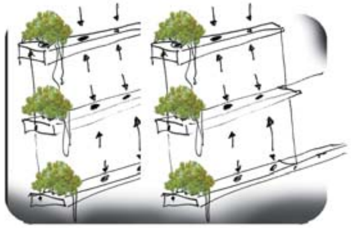
key concept:
hydroponic production

Indoor commercial or private food production relies primarily on a soil-less agriculture called hydroponics or aeroponics (see examples on the right). Hydroponics is a technology to grow crops with their roots suspended or hanging in nutrient-rich water. Today, the term is colloquial for growing plants without the need of soil whatsoever. The hydroponic system has its beginnings in many cultures, (Aztec culture, Hanging Gardens of Babylon), where crops have been grown on rafts or frames, suspended in shallow pools of water. Europe generally started experimenting with the soilless crops circa 1699 and the official term, “hydroponics”, was given by the Americans’ in the 1930’s. Today, it is a practical application in thousands of greenhouses worldwide and a large commercial industry [Turner, 2008].

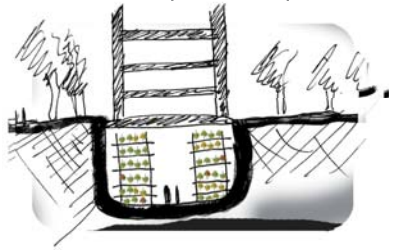
Hydroponics is a successful, viable solution to the food crisis, especially in destitute nations and the application can vary from a small, poorer village in Africa to food-production for space-travel [Martin, 2006:92-110]. Because of the many advantages that soilless crop production can bring (verticality and optimization of space, year-round production and optimum yields and crop quality control), it is essential that South Africa take a leading role in this technology. A sister technique is aeroponics, where the plant is grown without any need for a substrate and is totally suspended. This technology is in development still for large scale commercial production [Clark, 2008] but commercial greenhouses can be found in New Zealand, United States and Japan [Cox, 2010].

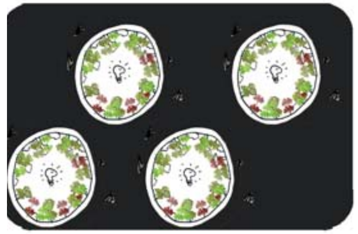
1. Figure 81: Diagrams of hydroponic methods [author, 2010]
2. Figure 82: Chicago [Blake Kurasek, 2009]
3. Figure 83: Pasona, Japan [www.treehugger.com]
4. Figure 84: South America [www.verticalfarm.com]
5. Figure 85: Pasona, Japan [www.treehugger.com]
6. Figure 86: Frasers, Sydney [www.sydneyarchitecture.com]
7. Figure 87: Private Window Farms, New York [www.windowfarms.com]

These technologies are not at all high-tech solutions only, and there are numerous products available to the home-gardener and for application in smaller, localised settings, especially in water-scarce environments [Martin, 2006:92-110]. The hydroponic food factory will provide a platform for commercial crop production, education and experimentation in alternative crop production strategies. The greater scheme will also facilitate education for Small Plot Developments.


1. soilless, suspended crops


1. residential crops


1. underground farming


1. rotating carousels

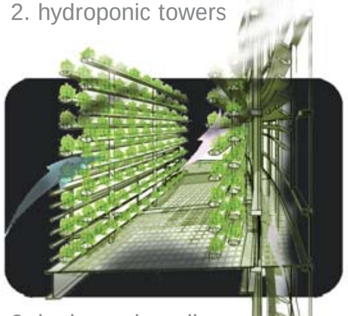

2. hydroponic towers


3. underground crops


4. hydroponic greenhouses


5. indoor hydroponic trellis crops


5. indoor aeroponic trellis crops


2. hydroponic walls


4. underground crops


6. mixed-used buildings


7. window farming

hydroponic food factory

Nutrient-film technique (NTF) is a hydroponic method where nutrients are dissolved in a shallow stream and fed to plants through channels. Aeroponic methods grow plants from a frame and suspended in an nutrient rich air-mist.

Vine crops (tomatoes, cucumbers et cetera) can be trained on frames or wires to grow in virtually any direction.

Figure 88: Hydroponic methods explained [author, 2010].

hydroponic nutrient film:

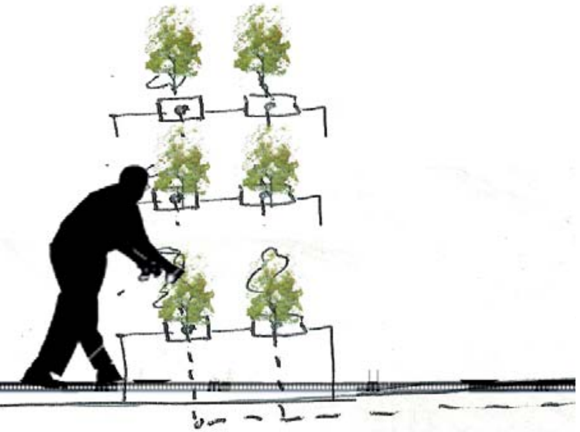
plant and nutrient feeding is placed in a plastic tray-system or container on ground plane, aluminium or timber framework.

A

hydroponic nutrient film or substrate:

plant and nutrient feeding is placed in a plastic tray-system and can be stacked

B



hydroponic dutch bucket

plant and nutrient feeding is placed in a bucket (like a pot-plant) and vine crops are trained to grow around the pot/bucket and onto frame (ceiling)

C

hydroponic or aeroponic

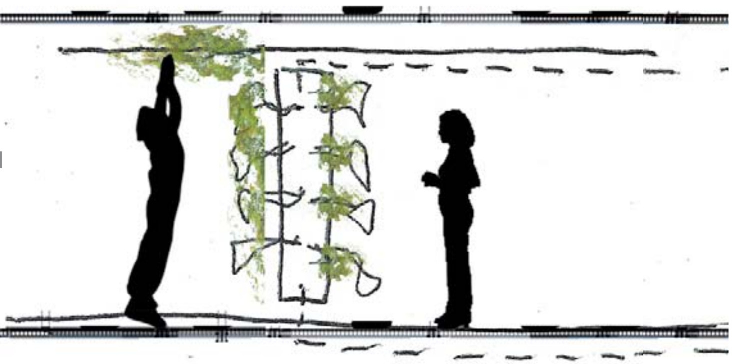
plant and nutrient feeding is placed on frame and hung from ceiling

D

aeroponic

plants are fed from a suspended feeding box and grown from holes gutted from this box.

E



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hydroponic food factory

key concept: crops and production types

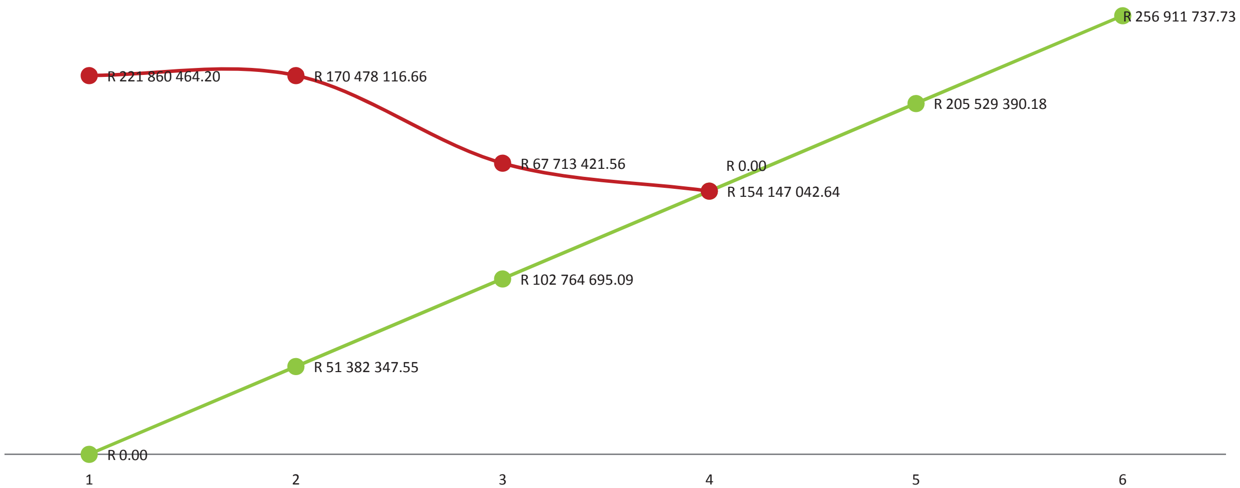
Considering the condition of the old coal bunker, it was decided that the environment within the bunker would be best suited for crops that required less sunlight. Underground production of typical hydroponic crops is possible and just as productive, but require much more artificial simulation. The bunker environment is best suited for plants that do not flourish on natural daylight. Most suited crops are typically mushrooms, sprouts, other fungi crops, potatoes et cetera [Combrink, 2010]. This will imply a more controlled and closed environment for the crop production as disease spreads about easily within these crops. Above ground, hydroponic and aeroponic production will be located. To determine the size of the new building, the tomato crop was used as a parameter since the plant is on the higher scale of most of the requirements concerning water, horizontal space, vertical trellising height, weight and sunlight [Combrink, 2010]. If the building can accommodate a tomato crop, then almost any other crop can be grown within it.

key concept: business

The design is conceived for ownership by a private company or as joint initiative with the municipality - the program aims to deliver a product for profit. It must be possible for an person or company to start the project and build it up to a factory that produces food (and the by-products of food production) for commercial profit within an urban setting. This is a parameter for design and determines the size and scope of the project.

key concept: business

A typical private client is Richard Branson, owner of Virgin Enterprises. He is reputed for controversial developments and such a project could open up a new dimension for his company. Other clients can also include local food chains (Woolworths, Fruit & Veg, or Spar.) The aim is to incorporate local food making not only into the urban landscape, but also to integrate vertical agriculture and urban agriculture as part of our general knowledge base as social urban dwellers. By building on this specific historic site with this contemporary program, the architecture can illustrate the proximities between the global and the local, history and future, industry and living. The site is ready for a goal-orientated, future-driven architecture.



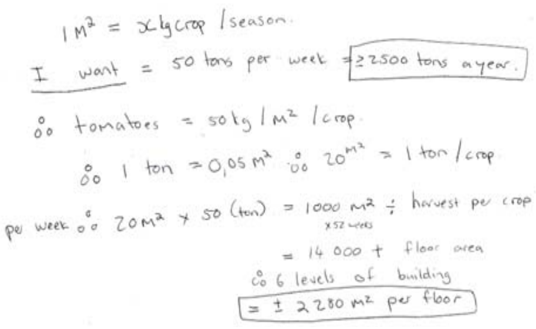


Figure 89 (above): Return on investment - building for production and profit [author, 2010]
Figure 90 (far left): Ordering crop production to suit conditions of the old coal bunker [author, 2010]
Figure 91 (left): Estimating building footprint [author, 2010]

profit return on investment

business urban agriculture is a great investment opportunity

hydroponic food factory

key concept:
biomass and electric energy production

In the case of the *Vertical Farm Project* by Despommier and his students, it was possible to produce a great amount of **surplus** electric energy from the vertical farm, and feed this energy back into the city grid [Alam et al, 2004]. This is due to the fact that the entire vertical farm is designed on the principle to supply 50,000 people of all their food annually. The aim of the new Pretoria West hydroponic food factory, however, is to make the process of resource-efficient, commercial, vertical, urban food production possible as a norm: it must be possible and viable for an person to make a profitable living from vertical and urban agriculture as a real business opportunity. This reduces the scale for the project considerably in comparison with *Vertical Farm*, yet the ratio's of the various building systems and its processes still give sustainable results.

Hydroponic growing is method of growing, but like human beings, plants need fresh air, clean water, wake up and go to sleep. Since the building is a large, stacked indoor greenhouse, it is impossible to give natural daylight to every corner. However, daylight can be simulated for growing plants and many agriculture industries use OEM Light Emitting Diode (LED) to grow large scale commercial crops. This was also factored into the calculation for how much electric energy the building requires (for example: tomatoes use 10.7 W/m², for minimum of 7 hours to a maximum of 12 hours a day) [Alam et al, 2004].

In the case of the new hydroponic factory, the internal composting process and biomass has the potential to supply surplus electric energy through bio-gas production. It is proposed that the building be able to collect and process additional biomass from the city (restaurants, schools, shopping centres, schools) in order to produce an even greater amount of electric energy since it would already facilitate this process internally.

The building is a pilot development for similar projects across the city. When one person can succeed in this venture, smaller and similar projects will develop within a city, and so aid in the development of local, resource-efficient urban cells and the agriculture CPUL for Pretoria.

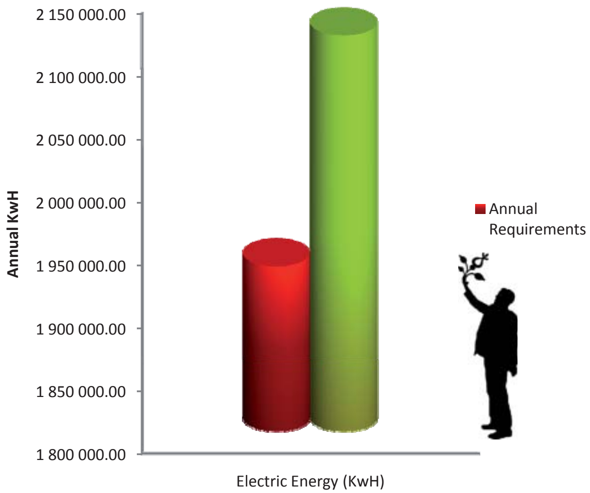
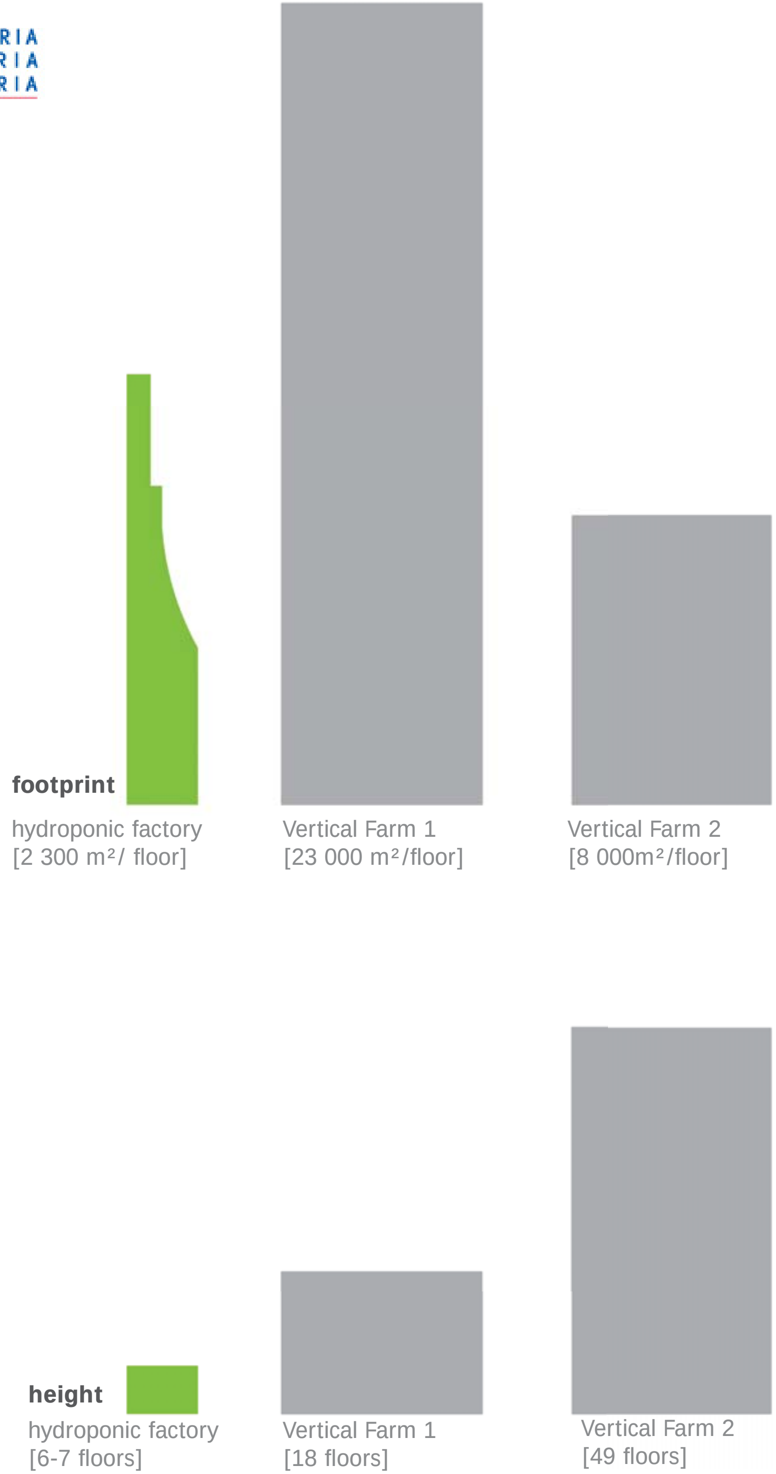


Figure 92 (top): Electric potential of the building [author, 2010].
Figure 93 (right): A comparison of the new hydroponic building in footprint and heights to the footprints and heights proposed by *Vertical Farm* [author, 2010].

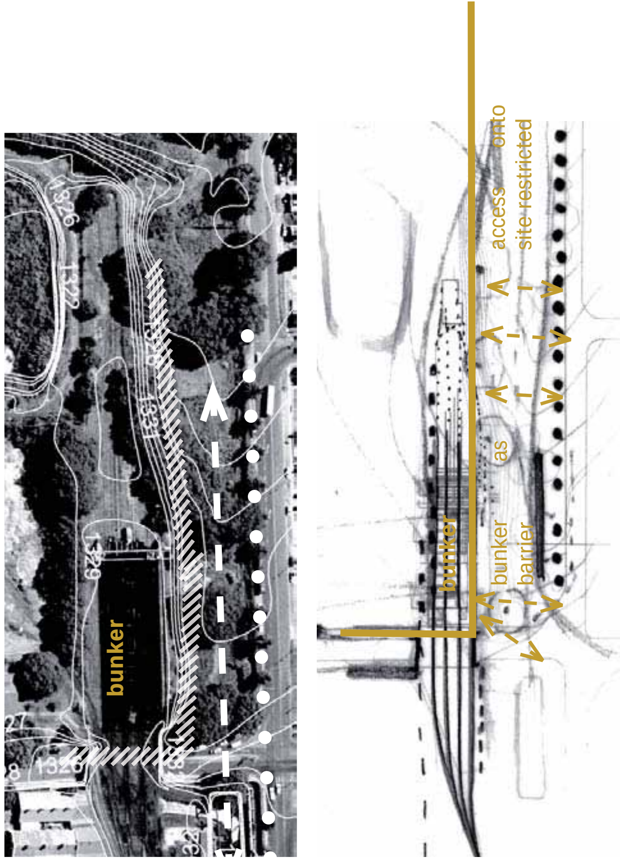


chapter five

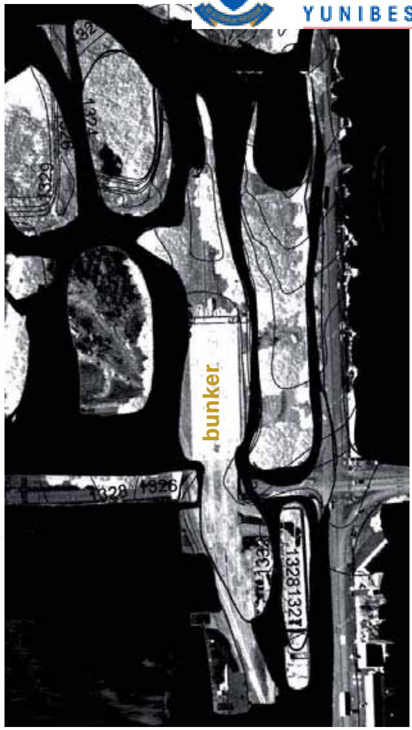
design development

As mentioned in previous chapters, the aims of the project is to encourage a mutually beneficial relationship between an urban environment and an productive environment by developing a *Third Landscape* urban space within the production environment. The design development is first approached from the manipulation of the bunker. The bunker itself is a massive single frame concrete object, but it is a frame that cannot be easily manipulated - it is completely immobile and deterministic. Though, in its scale, it is a majestic object, and in that is its beauty. The new architecture aims to expose the quality of the object and the space that it creates by changing it from a barrier object into a public space. The bunker is opened up to the public and a public market area is introduced.

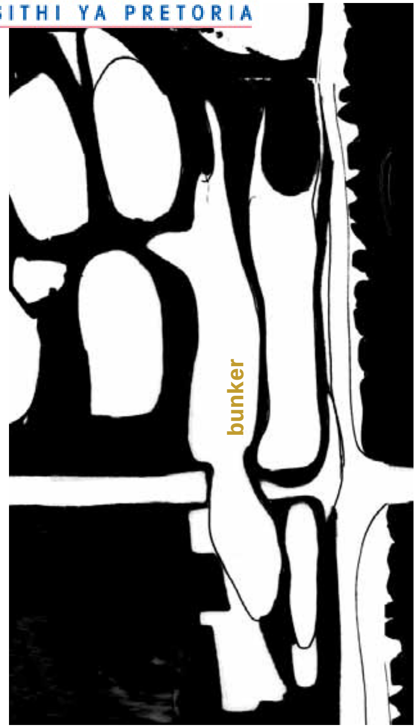
Next, the remaining site is referenced in the new design. Spatial references are made to the existing hidden conveyor system (south) and a physical reference is made to landmark characteristics of the surrounding buildings and site (west). Following this is a description of the various programs of the building and an accommodation schedule is provided. The strategies for a *Third Landscape* space are implemented. Following this is a description on how the program of hydroponics further determined building form and construction concepts; and lastly a material selection is given.



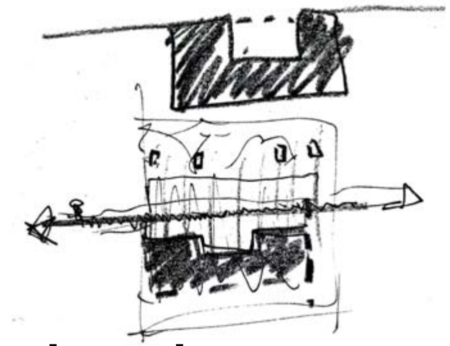
existing conditions



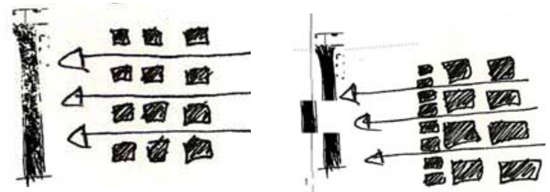
spaces and barriers



spaces

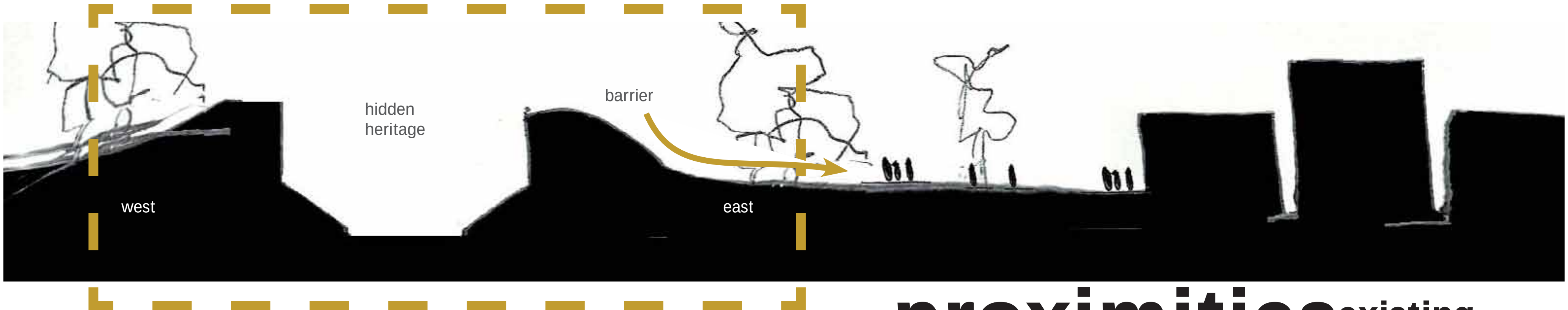


1 breach breaking the barrier



1 breach breaking the barrier

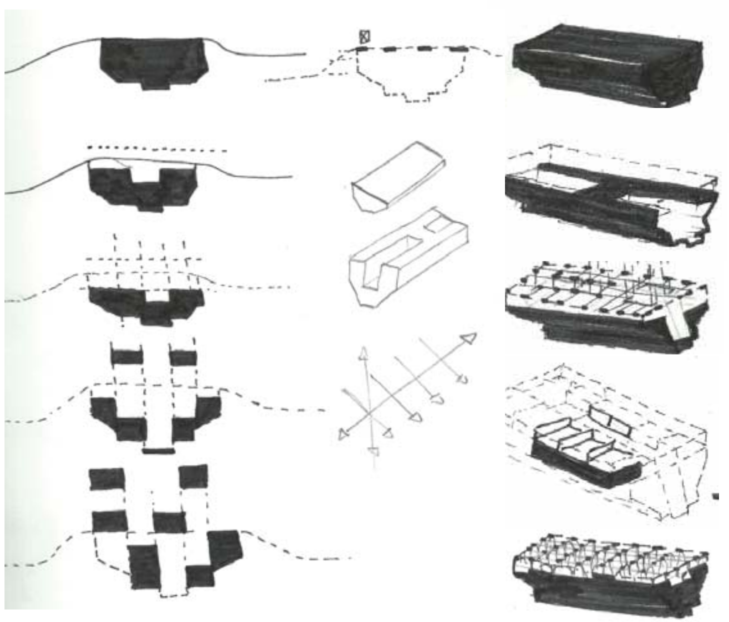
open up the bunker



The old coal bunker - a barrier
Isolating landscape [west] from city [east]
Isolating production processes [underground] from the urban dweller [above ground]

proximities existing

Figure 94: Diagrams showing barrier condition [author, 2010]. Section illustrating the isolation of the bunker from the cit.



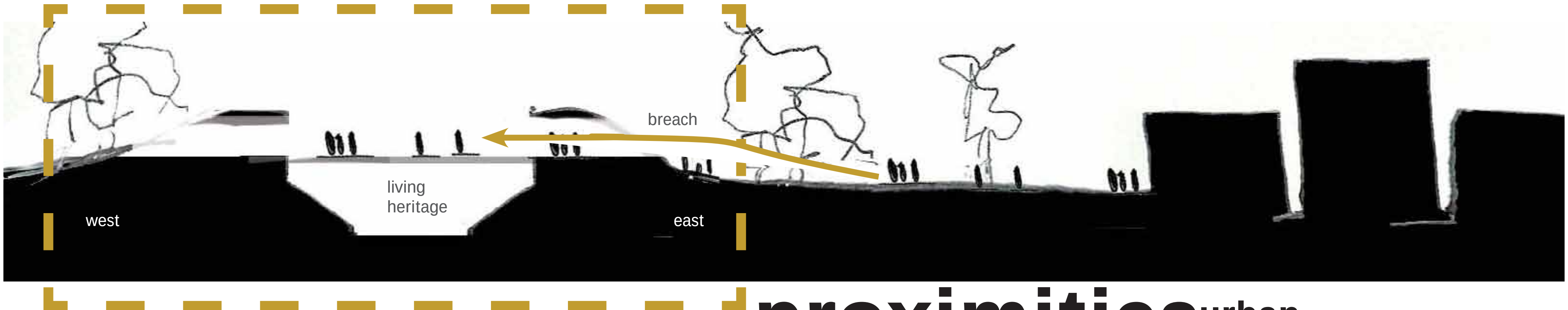
2 turn into urban building

introducing free pedestrian flow across and through the bunker

3 introduce pedestrian access

4 strategies

exploring options for opening the old coal bunker, [author 2010]

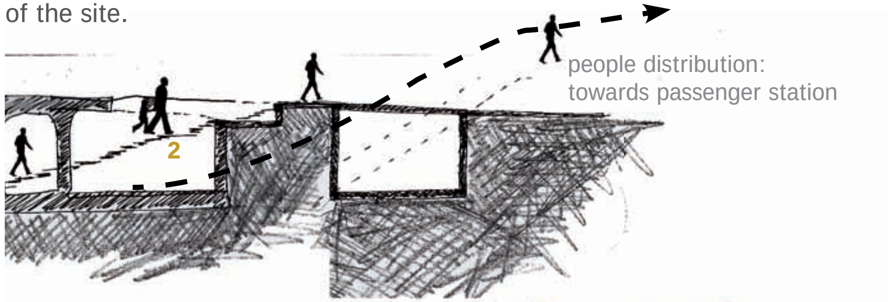


the intervention
Closing proximities with landscape [west] and city through heritage building [east]
Closing proximities of the production processes [underground] with the urban dweller [above ground] in a new middle ground.

proximities urban

Figure 95: Diagrams showing the barrier condition removed [author, 2010]. Section showing the opening of the bunker and removing barrier condition to integrate it with the city

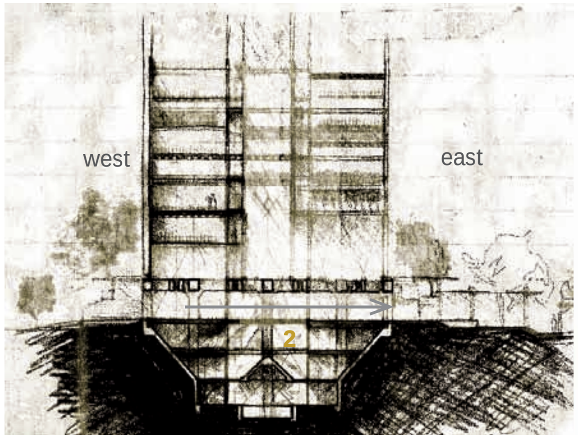
The existing coal conveyor system [3] is reconfigured to transfer packed pallets from the underground packaging areas to the larger distribution at the new proposed train station. It is also an informant to indicate how the public should be directed through the new hydroponic factory. This physical diagonal movement is very clear reference to the heritage of the site.

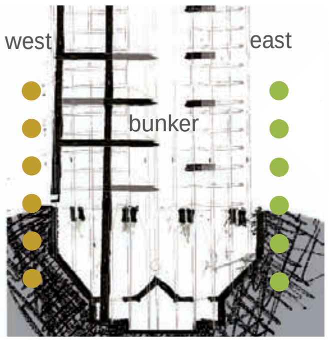


new distribution of people mimicking the distribution of products

existing coal conveyor system reconfigured for pallets

Figures 96,97 (bottom left, right): Referencing elements [author, 2010]. The power station and the palm trees inform a stereotomic and tectonic organisation, reinforced by the site orientation.

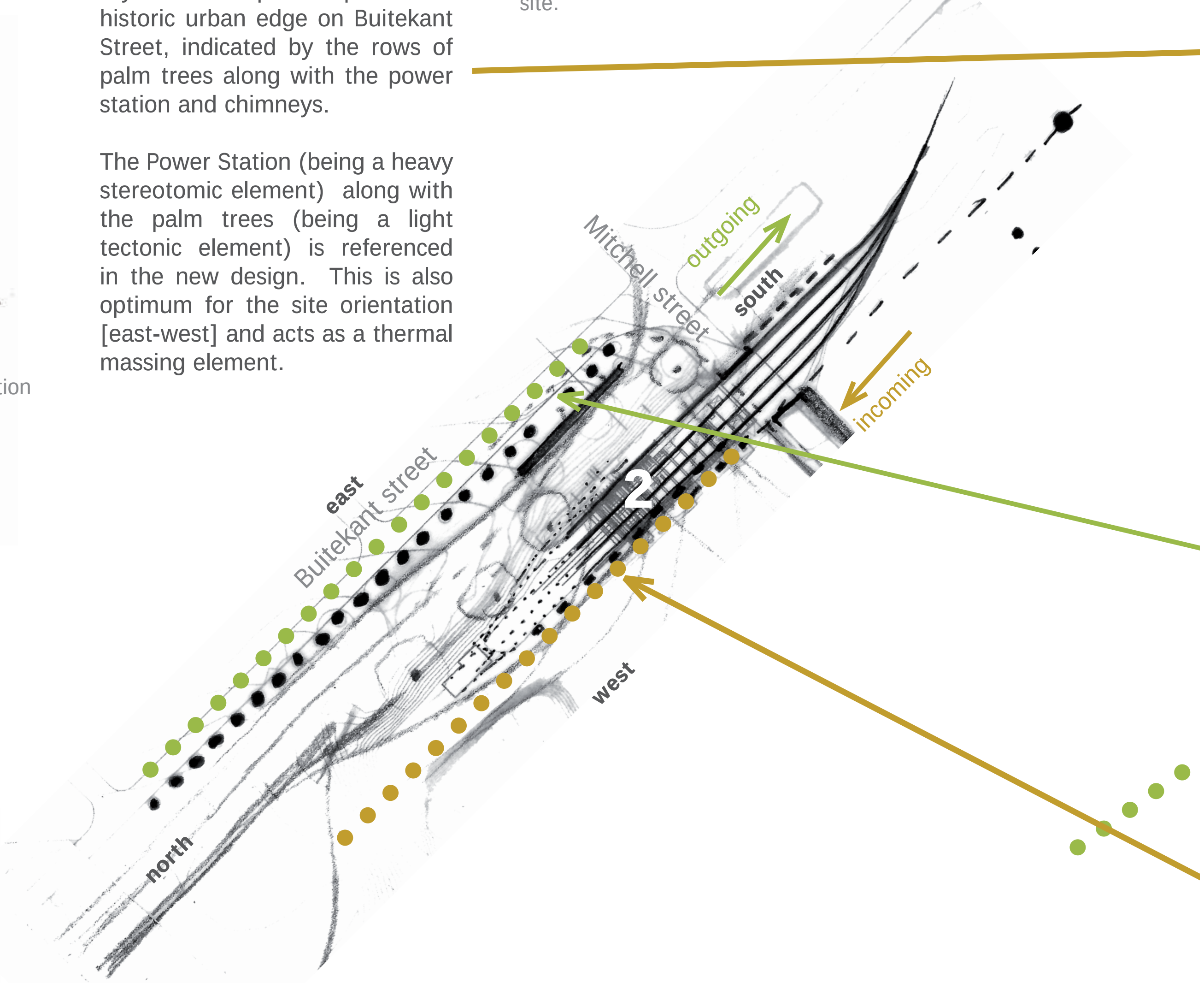




The palm trees [1] along Buitekant street created a historic definition of the urban edge. Upon exploration of the landscape, a rhythm can be picked up from the historic urban edge on Buitekant Street, indicated by the rows of palm trees along with the power station and chimneys.

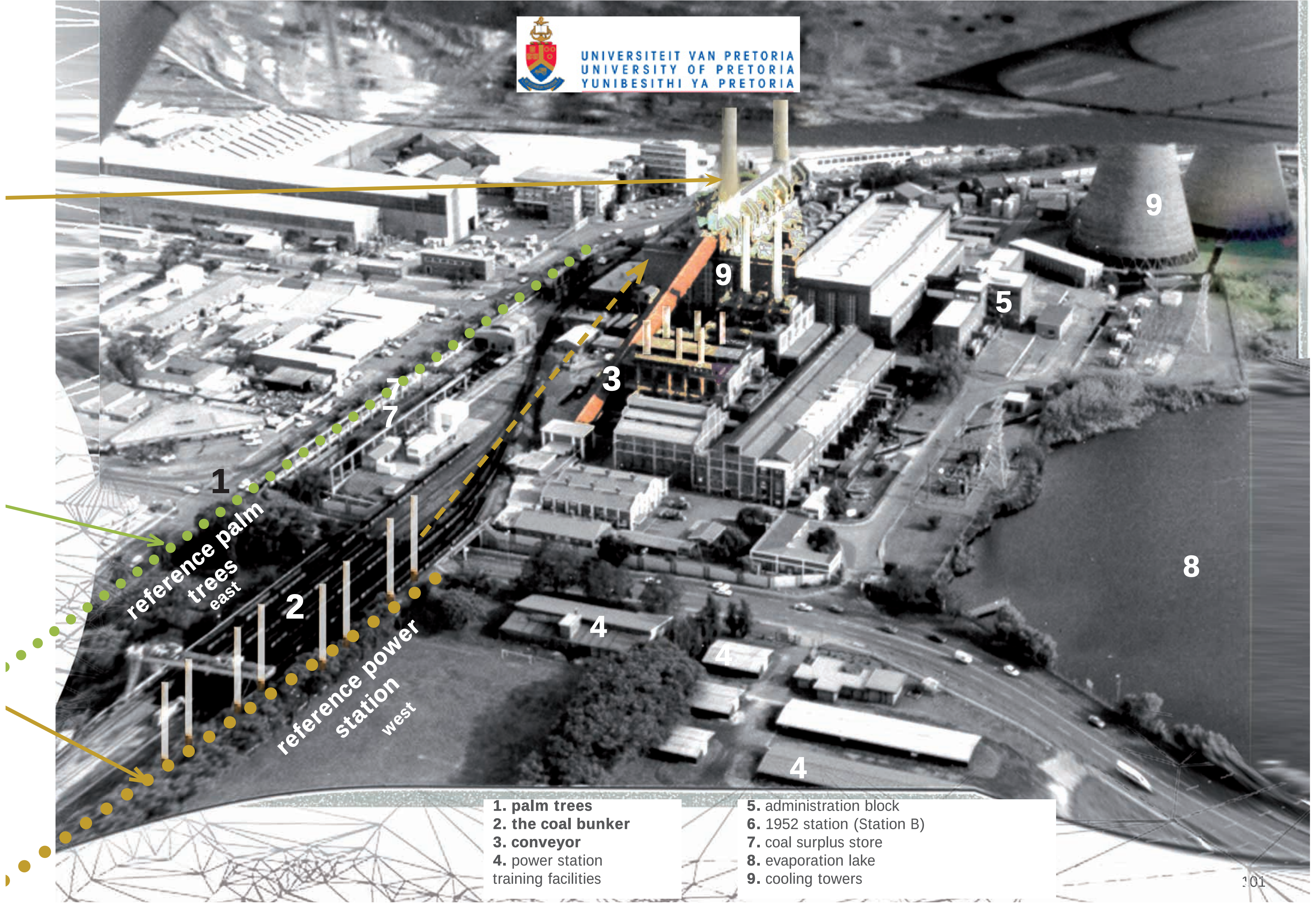
The Power Station (being a heavy stereotomic element) along with the palm trees (being a light tectonic element) is referenced in the new design. This is also optimum for the site orientation [east-west] and acts as a thermal massing element.

Figures 98,99 (below & opposite): Referencing movement [undated aerial photograph from Mr. Masut adapted by author, 2010]. The proximity of movement between people and products now becomes a physical and visual reference as informed by the heritage systems of the site.



proximity references

heritage reference using site elemental heritage to close proximities and create a tectonic and stereotomic order



1. **palm trees**
2. **the coal bunker**
3. **conveyor**
4. power station training facilities

5. administration block
6. 1952 station (Station B)
7. coal surplus store
8. evaporation lake
9. cooling towers

accommodation

As mentioned before, the determining factor for the building size was the crop production of the hydroponic factory. It was decided to produce commercially and therefore a target annual production of 2,000 tons of hydroponic crops is the goal. The model crop to calculate this was the tomato crop. Seedling growing space is also provided accordingly.

target 2,000 tons per year

tomatoes occupation
11,500 m² provided

seedlings occupation
grow rooms 100m² per floor provided

Underground, a mushroom crop was selected as the crop typology.

3,000 tons per year

Mushrooms
1000m² provided

The two crop typologies create bio-mass wastes that can be used as composting material. The composting spaces were configured into compost tower elements on the west side of the building.

35 tons a week

compost occupation
150m² total area provided
50m² packing and storage area provided

To run the various operations of the entire building (the hydroponic factory, the small plots, market and education), a central control room and administration offices are required, situated on the south of the building, next to the seedling growing rooms.

offices

65m² control room
160m² office space
20m² telecommunications server room

A small controlled greenhouse is also provided to perform tests and experiments with nutrient solutions or experiment with new cultivation methods. This controlled greenhouse is visible to the market space.

small controlled greenhouse

140m² greenhouse
180m² work areas

Packaging and refrigeration areas are provided in the lowest level of the existing coal bunker, where the existing coal conveyor system is also situated. This conveyor system has two belts and both can run upwards or downwards. Each belt is large enough (1,3m wide) and can be reconfigured to transport new incoming pallets (1m wide) or other goods from the freight station. Packed goods are packed in pallets and sent out via the conveyor system to the new proposed freight station (south) for distribution. According to Mr. Combrink [2010], refrigeration and distribution across provinces is a problem for small farmers, especially small fruit or dairy farmers of the nearby areas of Brits, Rustenburg, Hartebeespoort et cetera. Because the hydroponic factory aims to produce crops for local distribution, it does not need to refrigerate its own crops for long term storage (two or three days of the week maximum). This means that it can schedule its refrigeration and distribution to accommodate the crops from a couple of small farmers also and provide a means for them to extend their businesses. The building provides a means for these farmers to ship goods elsewhere. The farmers send their produce by truck to the hydroponic factory, where it is stored and refrigerated. A vehicular distribution and loading area is also provided. This distribution area is a double volume space, ramping down just below Mitchell Street. This double volume accommodates commercial trucks and increase stacking and storage space for pallets and pallet bins (which can be stacked 6 meters high comfortably).

distribution

170m² stacking space
170m² loading zone

pallet packing areas

400m² total packing areas
(no soil on crops - no washing required)
200m² general tools and small trolley store areas

refrigeration

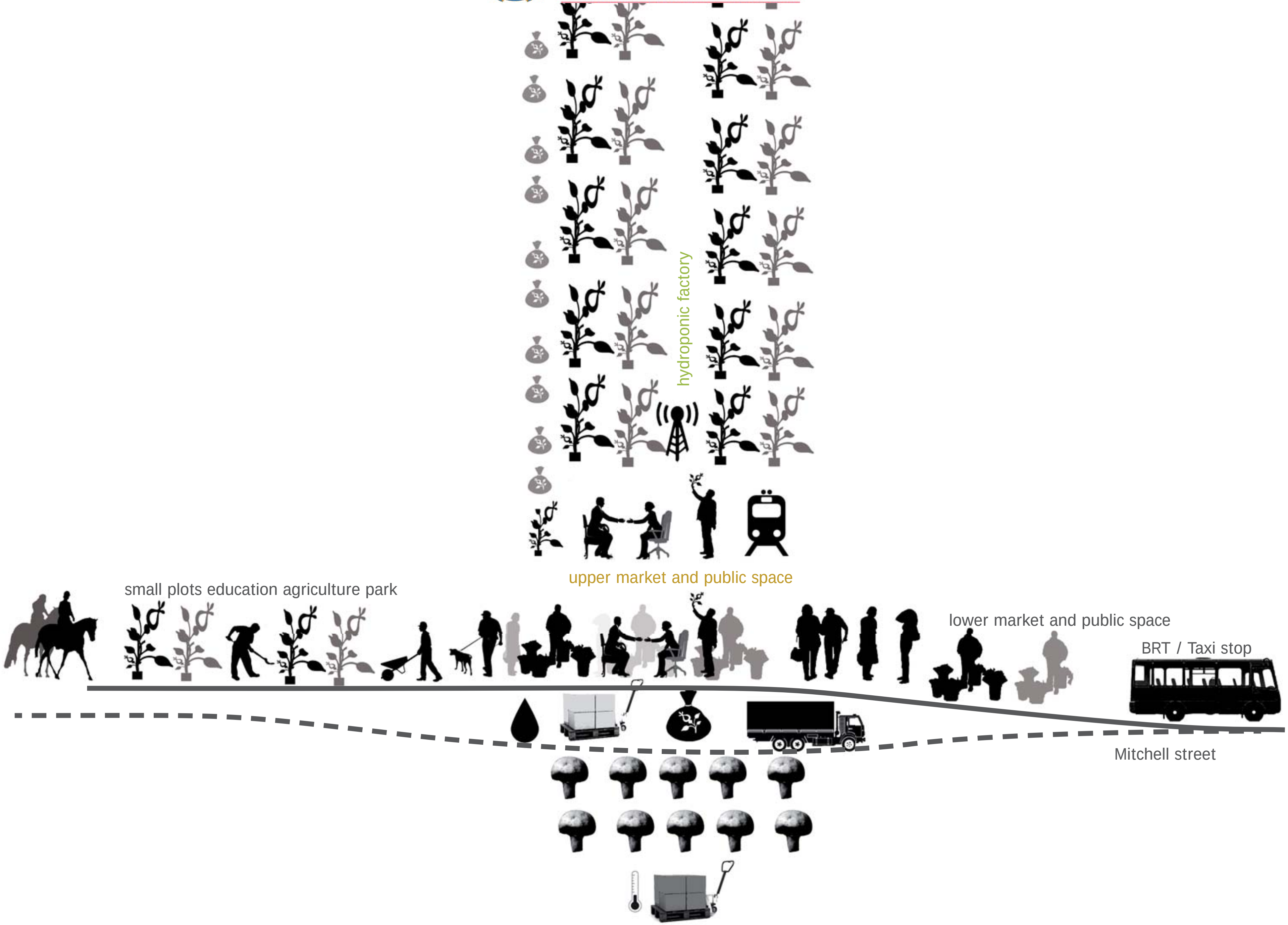
50m² refrigerated rooms
(approx. storage capacity of 125 tons)
55m² hvac room

conveyor

two conveyor belts:
1,3m wide belts each
pallet size: 1m wide
conveys incoming and outgoing goods from freight station

proximtiy accommodation

Figure 100: Typical cross-section [author, 2010]. The proximity of the various programs and accommodations.


hydroponic factory
upper market and public space
small plots education agriculture park
lower market and public space
BRT / Taxi stop
Mitchell street

accommodation

On the first floor of the new hydroponic factory, an incoming rail-line from the new framework freight platform, brings refrigerated containers that can be packed for distribution. The products from other farmers are packed and sent off to other provinces (for instance to Kwazulu-Natal, or Mpumalanga) for further distribution.

The market is introduced on the street level and public moves through the building towards the agriculture park on the west. The market is intended as weekly food or flower market. Tenants can either bring along their own tables, chairs or other furniture, or rent a table from the factory. A small furniture store room is provided nearby, under the public staircase. The market area is provided with taps at column spacings. This market space is a completely flexible, open and accessible public space and can therefore be manipulated for a range of other events also. The upper market space is a covered area within the hydroponic factory and can easily play host too activities ranging from holding a harvest festival, being a base for a city marathon, becoming a monthly community hall or even accommodating a church service or other functions. This increases its potential to develop community events and therefore increases the cultural value of the space. Offices are provided to manage the community space. A small restaurant / coffee shop and kitchen is provided, to increase the variety of activities that the market area can offer.

incoming refrigerated containers

7 ton containers
weekly refrigerated
storage space scheduled
accordingly

public space

300m² of covered
public space within the
hydroponic factory
60m² furniture store room
100m² small restaurant /
coffee shop
100m² restaurant kitchen

Education programs are also situate within the public space. Theses are aimed at training the staff of the hydroponic factory and educating school groups or other groups in hydroponic techniques. This provides an place to transfer knowledge and skills for indoor and urban agriculture.

From the market area, a public staircase on the east leads upwards towards the new proposed passenger and freight platforms towards the south. On the east there is a also new BRT bus stop and taxi waiting area.

Just immediately west of the bunker and the market there is the new public agriculture park. There are also existing masonry buildings, currently used as classrooms and boardrooms for staff training for the old power station. The largest of these buildings is empty at the present time. The northern part of the building's roof will be removed and structure will be converted into a greenhouse and a classroom for education on small plot developments on site. The small plot developments is introduced for public demonstration and education in urban agriculture, and is not necessarily a commercial enterprise.

It is proposed to turn the southern part of this existing building into stables for mounted police units who can patrol the large landscape and the immediate environment. A mounted police unit is a very friendly, yet effective public policing strategy. The horses will also be an attraction for the site as a whole.

hydroponic education
300m² covered
greenhouse classroom
150m² open classroom
venue

new BRT and Taxi stop

urban agriculture park

small plot
developments

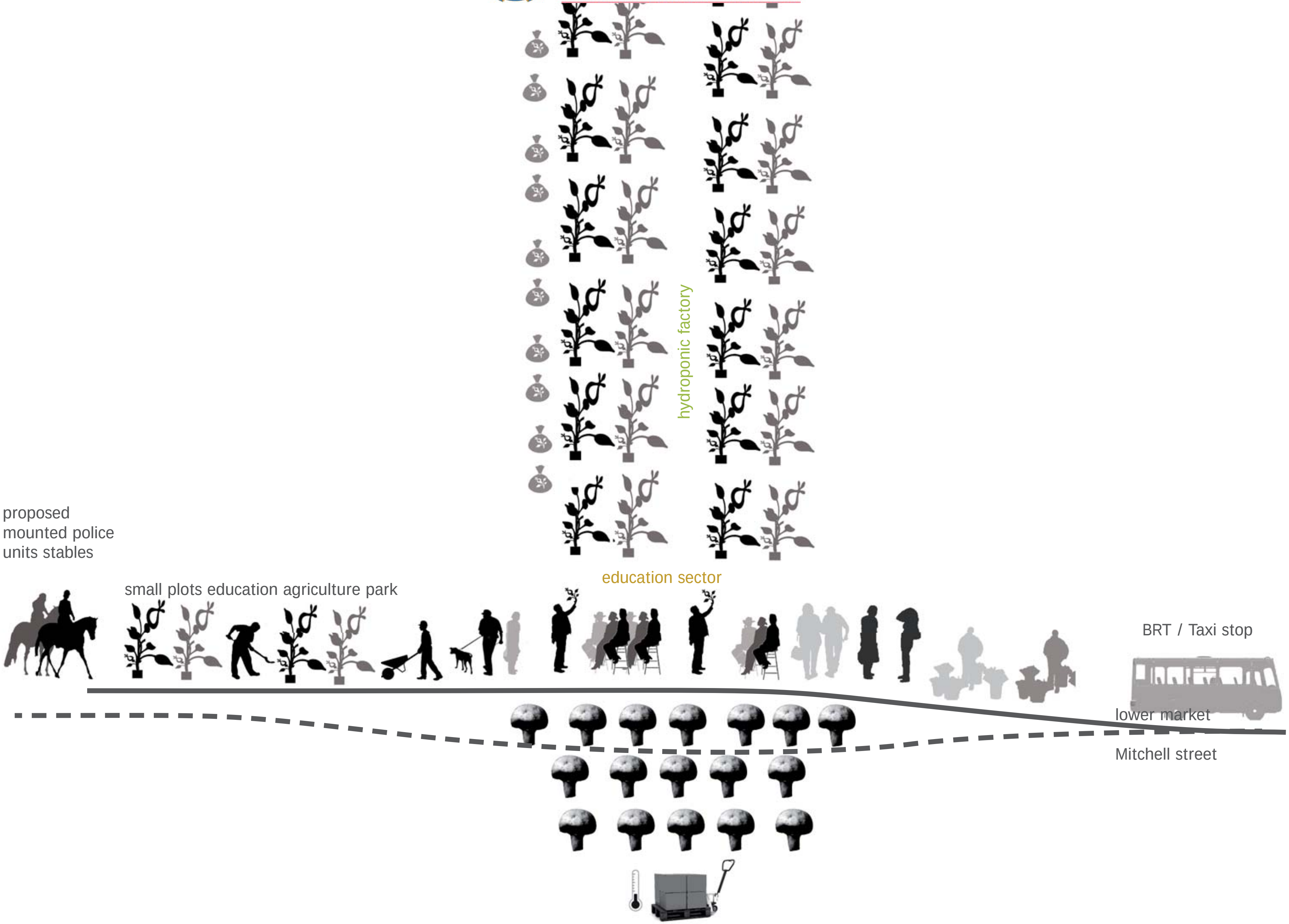
rework existing
buildings for proposed
small plots education
and greenhouse

proposed stables

rework existing
buildings for proposed
mounted police units
for the site

proximtiy accommodation

Figure 101: Typical cross-section [author, 2010]. The proximity of the various programs and accommodations.


hydroponic factory
proposed
mounted police
units stables
small plots education agriculture park
education sector
BRT / Taxi stop
lower market
Mitchell street

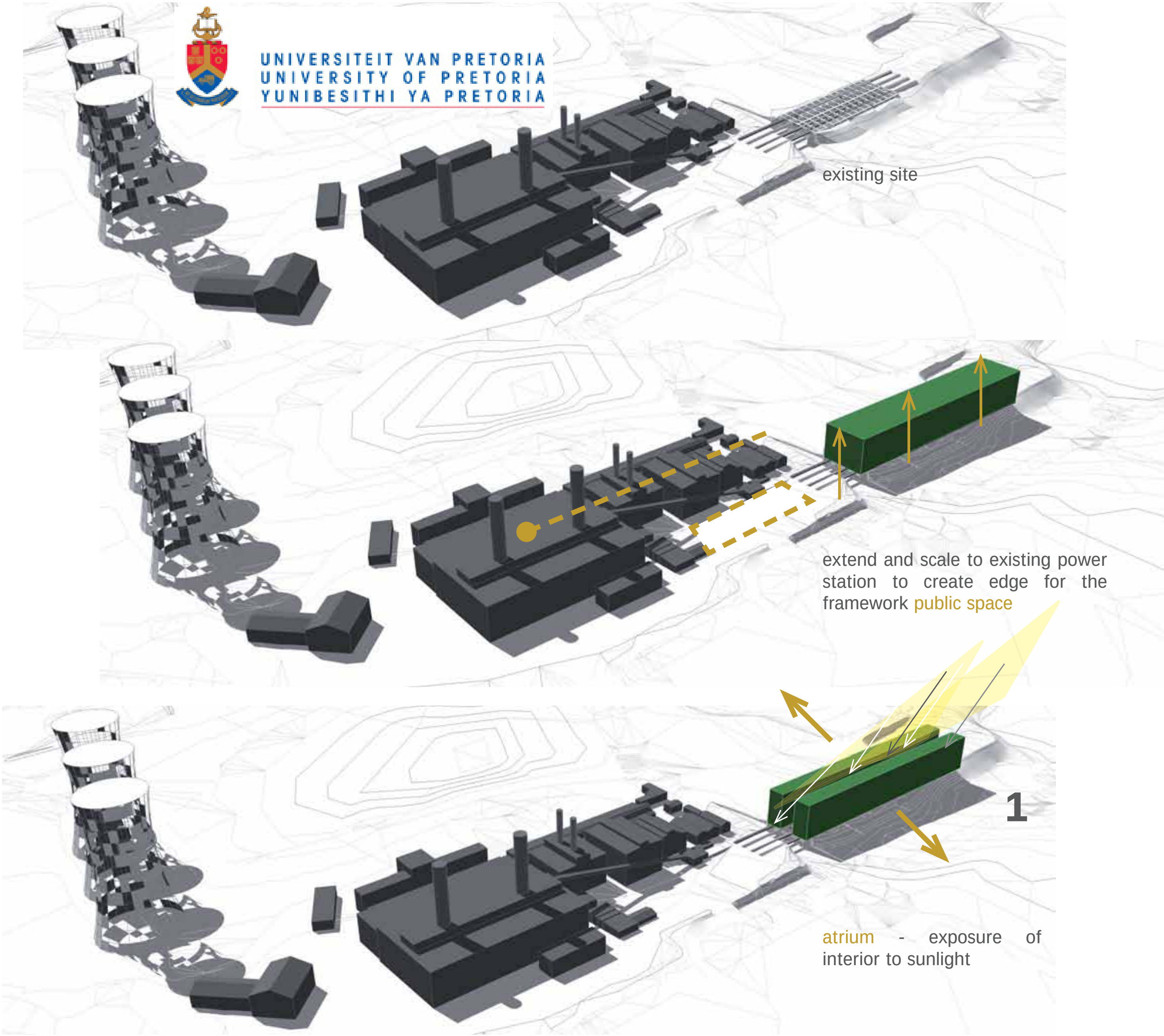
hydroponic food factory

The program of vertical agriculture can be applied virtually anywhere (underground, in space, in deserts or homes), but to maximise its energy potential, the new building exploits the use of natural daylight for the production of plants to its maximum.

The new building is split into two halves [1], creating a long atrium space which allows light to enter not only the edges, but also the centre of the building. These two halves join up again as a result of the limits of the topography. As a result, the building form is a literal expression of proximity - where two become one. Next, the building is terraced [2] from the north, to expose yet more natural light to enter from the translucent greenhouse roofs.

The building is as transparent as possible not only for the growing of plants, but also to reinforce the proximity of production program to the public. A public interface [3] is introduced in the form of a market space and horticulture classrooms. As the new building is integrated with the existing bunker, so too will the market space integrate into the production program. This parameter makes it clear that the market space should be inserted within the both the bunker and the new building, and not form part exclusively of either of the two. Light from the transparent roofs filters below onto the market and educational spaces. For the same purpose, some of the existing concrete walls will be removed.

Finally, the new building conceptually mirrors the old power station, signifying the new age of 21st century urban industry.



form in context to power station

Figure 102: Building in context [author, 2010]. Design development of new building in relation to the power station and urban framework visions.

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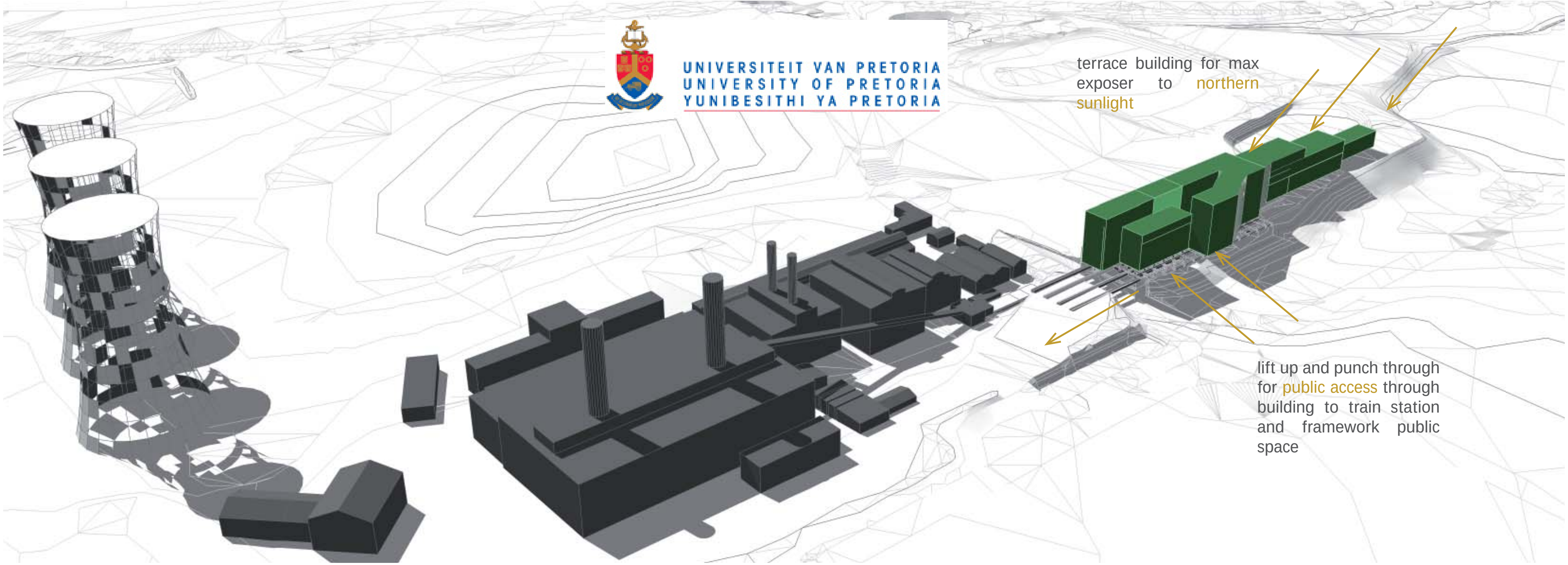
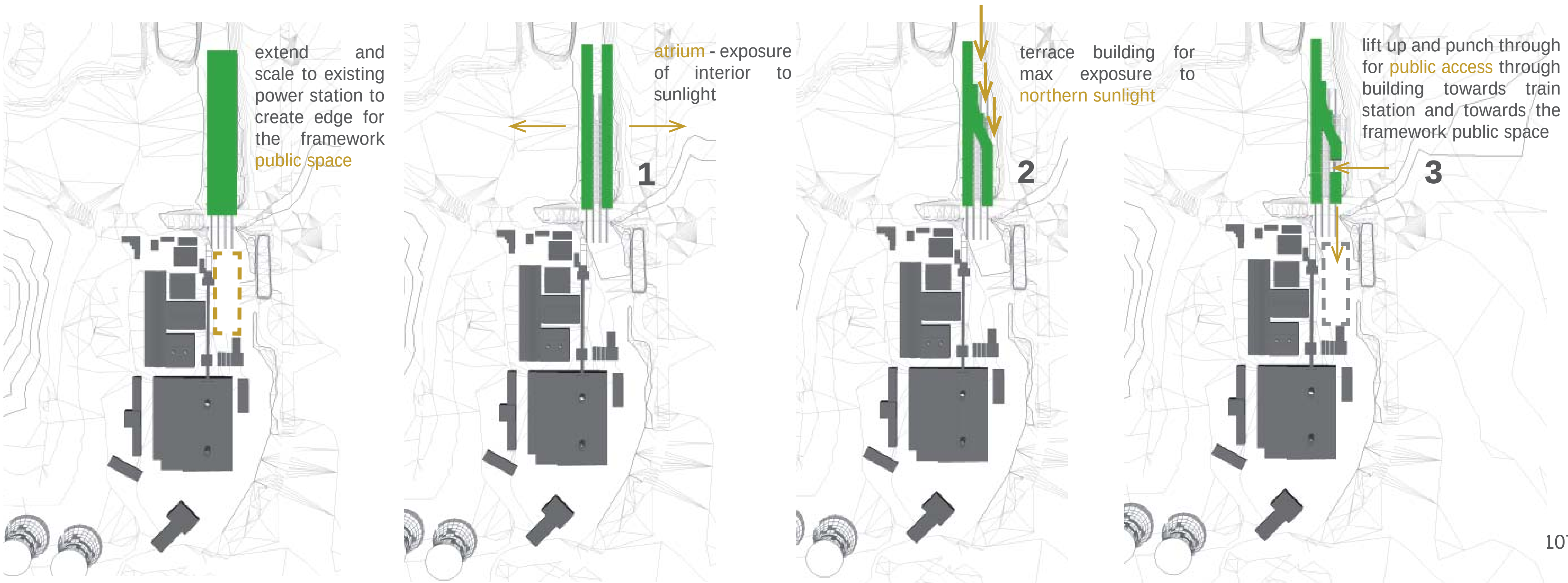
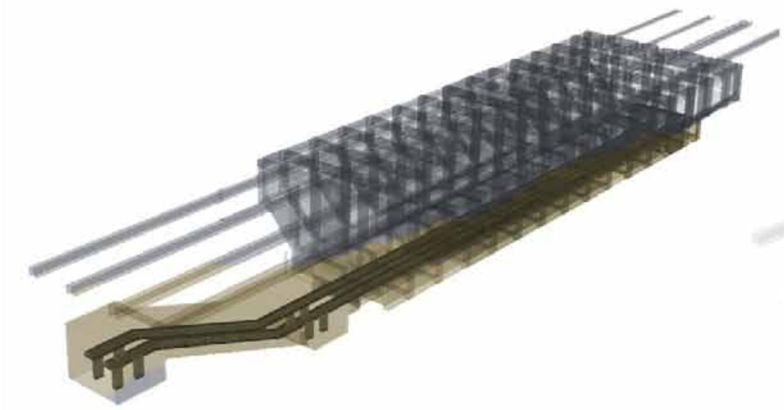
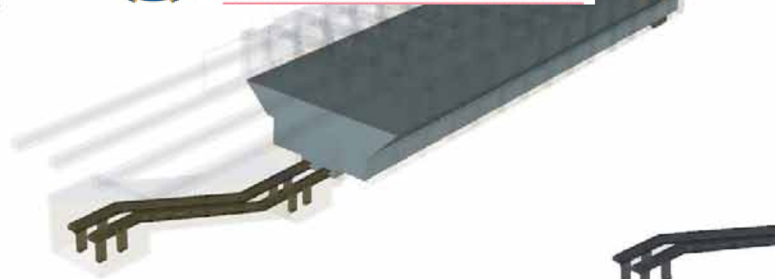


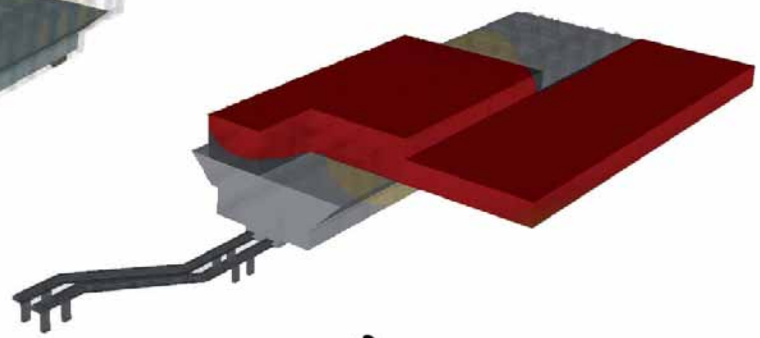




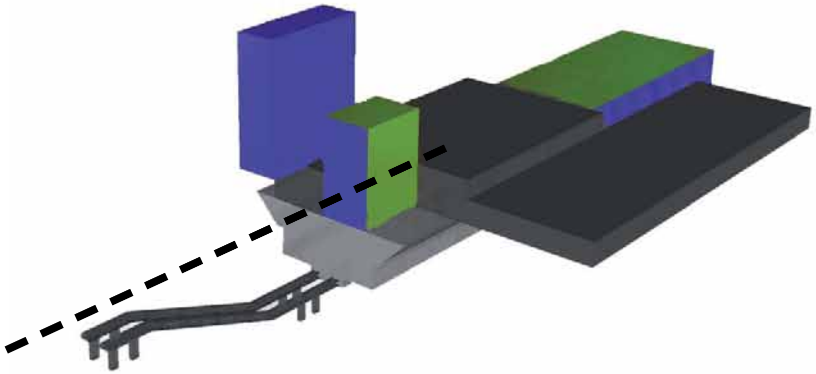
existing structure
and reconfigured conveyor system



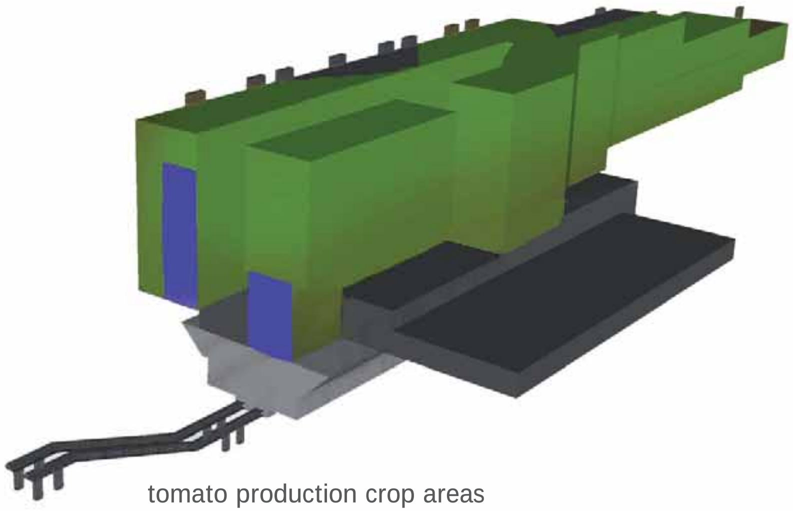
mushroom production, refrigeration, packaging, distribution [all underground]



upper and lower marketplaces, urban agriculture park (towards west)



offices, staff and public education, hydroponic demonstration, incoming railway line



tomato production crop areas

form organisation in mass

Figure 103: Massing diagrams allocation of the various programs forming the first layering of filtering of the design

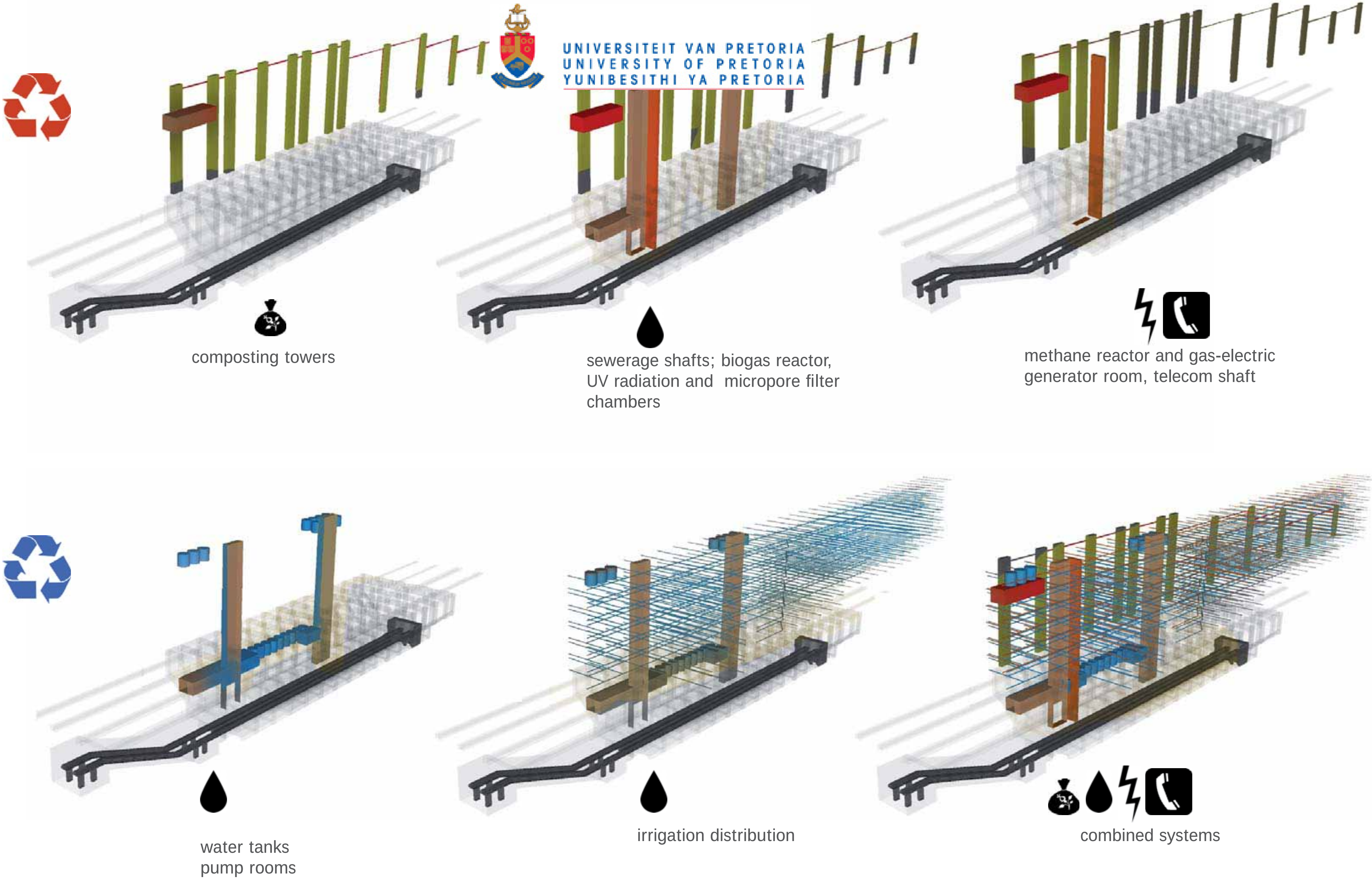


Figure 104 (top): Hydroponic food factory energy systems diagrams [author 2010]

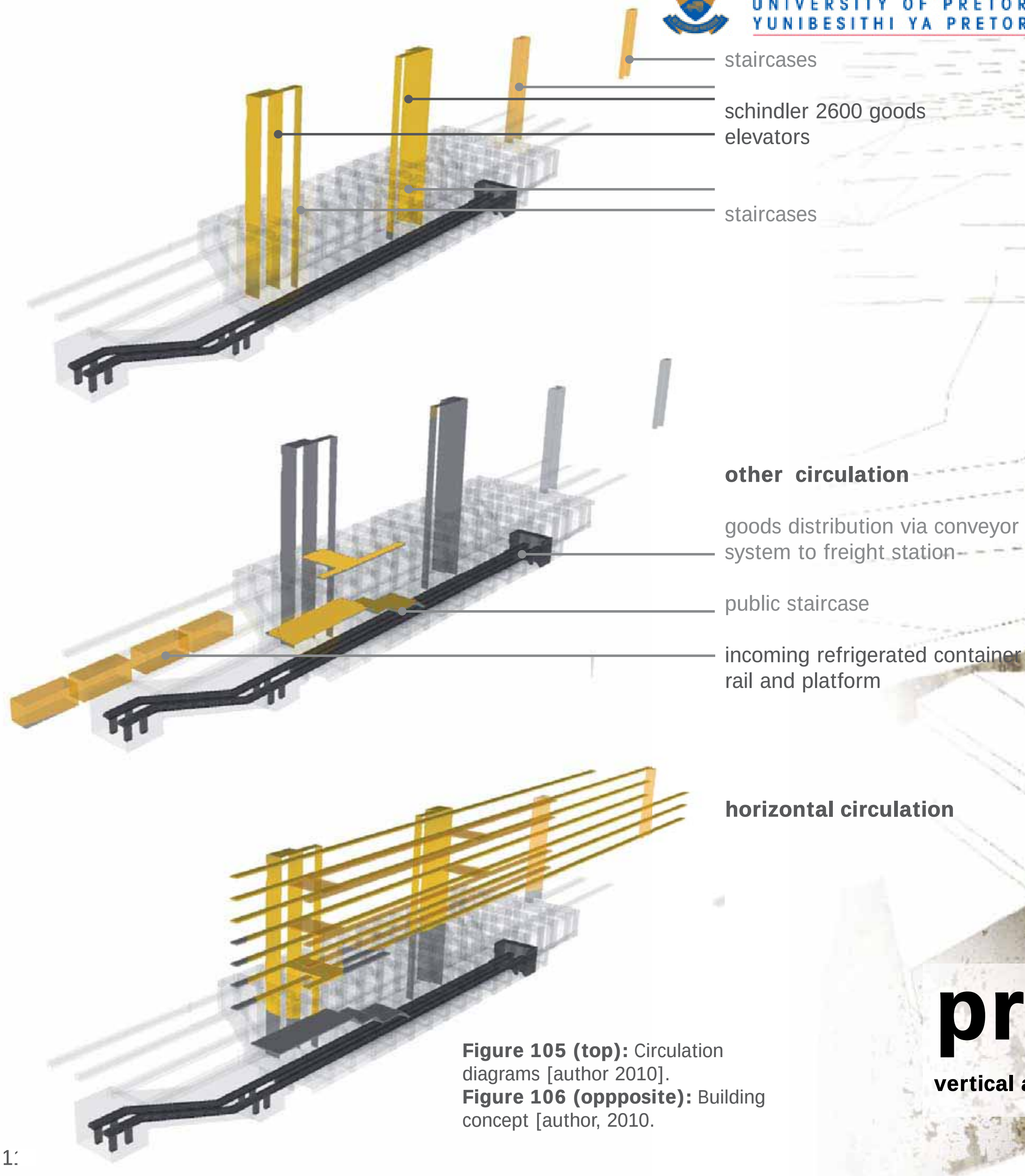
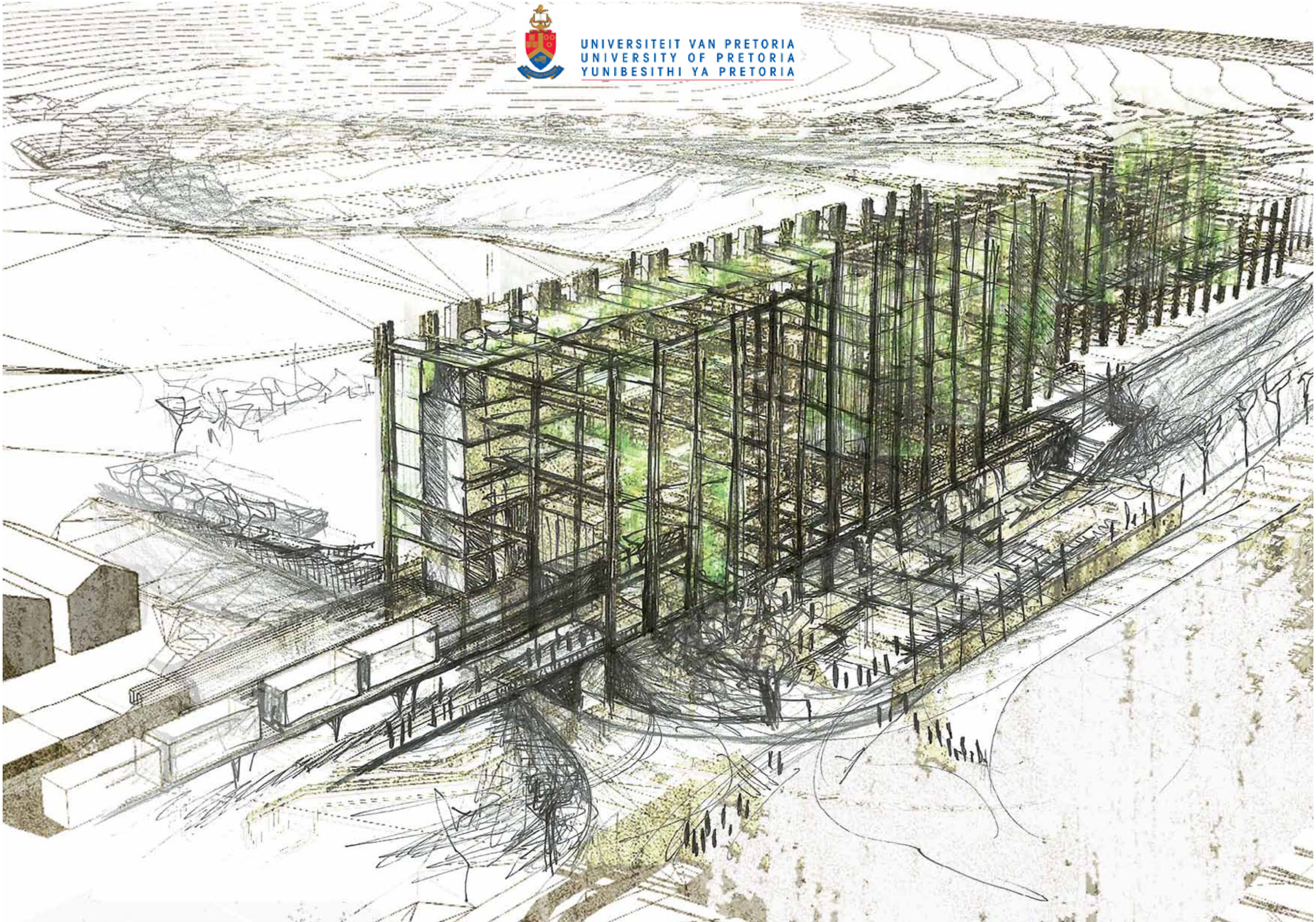


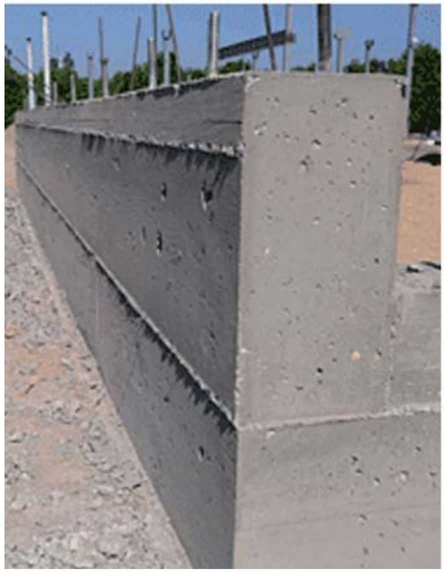
Figure 105 (top): Circulation diagrams [author 2010].
Figure 106 (oppposite): Building concept [author, 2010].

materials

The building has integral pragmatic needs: to optimise floor space and maximize natural light penetration and natural ventilation. This implies that the building must be as transparent as possible in as most directions possible. The design calls for a building of light and frame.

The materials and technologies for the design are chosen to meet the requirements of food production in ways that are functional, durable, sustainable and resource-efficient. Material choices are also based on the fact that the project as a whole is ecosystemic in nature, and so uses as much of on-site resources as possible in the construction materials or finishes. Lastly, the building has a great opportunity to explore and develop on alternative building and construction methods and materials.





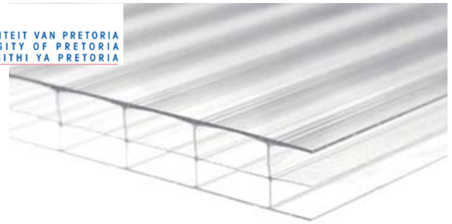
concrete
masonry

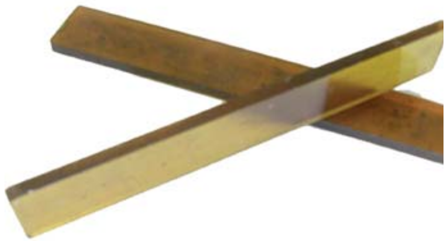
Fly ash is a product available in abundance on site because of the process of coal-fired power generation and the on site ash ponds. The substitution of cement in traditional building materials with fly ash significantly reduces carbon dioxide signatures and global carbon emissions [Ecosmart Foundation Inc, www.ecomsmart.ca]. The local community already collects fly ash from the site for masonry and concrete construction [Masut, 2010]. Another product that can be sourced from site is recycled glass. Consol Speciality Glass Factory is directly south of the Power Station. The factory produces glass bottles and glass packaging and the company has various recycling schemes in practice already. Glass is 100% recyclable [www.consol.co.za] and an effective substitution for traditional aggregates.

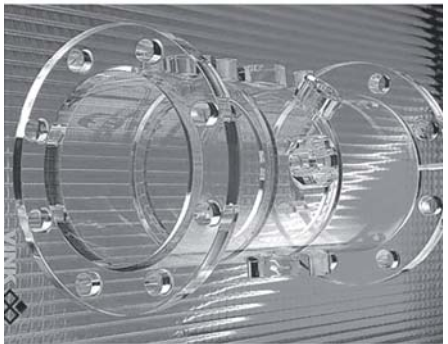
High carbon content fly ash cast in-situ concrete and precast reinforced masonry units are used for thermal mass and infill materials. The hydraulic lift shafts and other primary walls are cast in situ. High carbon content fly ash masonry is the primary non-bearing infill material. Precast concrete planks and masonry units are used at staircases, circulation and exterior landscape applications.

recycled glass aggregate precast concrete

Figure 107: Fly ash masonry.
Figure 108: Glass aggregate concrete.
Figure 109: Cast in-situ fly-ash concrete.







polycarbon
acrylics

Although laminated structural glass seems currently to be the best option as a skin for the building (because of its strength and transparency), it is also the most expensive option, and cannot compete with polycarbonate materials on thermal properties and impact resistance. Also, the structural components required to support glass are much more costly. Both the study on materiality for the Vertical Farm Project, and independent research indicate that polycarbonate, acrylic plastics and acrylic glass is the safest, sustainable, recyclable option as a alternative to glass [Fitzpatric et al, 2006:15; www.bwgreenhouse.com]. Not only will this give the opportunity for a transparent skin and roof, it is also possible for a transparent floor in the form of polycarbonate honeycomb structural suspended floor panels [www.bencore.co.uk].

Furthermore, research indicates advances in green plastics, or "bio-plastics". Though this technology is still in its infant stages for building application, it can be used for building services and fixtures. However, when this technology proves to be feasible for use in building construction projects [Fitzpatric et al:2006:21], the new hydroponic factory would be able to shed its polycarbonate skin (as polycarbonate is fully recyclable and generally needs to be replaced in 10-20 years) and literary grow a new one. The bio-plastic product can be grown from the biomass wastes of the building. This product can then also add a new dimension of production and experimentation for the building.

Figure 110: Twin-wall polycarbonate.
Figure 111: Polycarbonate structural floor.
Figure 112: Bio-plastic panels, strips, tubes and fixtures.
Figure 113: Acrylic/bio-plastic plumbing fixtures.

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b a m b o o
s t r u c t u r a l

Bamboo is an accepted contemporary product for applications ranging from flooring, fixtures and roofing. The material has proven through many sporadic organizations and trial projects to be a successful structural element for larger scale building and construction. Many contemporary architects like Arata Isozaki, Buckminster Fuller, Frei Otto and Renzo Piano have already combined conventional contemporary elements (concrete, steel) with bamboo in the pursuit of a new, resource-efficient structural building material. The greatest advantage of bamboo is that it can be used almost exactly as a steel element and so is a great material for anything from columns to trusses and frames. It is also possible to grow it in South Africa and there are already plantations in the Cape provinces pursuing bamboo crops such as Brightfields and the Biomass Corporation. It is viable to grow crops in Gauteng also [Heinrich, 2010]. The Biomass Corporation has planted crops to rehabilitate mine-dumps and other industrial sites, develop bio-fuels from this product and release these sites from dependency of the electric grid [www.biomasscorp.com/southafrica]. The biggest challenge currently is that mind-set of the general population to accept that bamboo construction is durable [Habitat for Humanity, 2009:12]. This is a challenge for architecture. Bamboo is a very viable option for the hydroponic factory as it is an incredibly versatile new material for South Africa and can now be grown and sourced locally.

1. bamboo scaffolding & construction

2. bamboo instead of aluminium in greenhouses for structures or pipes

3. multi-story, load-bearing, low-cost, structural bamboo

1. bamboo scaffolding & construction

4. bamboo structure as durable lightweight, public exterior material

1. bamboo scaffolding & construction

5. bamboo as structure column

6. laminated structural bamboo

1. Figure 114: Scaffolding in China, Japan.
2. Figure 115: Greenhouses, Kyoto, Japan.
3. Figure 116: Staff Housing, India.
4. Figure 117: Hand-Made School, Bangladesh.
5. Figure 118: Structural columns.
6. Figure 119: German-Chinese pavilion, 2010 Shanghai World Architecture Expo.

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p l a s t i c
vs. glass

- Light-weight: plastics weigh on average 50% less than glass, are easier to install and simple to replaced when damaged.
- Impact resistant: plastics generally have a 6 to over 15 times greater impact resistance than glass.
- Safety: plastic products do not shatter when impacted beyond their resistance factor.
- Weather resistant: plastics can withstand the effects of weather, unaffected by sun or salts.
- Insulation: a standard 16mm Triple Wall Acrylic Panel has an R-Value of 0.44 where a Glass Triple Layer with 6mm air space only reaches an R- Value of 0.37.
- Dimensional stability: acrylic plastic expands and contracts with changes in temperature or humidity - the plastic will return to its original state when the temperature returns to normalcy.
- Transparency: acrylic plastic is as transparent as the finest optical glass. White light transmits at 92%, glass at 89% and clear acrylic only a few points lower at 86%, with polycarbonate plastics at 83%.
- Chemical Resistance: acrylic plastic has excellent resistance to most chemicals.
- Electrical Properties: it is an good insulator.
- Easily Fabricated: acrylic plastic can be sawed, drilled, and machined, much like wood or any soft metal, and does not require high skilled craftsmanship or complex tools. When its heated, it is completely malleable and can be prepared for any application.
- Environmentally safe: acrylic plastics have no harmful chemical solvents, do not emit VOC's, the plasitcs are non-corrosive, non-flammable and they have no harmful effects of any form on humans or animals.
- Recyclable: plastics are much easier to recycle and/or reapply than glass products.

[summary on Fitzpatric et al, 2006:15]

b a m b o o
vs. steel and aluminium

- Tensile Strength: with members of the same weight, bamboo has a tensile strength of almost 200 kN/mm² where steel only has a tensile strength of 150 kN/mm².
- Allowable Force: with members of the same weight, bamboo has a allowable force of 25.6 KN and steel 27.6 KN.
- Cost: incredibly economical when compared to steel or timber.
- Can substitute steel: bamboo can replace steel (and timber) completely as scaffolding, trusses or space frames. Current research and design indicate that multistory buildings with only bamboo as vertical structural element can reach up to 3 levels, or 12-15 meters [www.architecturebrio.com] and lightweight buildings can reach even higher. Bamboo as cladding and roofing can also replace steel cladding or roofing.
- Substitute timber: Bamboo competes and beats timber in every way, and laminated bamboo beams are also available. [www.lamboo.com].
- Substitute aggregate: bamboo can be mixed in or replace aggregates in certain concrete applications.
- Renewable Resource: can be harvested annually, non-destructively; matures within 4 years (timber anything from 20 years), crops are available for growth in Gauteng, South Africa, [Heinrich, 2010] and does not require sophisticated farming methods.
- Recyclable Resource: bamboo structures is much more recyclable than steel, can be dissembled easily, reapplied or used to feed new crops, make bio-diesel or bioplastics.
- New skills and job opportunities: the training and development of this technology for South Africa can supply a countless amount of people with work.
- Variety of applications: Like steel, bamboo can and has been used in modern construction as scaffolding for very high structures (more than 50 storeys), columns, beams, trusses, spaceframes, roofs, floors and large bridges. It can also be used in greenhouses, as piping and irrigation, as gutters and downpipes, and as roof, floor or wall material in humid or dry environments.

[summary on De Groot:2010; Jansen, 2000]

why not south africa?

Yes, though South Africa has some commercial hydroponic systems, it is an undervalued practice and in general, our farmers are scared or sceptic to use it, favouring traditional resource-intensive agriculture. Our farmers expect that our seemingly boundless land and sunshine will sustain us in food security, yet we know that this is not possible - even for South Africa. Instead, it is exactly this issue that should encourage the idea of **urban** agriculture in African climates. Our boundless sunshine aids even more in the viability of vertical farming as it would reduce much of the energy needs in such a project, more so as in a countries like England, New Zealand or Japan for instance. Furthermore, more and more farmers are forced off lands for reasons other than agricultural malpractice - mostly socio-political reasons. Private ownership of a building for agricultural practice could provide a solution to this problem.

By not exploring the viable, working practices of growing commercial hydroponic or aeroponic crops indoors, African cities are wasting great opportunities on many, many levels.

morkel combrink
economist and professional in agricultural practice
[combrink, 2010]

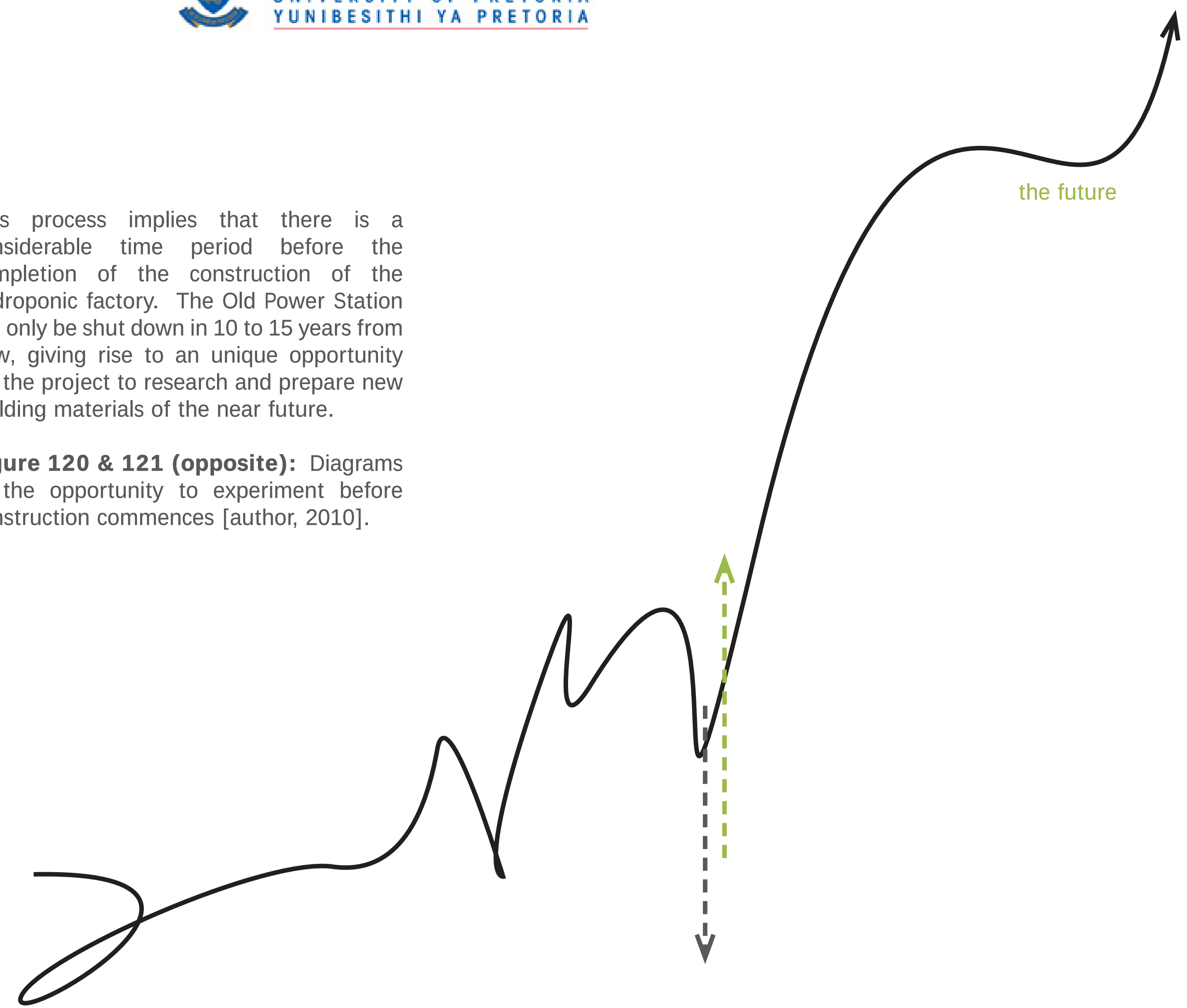
key concept:
future-orientated opportunity

The Pretoria West Power Station will not shut down immediately, but only in the next 10-15 years [Masut, 2010]. It was therefore decided that the greater framework development on site is divided into four phases. Phase One can start immediately. It is the phase that develops long-term solutions for the immediate environment and repairs the existing landscape and infrastructure in anticipation for the new developments. Phase Two, 3-5 years later, further refines the urban edge conditions on and around the site. This phase introduces housing and mixed-use developments around the site. This phase also introduces new productive programs within the existing building stock on site. The power station is used as an educational attraction throughout these phases to create awareness of the greater site as a destination point and so imprints the site into the memory of a greater urban population. During these two phases the power station is still operable and running.

Phase Three sees the death of the Old Power Station as it is shut down and the new production programs are introduced. It is during this phase that the hydroponic factory will be constructed. The immediate landscape around the bunker is to be designed as an urban agriculture park. During Phase Four and the completion of the entire development, detail design is carried on for the remainder of the site. This is the ultimate culmination of the urban agriculture CPUL city as it refines the newly established urban agriculture park and landscape.

This process implies that there is a considerable time period before the completion of the construction of the hydroponic factory. The Old Power Station will only be shut down in 10 to 15 years from now, giving rise to an unique opportunity for the project to research and prepare new building materials of the near future.

Figure 120 & 121 (opposite): Diagrams of the opportunity to experiment before construction commences [author, 2010].



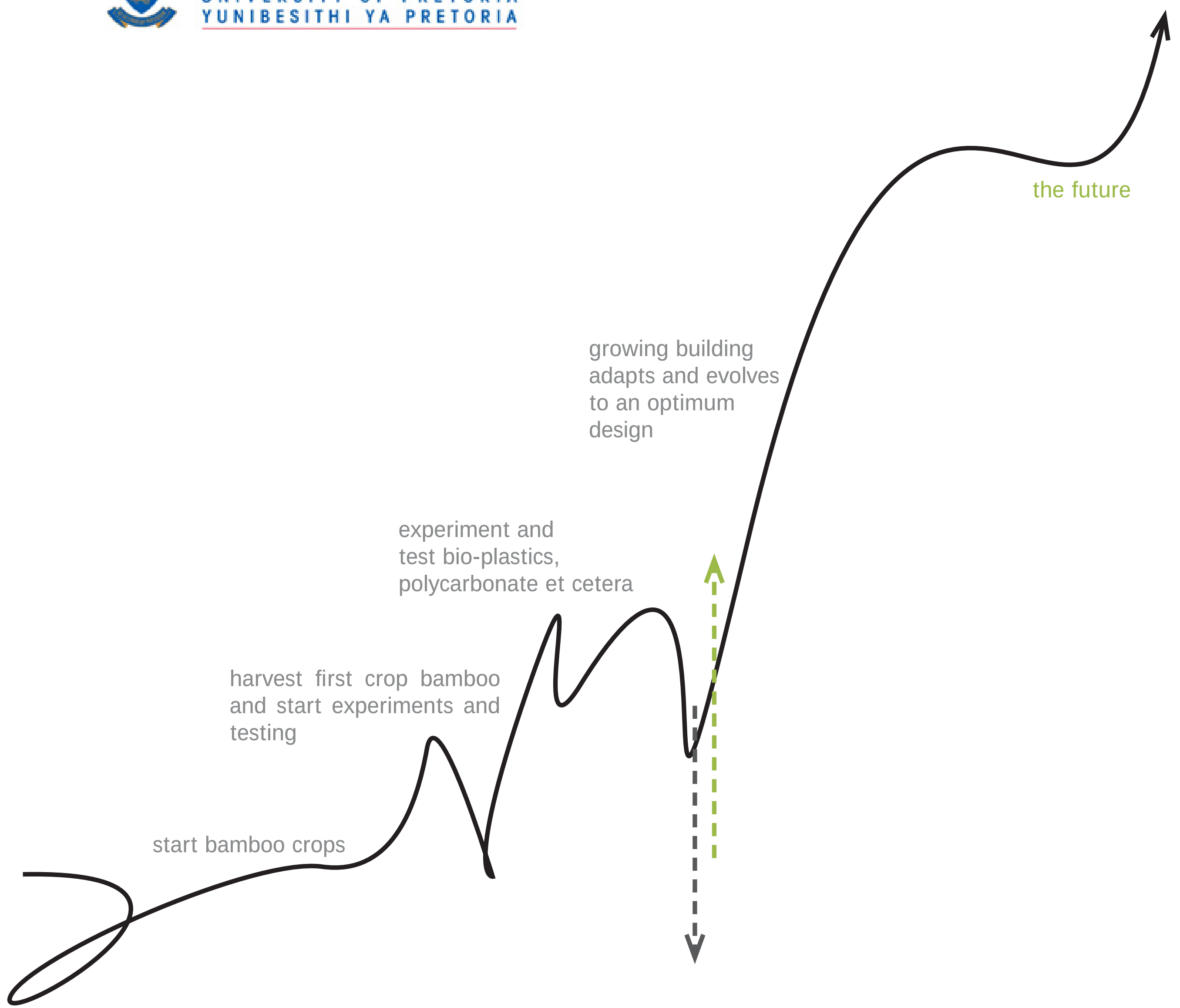
b u i l d i n g w o r k s h o p

key concept:
testing and experimentation

The bunker itself will also therefore have 10-15 years to do real and actual experiments with materials such as bioplastics and bamboo **on site.** This window in time will be a unique opportunity to test the materials against weathering, on-site production (growing bamboo, nuts or beans for structure or creating bioplastics), testing structural stability or configurations, researching recycling potential of the materials and many other facets. This research has immense value, not only for the hydroponic factory itself, but for building technology for South Africa. A design proposal for this period in time is therefore a building technology workshop and studio. This structure will also be made of steel, bamboo and polycarbonate - a live mock-up - and it is placed over the existing bunker so as not to intrude on any on-going process while the power station is still active. This workshop will be transparent to the public, an educational platform formally and informally - a public laboratory and library for building technology, attracting visitors and researchers to the opportunities that new building technology can bring by exhibiting the experiments both in the nature of the constructed built object and also an evolving construction sculpture.

"Architecture is not just about making good buildings and solid, it's also about telling stories in some way."

Renzo Piano
The John Tusa Interviews, 2008
[Tusa, 2008]



2010:
stagnant site

2011 - 2015
phase 1
construct a building workshop over existing bunker and rail tracks

2016 - **2020**
phase 2
experimentation and testing

2021-2025
phase 3
evolution into hydroponic factory

>2025
maturity

b u i l d i n g w o r k s h o p

key concept:
making industry urban

Currently, the site is inactive and does not contribute or activate any part of its immediate or greater urban environment. The hydroponic food factory, however, is a building that wants to embrace the new idiom of urban living: a resource efficient **society** in productive buildings and landscapes. The 10-15 year window before the completion of the final building gives an opportunity for the hidden site to become part of the urban heritage by becoming a place of event and public art. It is suggested to invite artists to take part in sensational large scale urban artistic festivals with the building workshop as a home-base. When the final building is then built and the greater site and landscape opens up, the old coal bunker as a place of event will be established in the urban memory. When the bunker itself opens up, the design can naturally evolve into its intended program of becoming a permanent public market as the public can filter through it to the new adjacent park or towards the new train station. The new building workshop and the immediate urban landscape and surfaces are to be established first and the building front is to become public. Public Art and Event for the site's future development will also holds office in the new building, maintaining the closer relationship that industry and urban living should have towards each other. When the proximities of the creative industry and productive industry close in on each other, undiscovered exciting opportunities develop.

Figure 122, 123, 124: Live building workshop as testing ground for bamboo construction for South Africa.

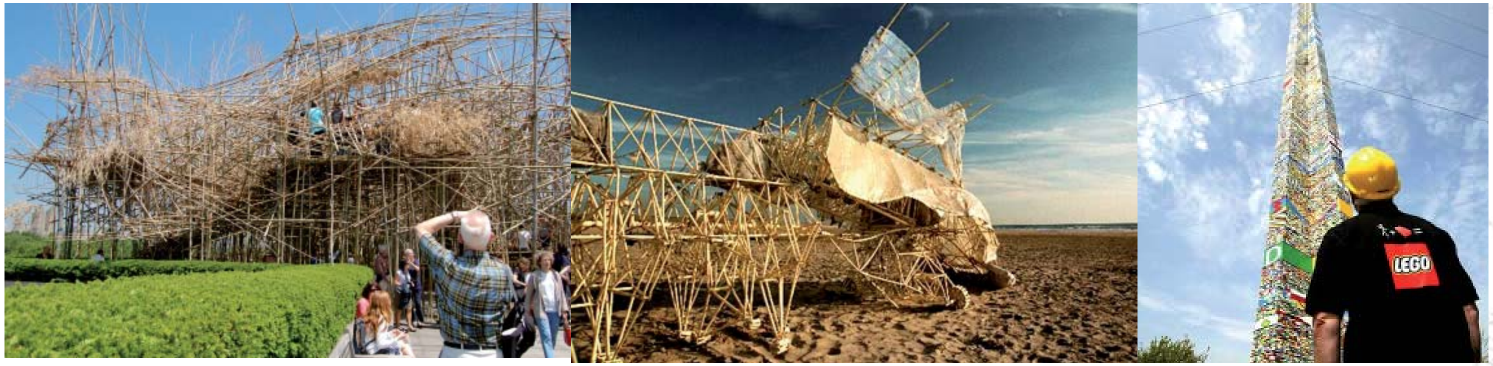


Figure 125, 126,127: Public art as awareness for place.

Figure 128 (below): Existing site for the initial building workshop concept [author, 2010].

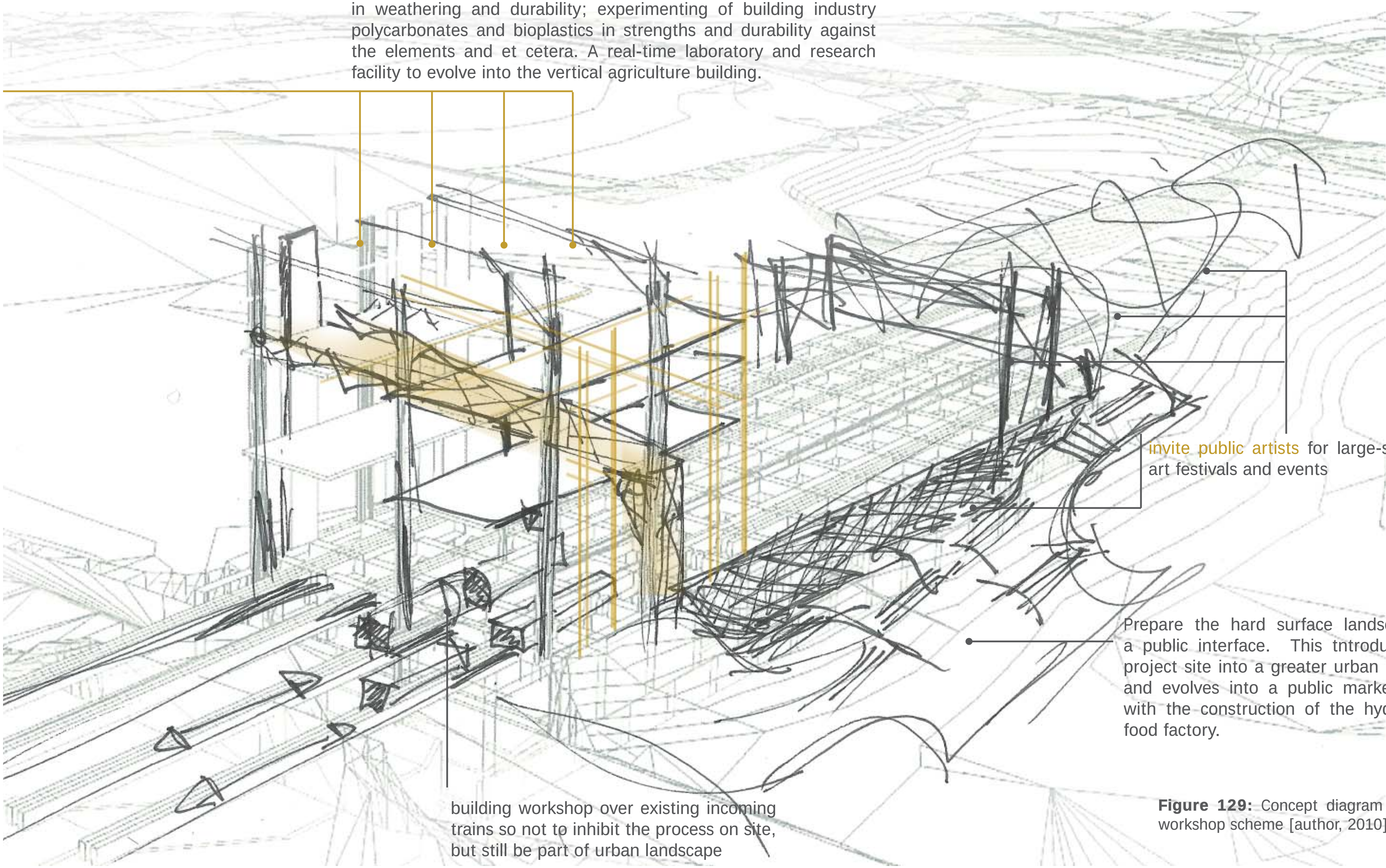


Figure 129: Concept diagram for building workshop scheme [author, 2010].

living building

key concept:
optimum evolution

The building and project in its entirety is therefore a platform for experimentation and innovation, not only in the virtual realm of its program, but also in its physicality as a developing, growing built object. By maturing into its final form over time, the design is a learning organism and empirically develops itself and its purpose within the city. This strategy ensures that the building will ultimately evolve into a creature that understands itself, grows according to its own needs, adapts with the environment it is in and can incorporate exciting future technological developments into its built fabric.

"I've been thinking a lot about this lately. There must be a difference between things that change, and things that become.

Things that "become" are rare, exposed to misunderstanding, and possibly disappearance"

Jean Baudrillard
The Singular Objects of Architecture
[2002:45]

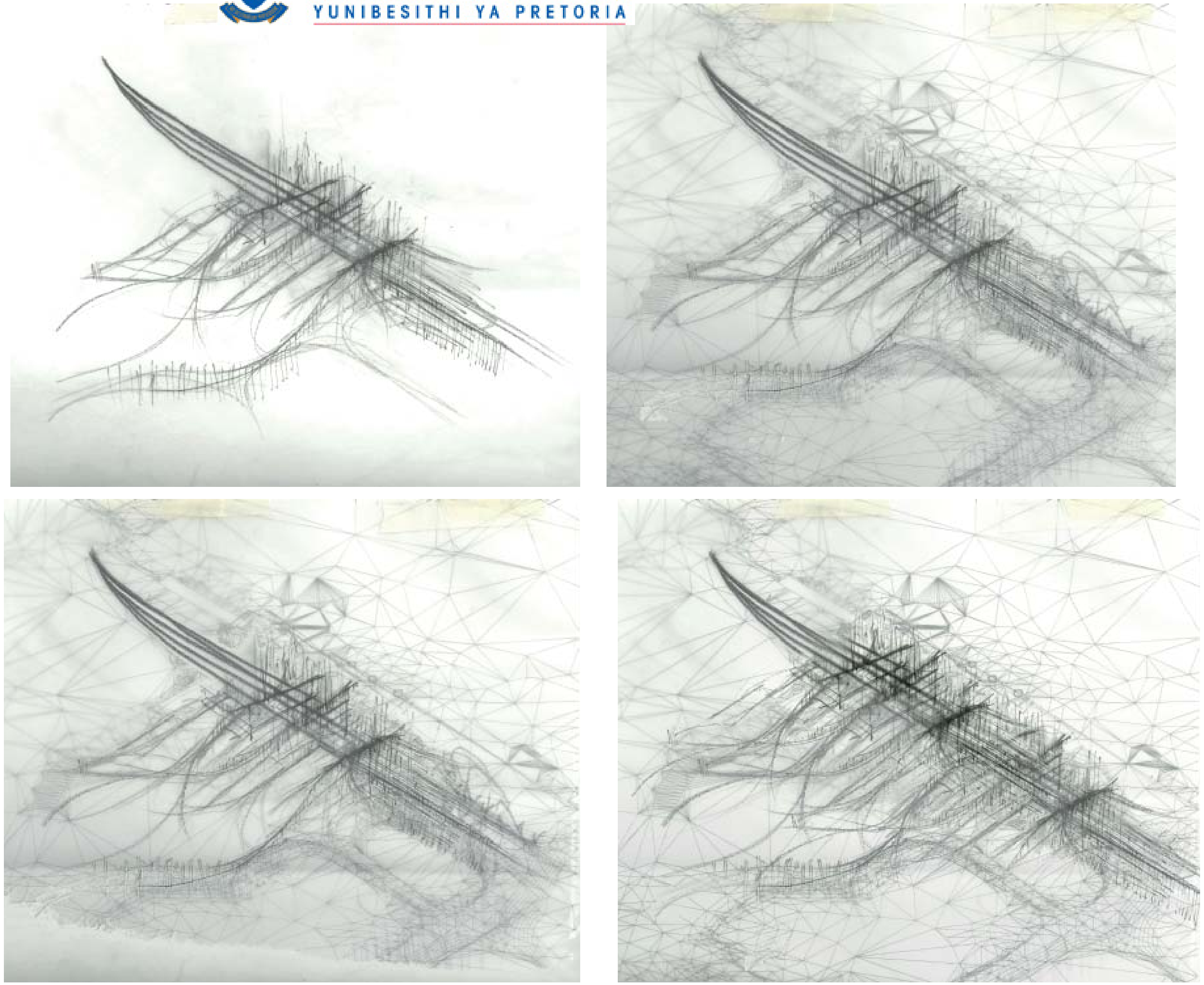


Figure 130 (left, opposite): conceptual sketches [author, 2010].
Building workshop over bunker and tracks (growing bamboo, testing materials, experimentation, education et cetera) grows into a mature design.

evolve growing to maturity

living building concept using site as a building workshop in experimentation and preparation for the final design

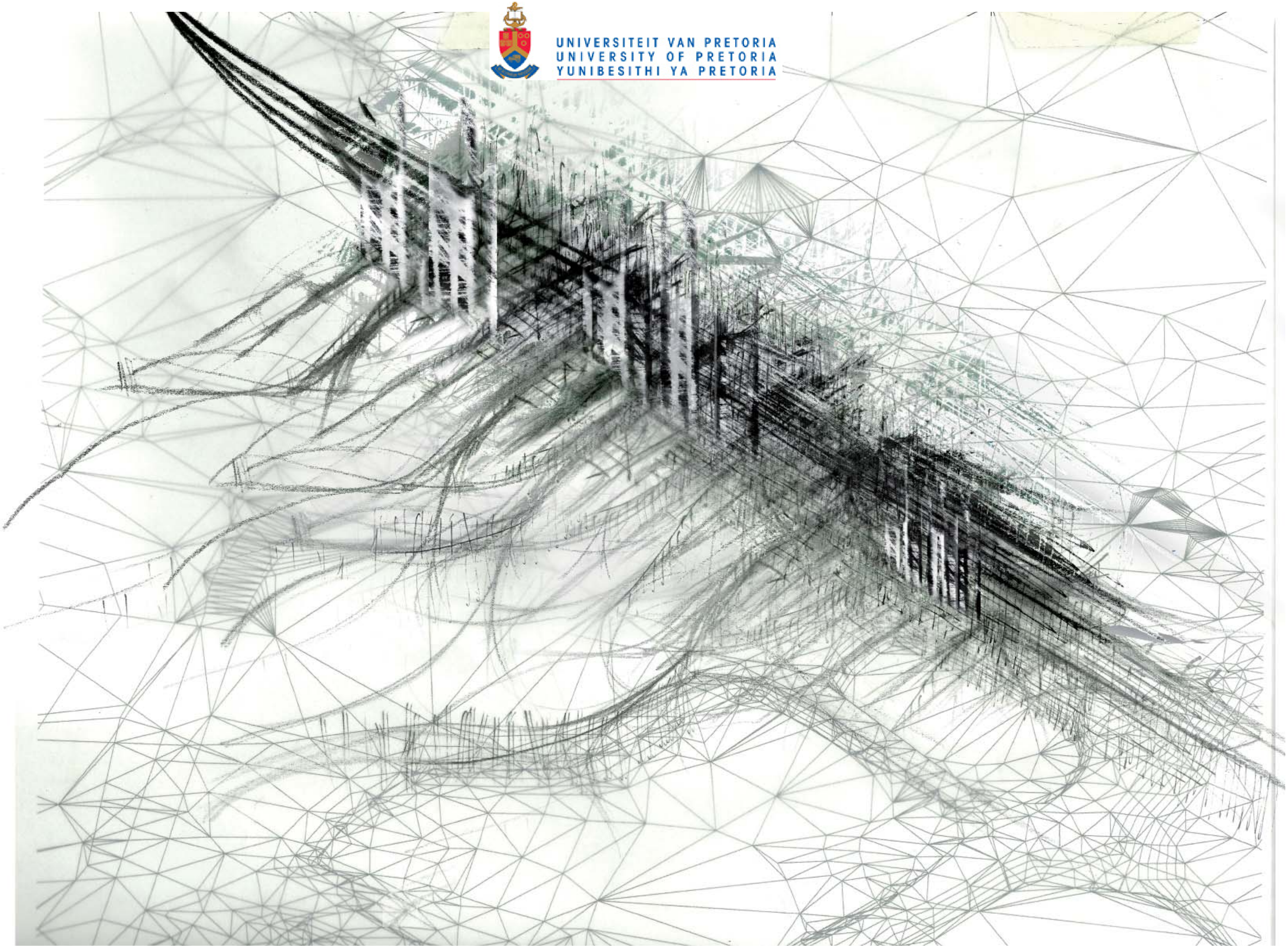
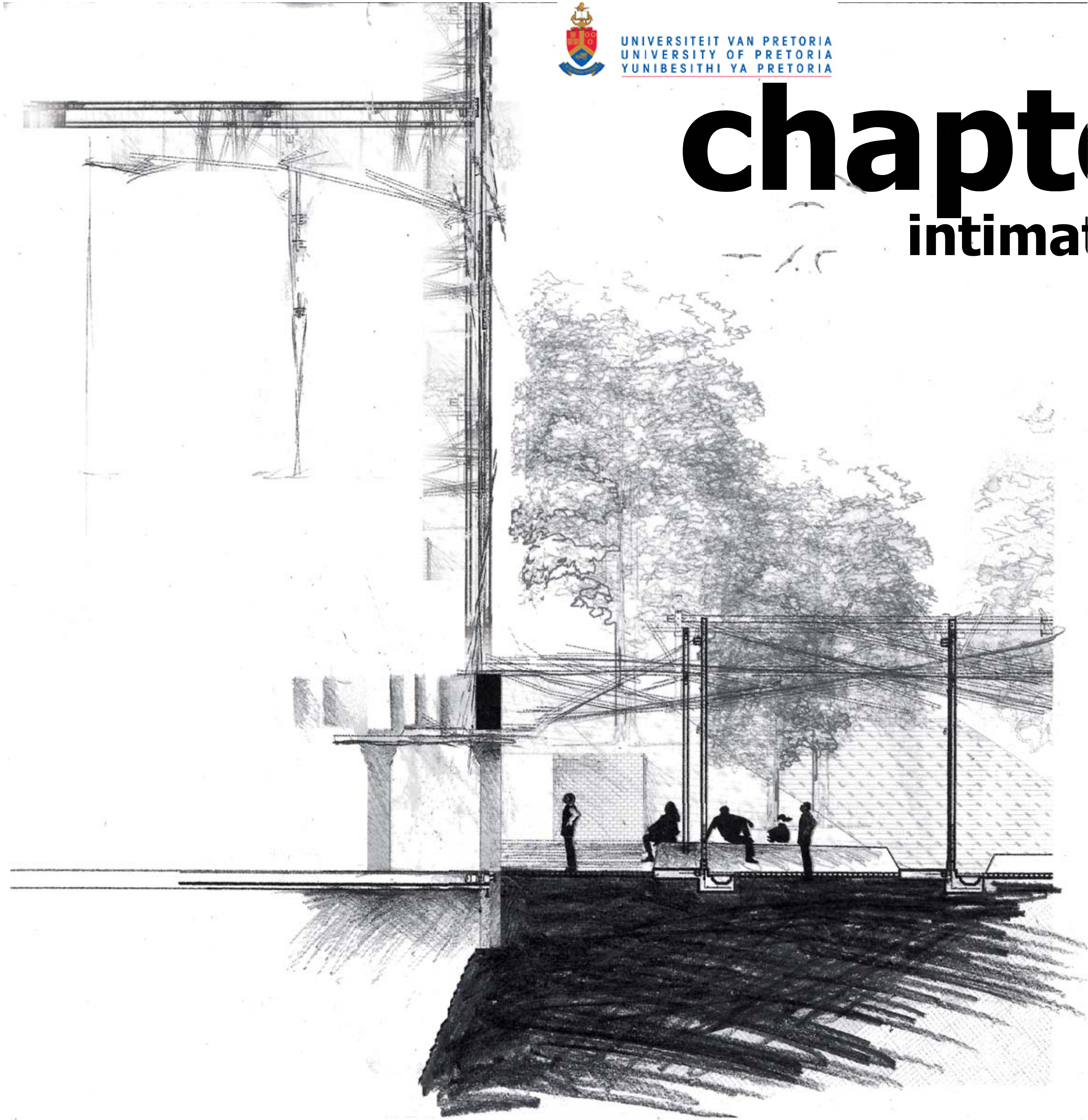


Figure 131 : Conceptual sketches [author, 2010].
Blurring the edge of public and industry



chapter six

intimate proximities

Jean Nouvel and Jean Baudrillard state that the built object is not always the ultimate purpose of architecture, but it is more the world of virtuality that it translates into new reality [Baudrillard & Nouvel, 2002:4]. In this thesis, the architecture is the means to translate a world of systems and processes from virtuality into an architectural reality - a tangible place of activity. In parallel to this theory, Michael Benedikt defines the essence of a reality of architecture to possess presence, significance, materiality and also emptiness [Benedikt, 1987:32]. This unique reality also the quality of the *Third Landscape* space. This reality for architecture encompasses two characteristics - virtuality and singularity. The essence of this design is to translate the virtualities involved in the process and intent of the program into a physical expression of a built form, as a singular object of architecture.

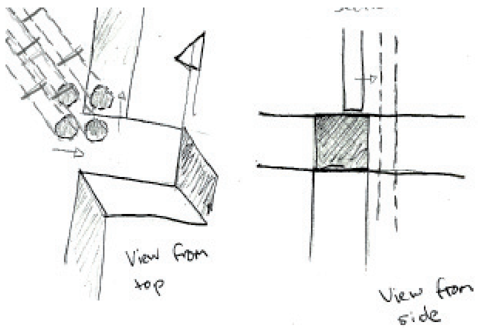
The design has already drawn closer virtual proximities by turning a dead passive object, passive space and passive heritage into a active, living, future-orientated reality. The questions posed by site and program governs the design decisions on scale and materiality and reveals the remaining intimate proximities between system, building and the human experience.

structure

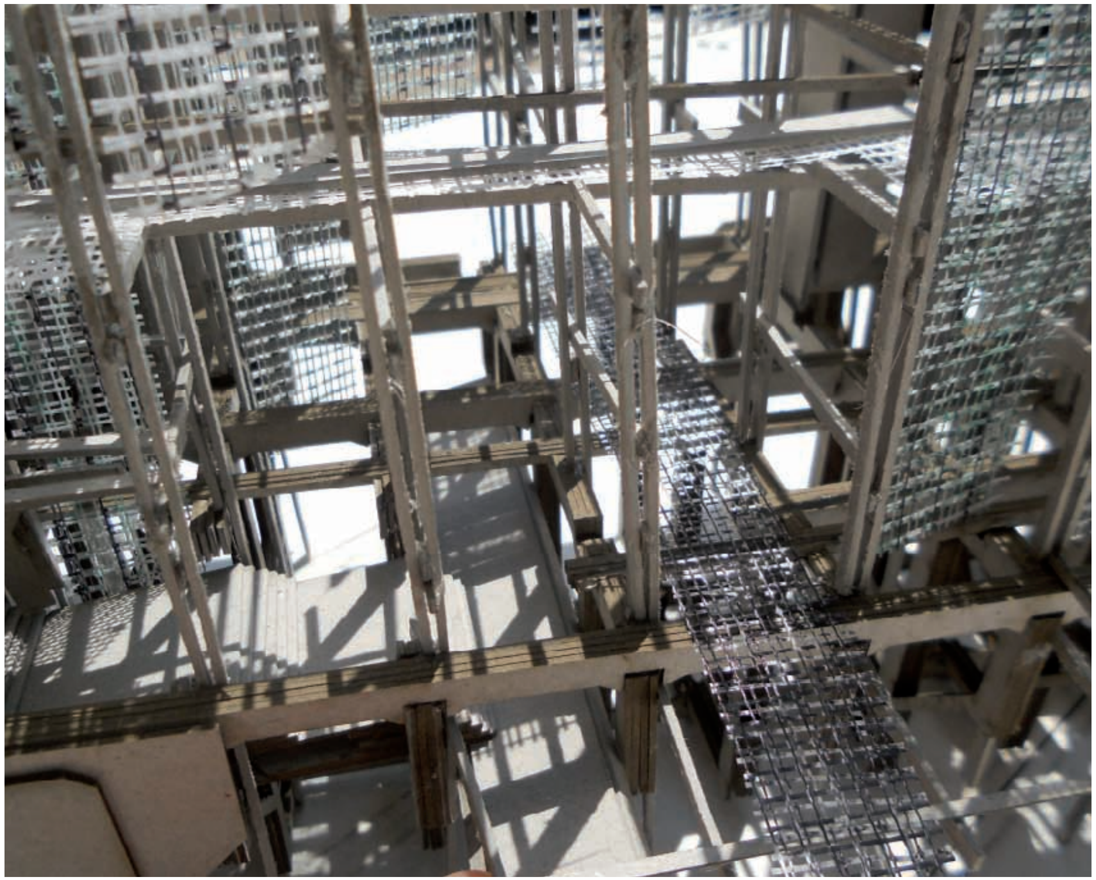
The decision was made to enhance the integrity of the concrete frame of the bunker by reducing any additional impact that the new design will have on the existing structure. The experience of the building is in its verticality and this is achieved by exaggerating the slenderness of the vertical elements and contrasting them with horizontal character of the massive concrete bunker.

The design aims to reduce the use of steel members and replace where possible with bamboo as a structural building element. Bamboo is considered a "foreign" material, though ironically it is a native plant in every continent except Europe; grows practically anywhere and has been used in a range of contemporary construction applications from impressive bridges to monumental buildings and structures. According to Bereis and De Boer, bamboo is an incredibly strong fibre with double the compressive strength of concrete and almost the same strength to weight ratio of steel in tension [Bareis & De Boer, 2002:3]. The only real weaknesses are at the joints and connections, but even here, architects like Simon Velez and Renzo Piano have almost perfected bamboo structural connections. Bamboo members are called culms, and the most efficient way so far to design large structures is by reinforcing the bamboo ends with steel or cement. One method involves drilling the ends of the bamboo culm and inserting a threaded rod or cable, and then fill the culm with cement or mortar. Epoxy or other glues can also be used. The similar method is to bolt right through the culm and the use a steel strap to fix the culm to the next structural member. Both methods create very strong connections and transmits the forces from the different parts of the bamboo equally. These methods are the recommended connections from all the individual resources that were researched and will be adopted by the new design also. From this research, it is clear that bamboo works at its best in composite with other structural elements, especially steel connections. By replacing major steel elements with bamboo, the design can greatly reduce its embodied energy and carbon footprint.

Bamboo can be used extensively as exterior material, but when bare bamboo is overexposed to the direct sunlight without treatment, it can sometimes crack. Although, bamboo works well in humidity. This means that it is a perfect substitute for almost all steel or aluminium elements that would have been used in interior of the hydroponic greenhouse spaces. As a new building of frame and light, the design decision is to not disregard the use steel as framing element, but to encourage a composite structure. By replacing the "indoor" steel with bamboo, the amount of steel structure can be reduced significantly. Furthermore, by using steel, a direct reference to the industrial heritage is made. Steel can be visibly found in every building on site as a major framing element. Steel as structure also references



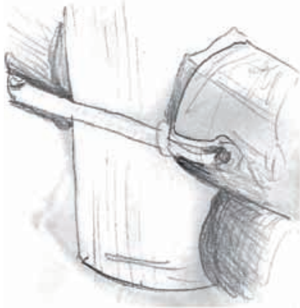
Figures 131 (top): off-set [author, 2010]. Slightly off-set the new frame structure on plan and on section.



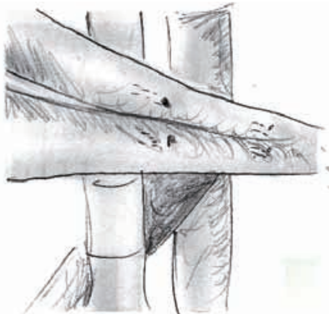
Figures 132 (left): working model [author, 2010]. Slightly off-set the new frame structure to respect the structure of the existing bunker.

Figures 133 i -v (opposite): Current methods of bamboo connections [author, 2010]. Other diagrams: exploring possible connections for bamboo members.

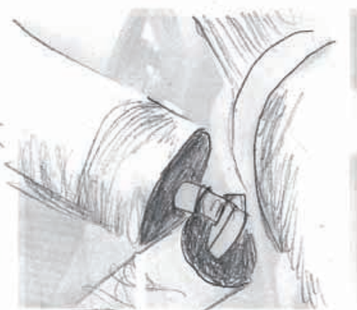
the railway on site and the legacy of the steel industry left by Iscor. Steel is therefore a golden thread element that keeps the bigger picture together, but it is not by itself the bigger picture. Cecil Balmond, the engineer for Rem Koolhaas, states that in the matter of structure, simultaneity matters, not hierarchy [Balmond, 2002:23] and that a structure is a whole system, not one element on holding out on its own. With this in mind, together with the weaving character associated with bamboo construction, the new building frame is designed with an intertwined quality, closing the proximity between traditional autonomy of structural steel to the contemporary hybridity of structural bamboo.



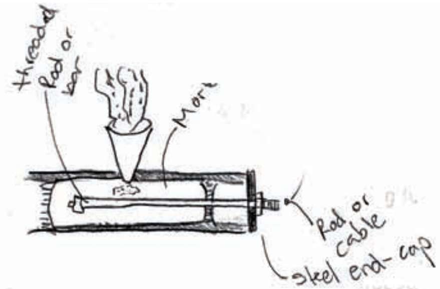
i - traditional connection
straps



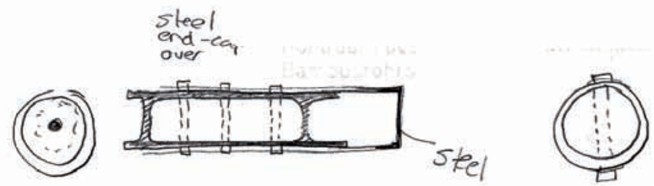
ii - traditional connection
nails and pins



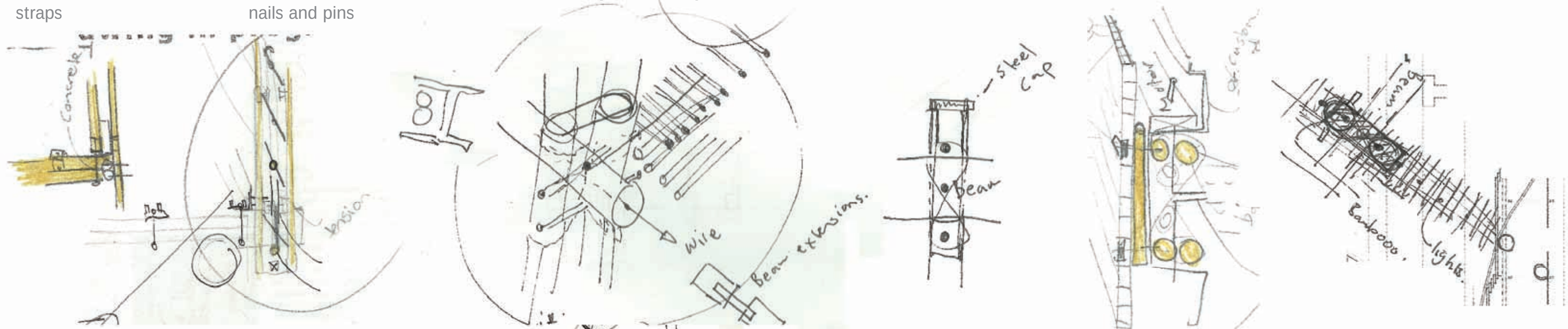
iii - steel end plates and joints



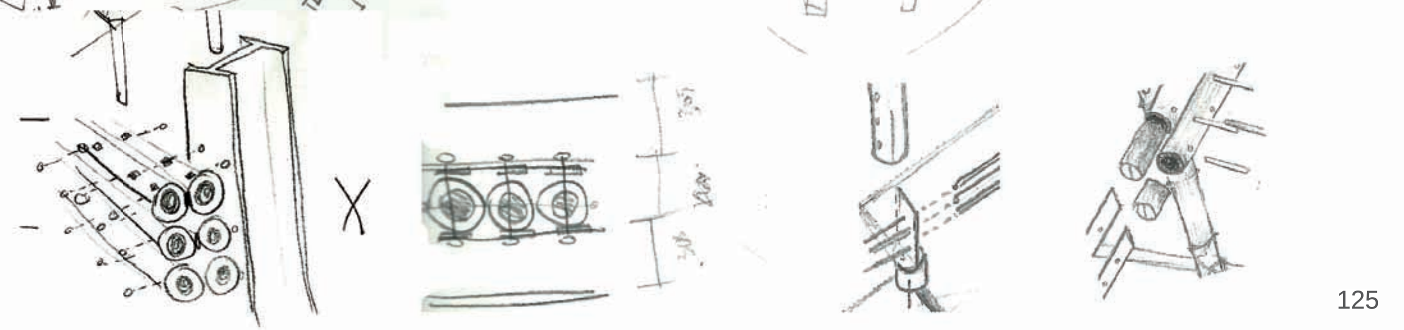
iv - mortar and threaded rod

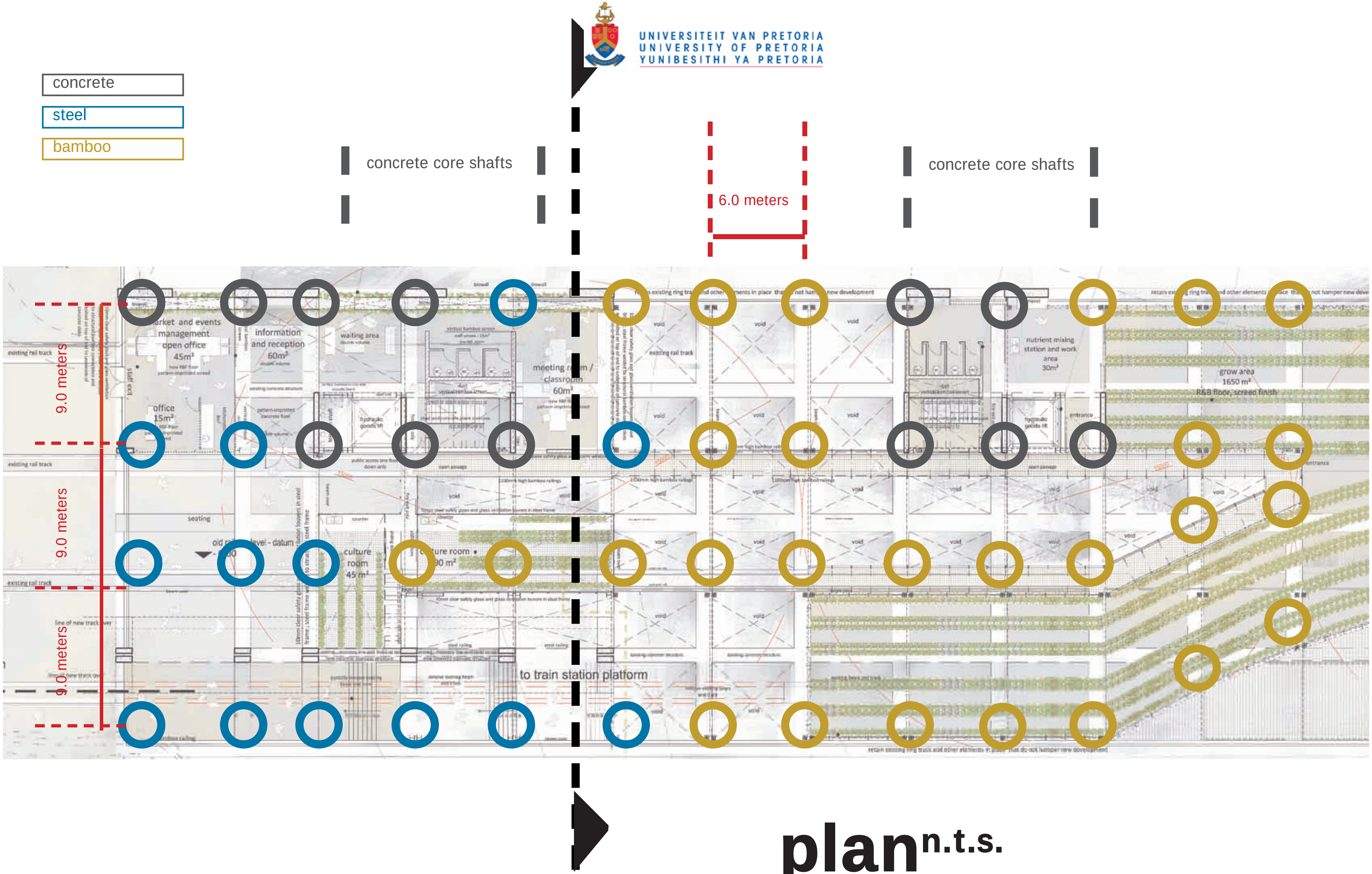


v - washer and bolt with steel straps



connections and formations
exploring bamboo connections or configurations



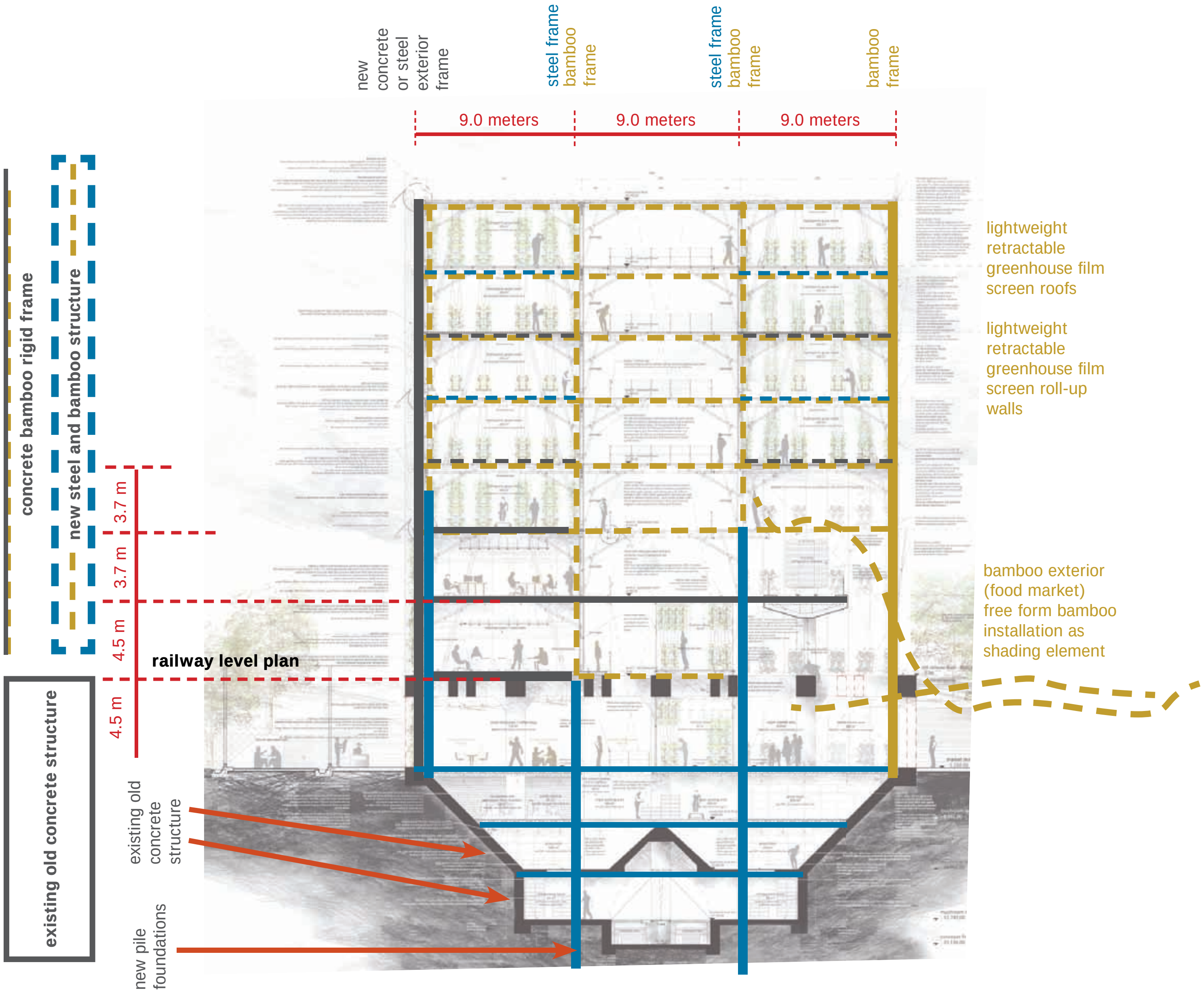


plan$^{n.t.s.}$

Figure 134: concept for structure [authorm 2010]
typical plan (on existing railway level).

structure

Mr. Mike Mahant and his firm of Luit Nirman Engineering Design, Contracting and Systems (India) has over 30 years experience in the bamboo industry. After correspondence with Mr Mahant, he suggested that for a residential building, it would be possible to reach 6 storeys with only structural bamboo, given a light-frame design. According to in-house tests done by his company, a single dia 100mm bamboo culm has a compressive strength of 20 tons, or 200 kN [Mahant, 2010], so when grouped in four or more, the columns can resist to 800 kN or more. The new building components are lightweight - with a retractable greenhouse film roof and polycarbonate or greenhouse film walls. Skipping a beat, every other level becomes a composite concrete floor, with the intermediate floors being a steel/bamboo and mentis grid light-weight floor. Also, most of the heaviest elements (compost and organic storage, water and nutrient tanks) are grouped together or around elevator and service shafts. Furthermore, the hydroponic production method is soilless, and therefore plants will only reach a maximum dead load of 50kg/m² or 0.5 kN (tomatoes) in the fruit that they produce at harvest time and with the heavies of methods (the Dutch Bucket Method) greenhouse occupation is estimated to reach a dead load of 100kg/m² - pipes and water included. With composite bamboo concrete floors, the estimated loads reach a maximum of 130kg/m². No heavy machines are required either. It is suggested that the building rather start off with steel and phase into bamboo towards the roof. This means that a weaving process of materials can begin, where the three different elements of mass - concrete, steel and bamboo - grow closer in their proximity to each other and be perceived as a single unit of structure.



section n.t.s.

Figure 135: concept typical cross-section [author, 2010].

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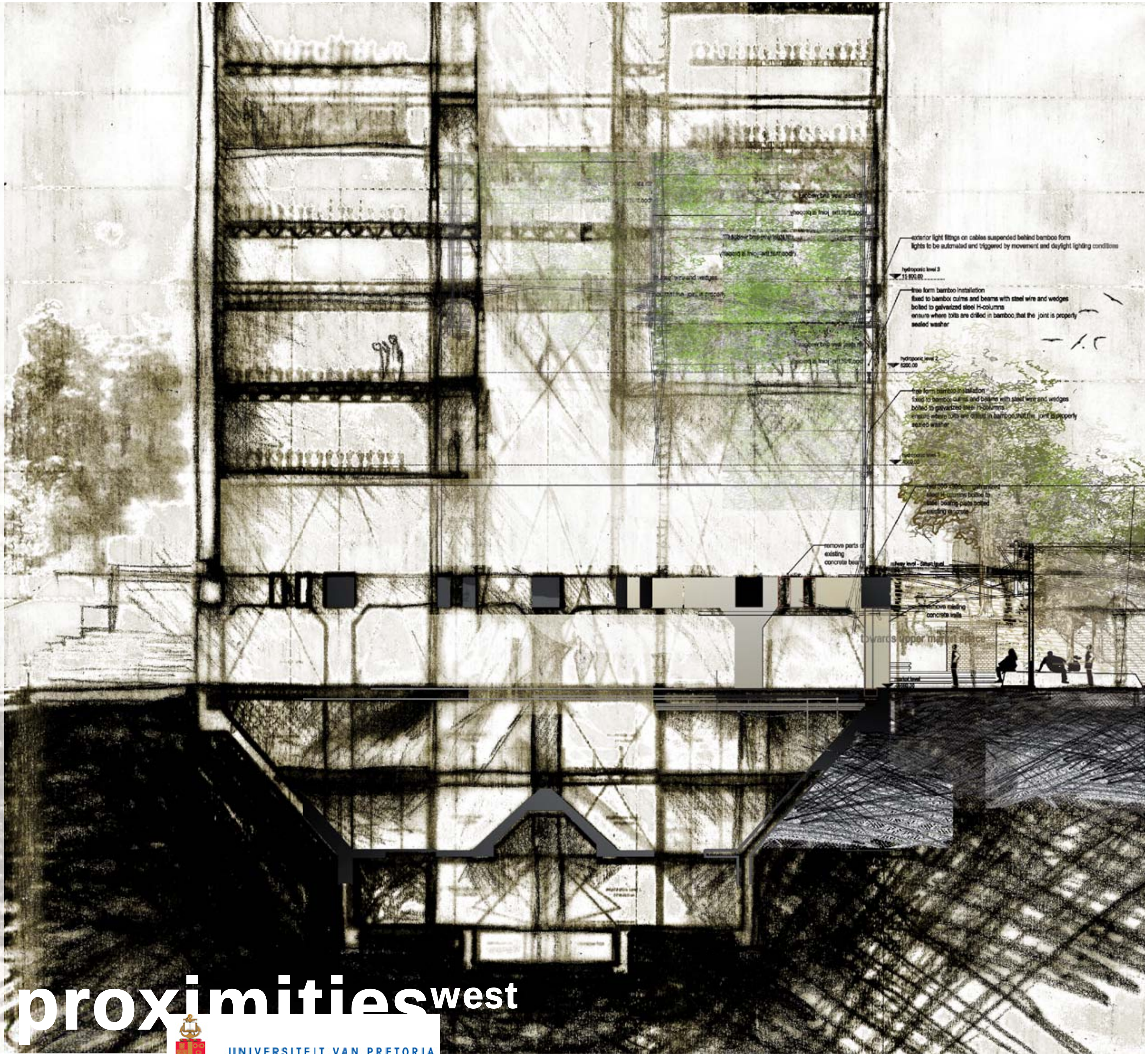
u n r a v e l

The virtuality of the architecture is expressed by creating spaces that are not immediately legible, spaces that are “a mental extensions of sight” [Baudrillard & Nouvel, 2002:6]. This is done by physically creating a dissolving materiality in the composition of building elements and creating a network of materials of mass and materials of light. As the aim of the thesis is to remove the edges between industry and urban living, the new building extends itself into the urban landscape, making it unclear where the building begins, where street ends and where the boundaries of the urban landscape actually are. Just as the structure of the old coal bunker is freed from its confinement, the new design will also be extricated. This is expressed through the unravelling of the building structure into the streetscape.

With the concept of intertwined structural elements, an unravelling process can begin in an attempt to infiltrate the physical building into the streetscape (or if you will, the streetscape into the building). Also, the need for transparency and the needs of a living organic interior program of crop production encourages a building of light and frame. Lastly, the patterns of production and consumption of energies shows that the building needs a stable system to feed from and drain into.

The western elevation becomes this concrete reality of the building, emphasising the materiality of the concrete bunker, referencing heritage of the power station in a series of strong tower elements and finally acting a the host for essential building services. The towers and the vertical circulation shafts are heavy concrete elements, hosting the buildings composting requirements, gas distribution, nutrient supply and rainwater distribution.



proximities west

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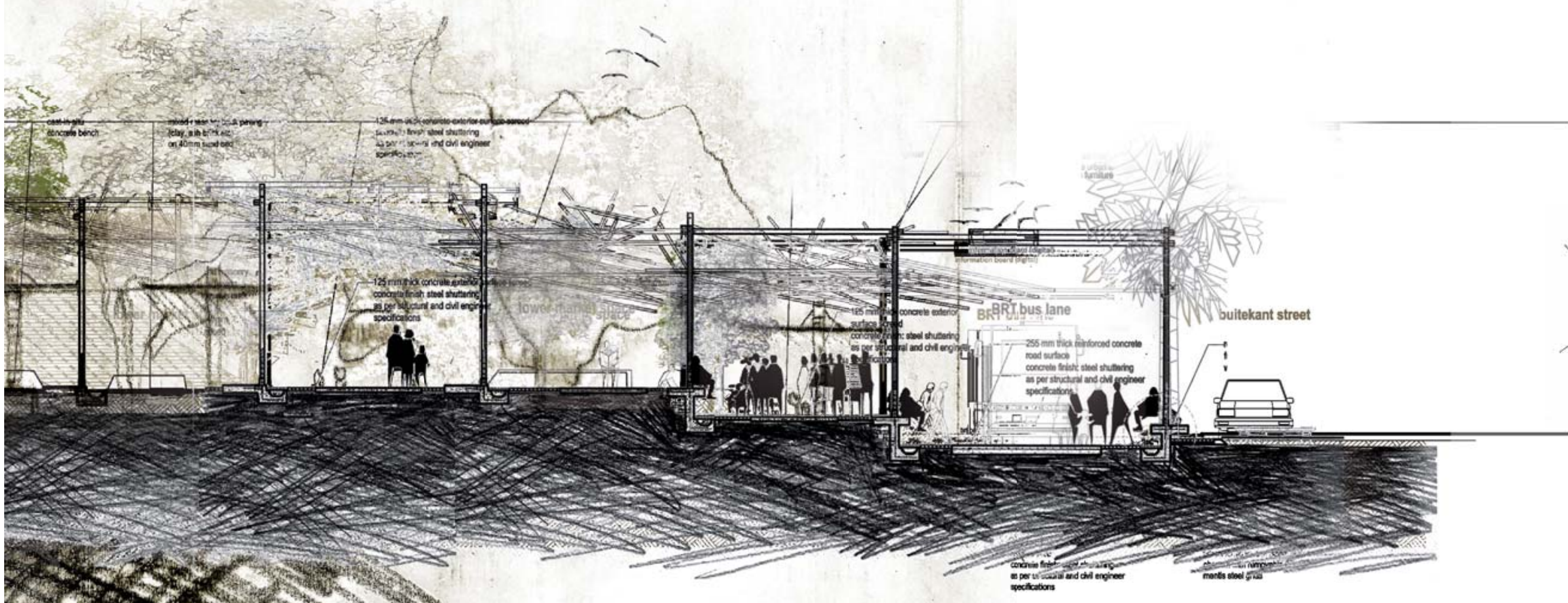
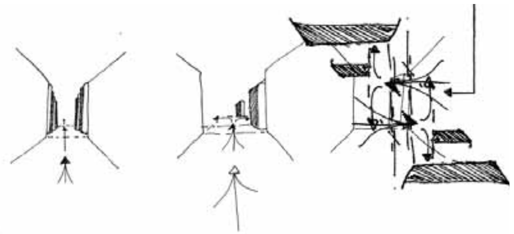
The compost towers take on a stereotomic character to protect the hosted infrastructure from heat: compost and gas are particularly sensitive to heat gain. From here, the building dissolves into tectonic resolution towards the streetscape as it embraces the market [downwards and outwards] and the hydroponic frame [upwards]. This informs a hierarchy of material use. From the solid concrete towers, steel beams and columns escape to form the primary structural steel frame. This steel frame is to safely support the higher scale of the building on the south (7 storeys high). As the design terraces down towards the north the steel structure is mimicked and taken over by a structural bamboo system and filters out into the urban park landscape and alsot the urban market streetscape to the south and east. This dissolving composition of materials forms part of the experience of the building. It illustrates the proximity of built object to landscape object, as well as the proximity of the program of a formal industry (agriculture) to an informal urban experience (markets, bus stops and streets).

The building presents itself illusive at first, layered by cross-programming and composite structure. As one enters it and moves through the spaces, the building progresses towards a more tangible object, revealing the functionality of the productive program and its interactive proximities to the urban experience. The architecture tries to create an experience in the user of being proximal to something virtual, something illusive - a virtuality that only explains itself upon exploration.





Figures 136 (top): edgeless city
Diagram illustrating the removal of boundaries between street and building [author, 2010]

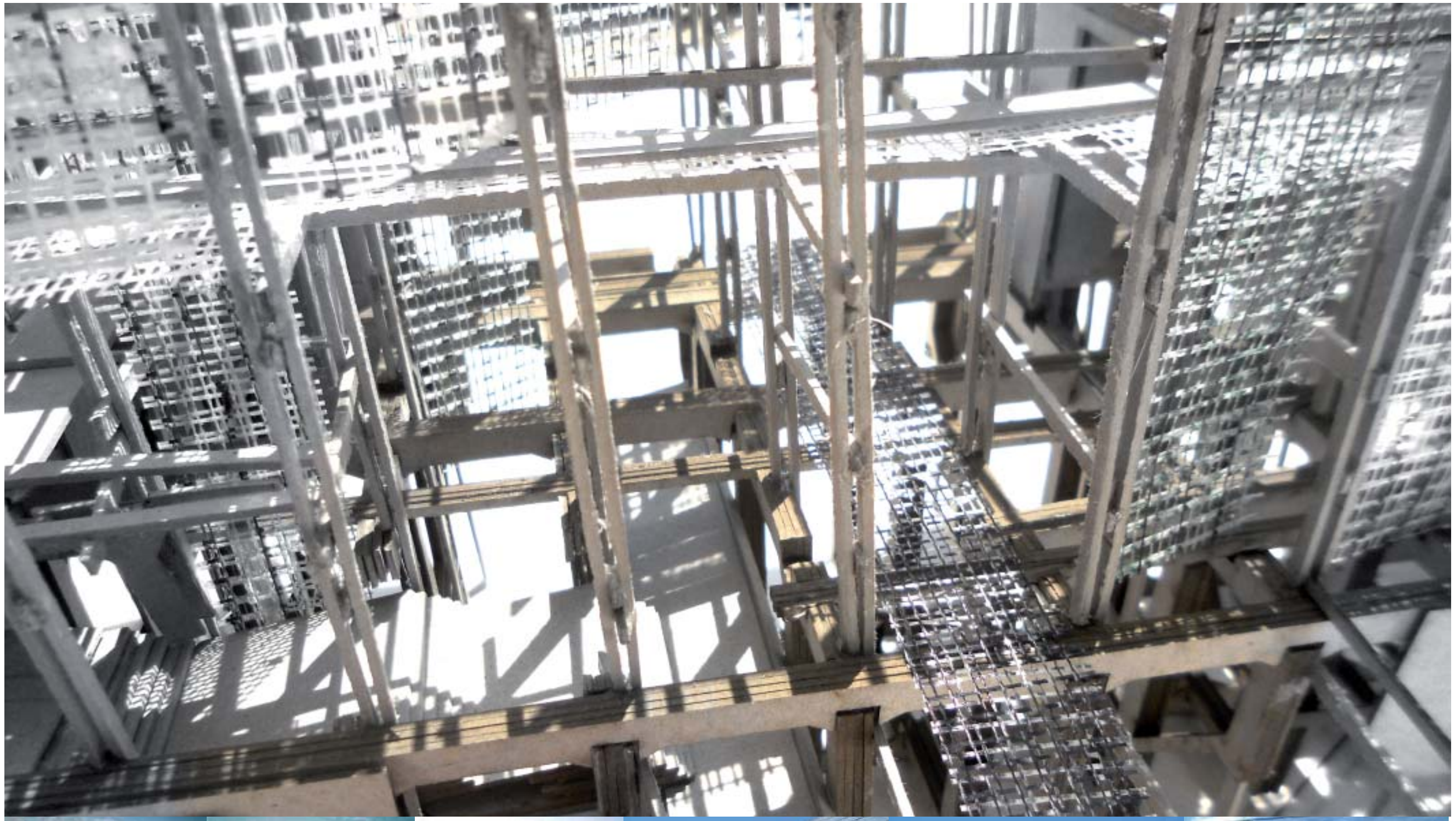
Figures 137 (left): edgeless building
Using a unravelling structure to draw closer the proximity of the exterior experience of the streetscape (right) to the interior experience of production (left) [author, 2010]

proximities east

b r e a t h e

Plants need air as much as we do. This means that the building must be able to open up, to let in as much fresh air as desired. Fresh air is not only needed for the growing the plants, but also helps in controlling moisture. Though the hydroponic method itself doesn't require traditional sprayed irrigation (plants are drip-fed), the humidity in the greenhouse spaces can create unwanted moisture. Ventilation is required to reduce humidity and consequently the formation of undesired droplets that gather on the ceilings or walls, which fall back onto the crops. This can cause disease in the plants as the droplets become contaminated by dust or other chemicals before they fall back onto the crop. Many greenhouses use varying combinations of ventilation, but the most effective and cost-efficient is clearly natural ventilation.

Ventilation is achieved by a simple method of retractable walls and roofs. The screens are automated, adjusting to the needs of the crop and environment. The retractable screen is a motorised system comprising of two layers of 200 micron clear polyethylene plastic (or similar) with separate dust screen, fixed to bamboo intermediate supporting poles. When closed, it will be possible to pump air between the two layers, creating a insulated wall. This is effective especially during winter, as most crops need a minimum temperature of around 16 degrees Celsius to grow. The roof has a similar strategy and is also a retractable system. It is a flat retractable automated greenhouse screen, but with opaque greenhouse film, to reduce the risk of the plants being scorched in the summer. Being retractable, it is also easier to service the roof from the inside, reducing any need for dangerous exterior roof access on the higher levels. For added control and conditioning during winter or raining spells, smaller reversible fans are located in the open joists. The hydroponic factory can be divided into grow rooms of approximately 200m² each to ventilate and control the environments on a smaller scale. Not only does this help to contain any risk of disease and so lose an entire crop, but also to gives more options if the factory wants to change crop production strategies and require more variations in environments. The "smaller" greenhouses are divided by a clear 25 millimetre interlocking polycarbonate wall panel system, which is easy to disassemble and move about to adapt to any changing needs.

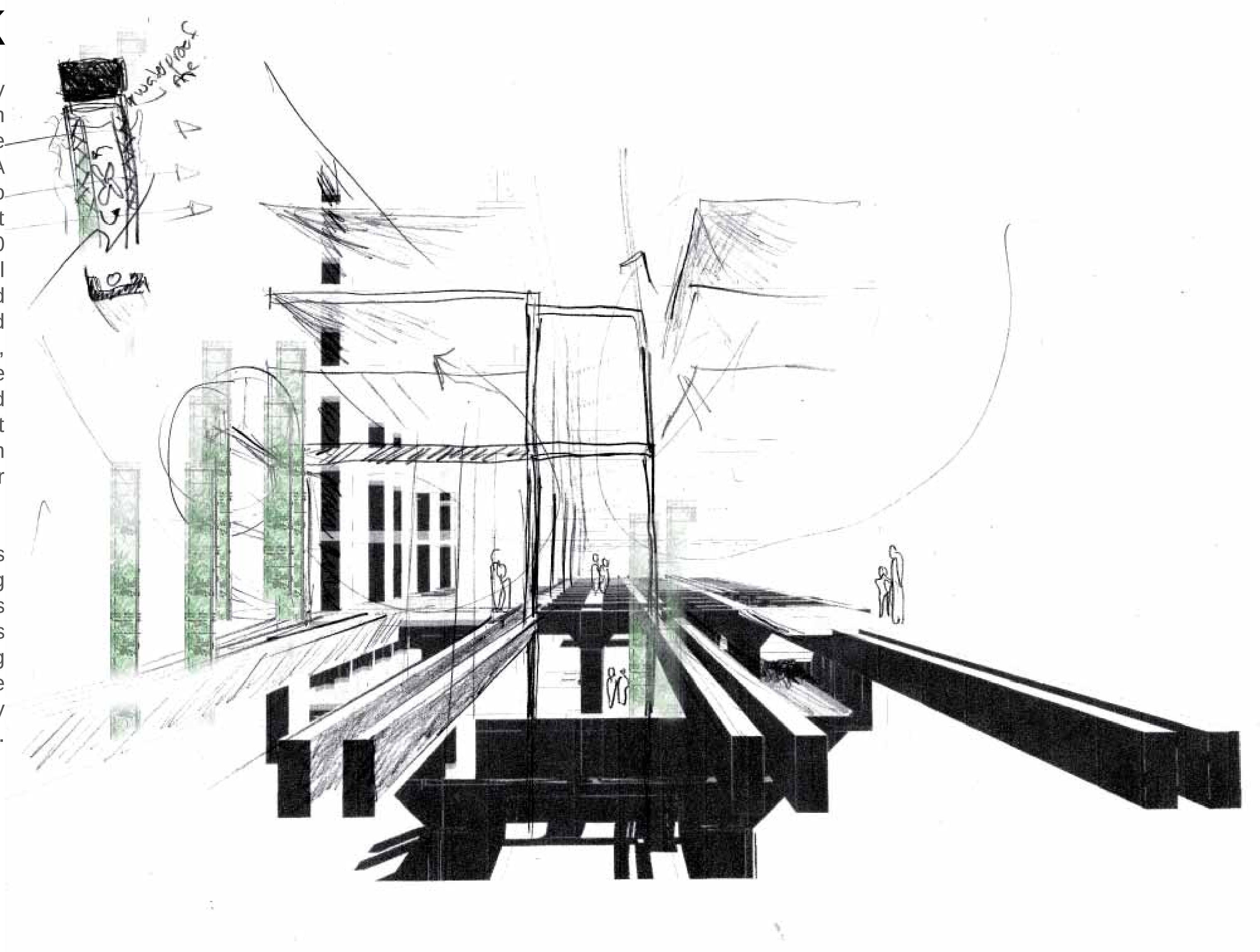


proximities having outside inside

live and work

Building for air and vegetation is a contemporary strategy for energy efficient buildings and an opportunity rises to construct a bio-wall for the spaces occupied by humans in the building. A bio-wall is a structure that uses vegetation to filter air to be issued to an interior environment The bio-wall is constructed by using two 50 millimetre porous substrates (cork, rock wool or similar) fixed in steel and bamboo grid frame that is bolted to concrete walls slabs and walls. Within the frame is small reversible fan, aiding in drawing air through the wall. The plants are placed in the porous substrate and fed hydroponically. A concrete catchment channel and pipe is placed at the at the bottom of the wall guiding excess water to the water recycling system.

From the dissolving structure concept, it was decided to have free-form bamboo shading system over the lower market area. It is proposed to halve some of the bamboo culms and also fit them with a substrate, feeding the shading system with vegetation from the factory. In this way, the hydroponic factory literary creates a growing urban environment.



Figures 139 (opposite top): breathing building [author, 2010]. Working model showing operable screen walls and roofs.

Figures 140 (opposite below): flat retractable greenhouse roofs [www.gothicarchgreenhouses.com]. Applications of flat retractable greenhouse roofs

Figures 141 (right): bio-walls as part of working spaces [author, 2010]. Using steel-framed bio-walls to clean air for the office spaces.

approach to the hydroponic factory to the market

chapter seven

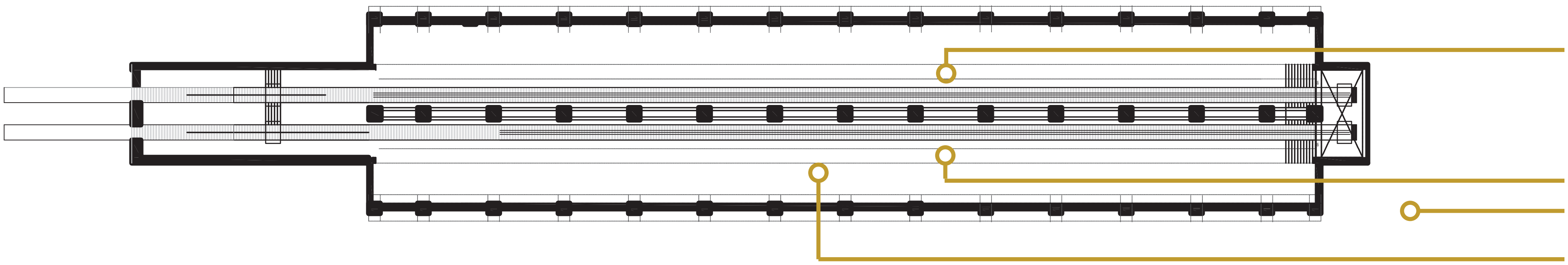
design conclusions

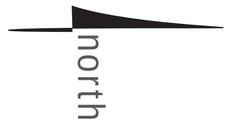
The new design fulfills the principle aim of the project: it creates an interface that closes the proximity between industry and the urban environment. Because of this, the design aids in the development of a sustainable, resource-efficient and productive culture for Pretoria West and the greater Pretoria also. This aim is fulfilled by drawing closer the legacy of 20th century autonomous industry to the future of 21st century hybrid urban industry through the program of vertical and urban agriculture. The design is also prototypical in program and use of new materials.

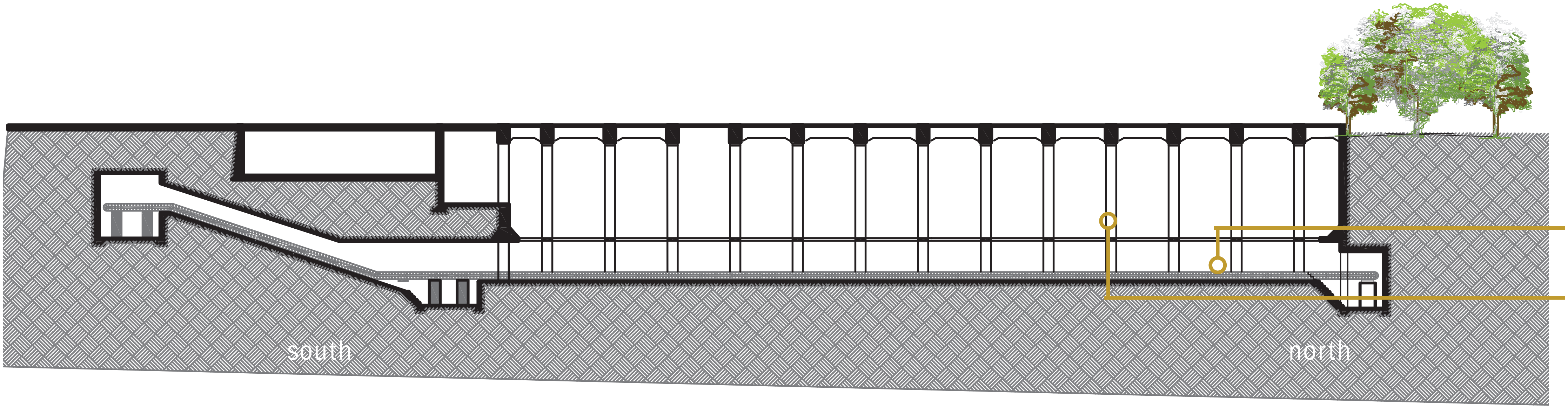
There is great opportunity in the further development of this project, in many fields of specialisation - from engineering, building energy design to new building technology for South Africa. This project aims to be a starting point for debate, research and innovation.

Through the new role of architecture as producer, the new design illustrates the harmony of a social urban landscape, industry or productive process and the natural environment - one building illustrating the proximate conditions needed between man, technology and the environment to develop a positive, evolved urban society for the 21st century.

Figures 142: productive urban landscapes
[author, 2010]




north


south
north

existing underground

Figure 143: Typical lowest level of the bunker [author, 2010].

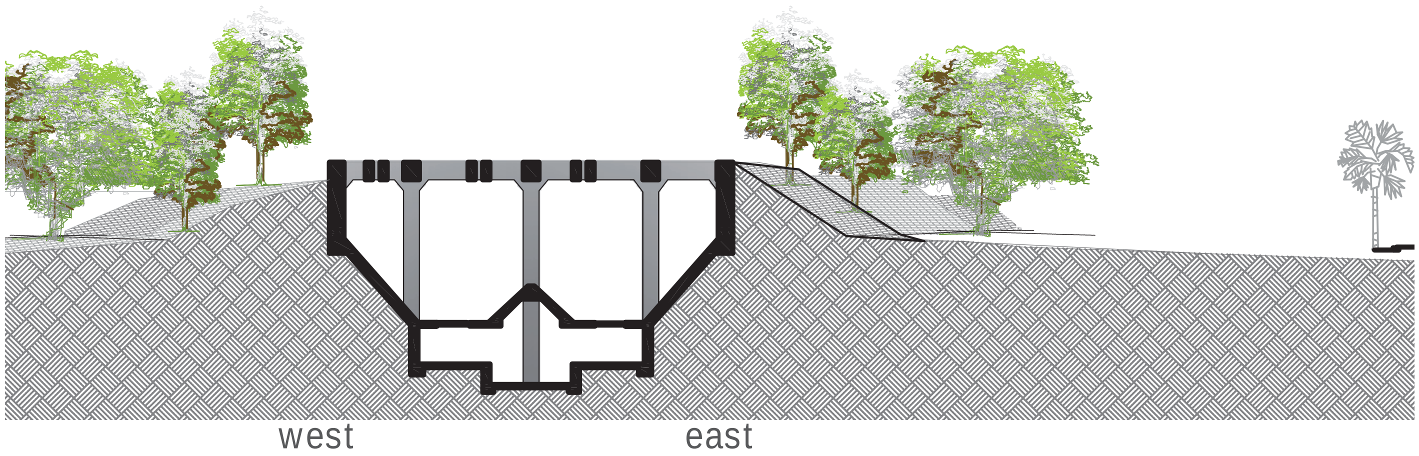
conveyor belts exists towards the south

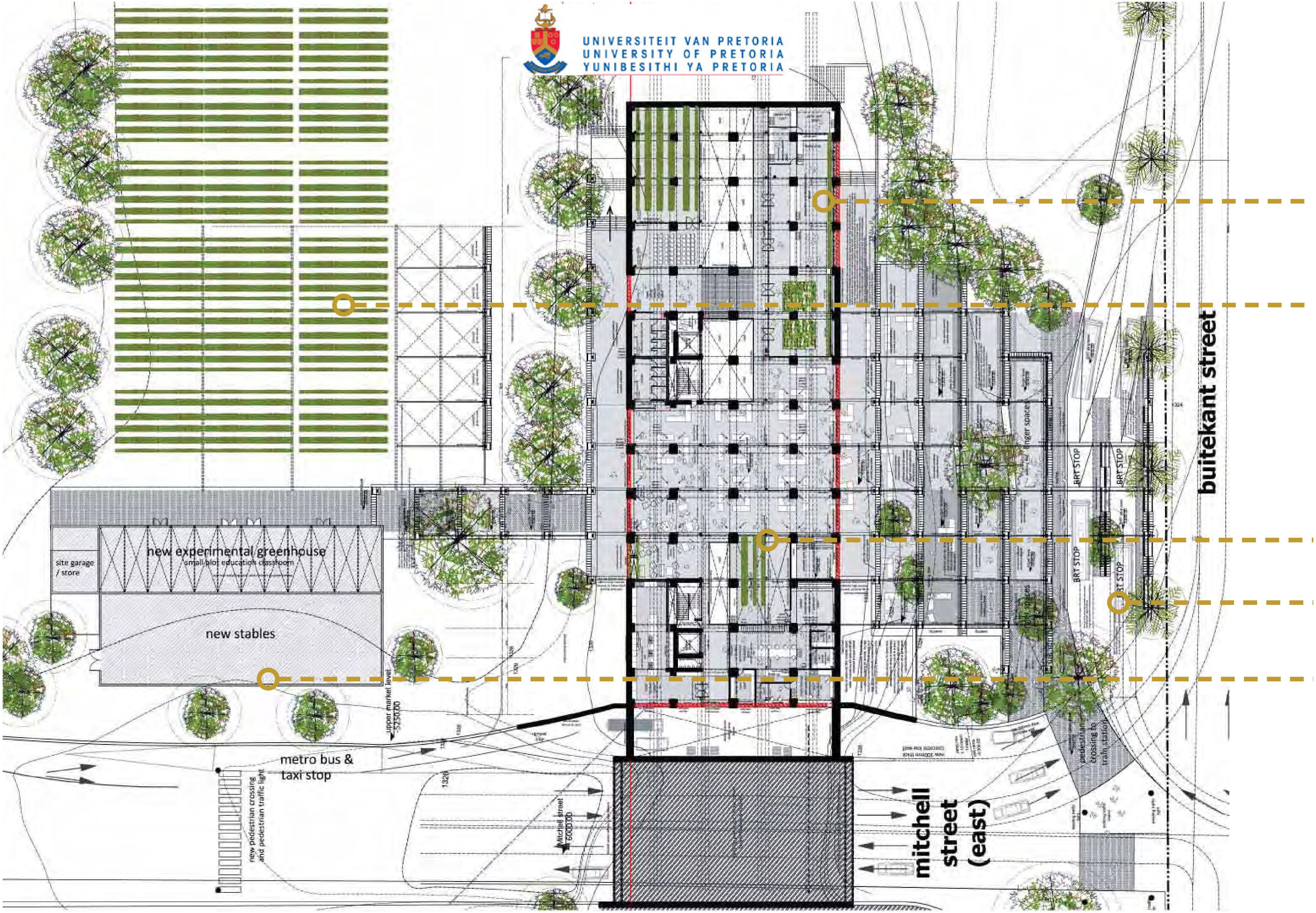
solid concrete structure
hollow void space

Figure 144 (opposite) & 145 (right): typical section of the bunker [author, 2010].

conveyor belts exists towards the south

solid concrete structure
hollow space





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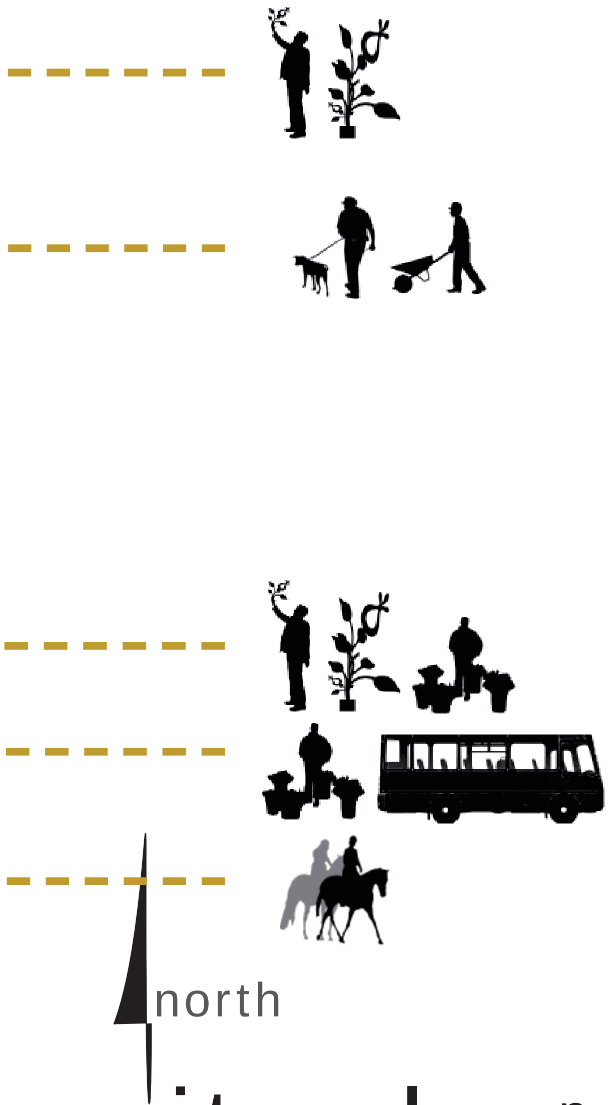
new experimental greenhouse
small plot education classroom
site garage / store
new stables
metro bus & taxi stop
new pedestrian crossing and pedestrian traffic light
upper market level 5250.00
Mitchell street 6000.00
mitchell street (east)
buitekant street
BRT STOP
BRT STOP
BRT STOP
BRT STOP



site plan n.t.s

Figure 146: Greater site plan [author, 2010].

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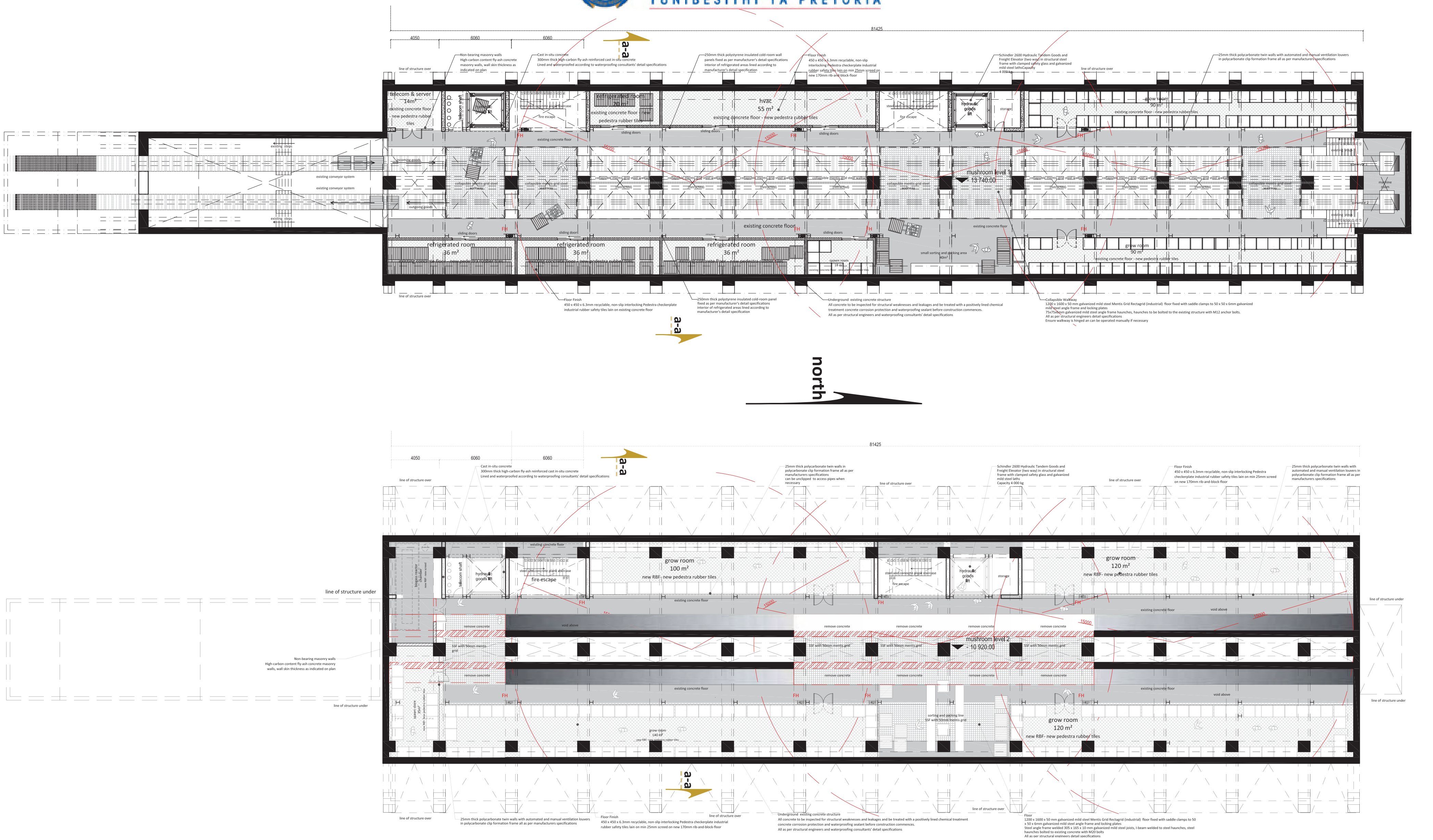
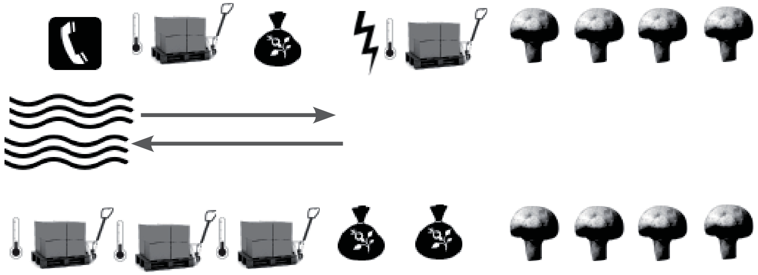
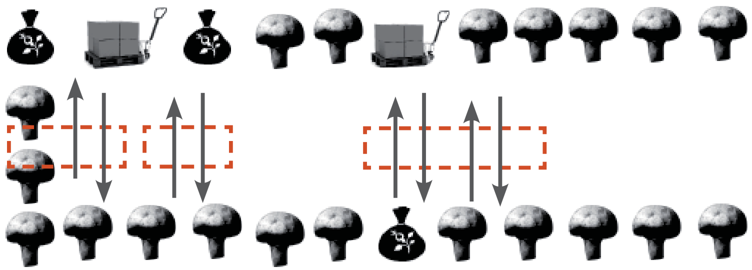


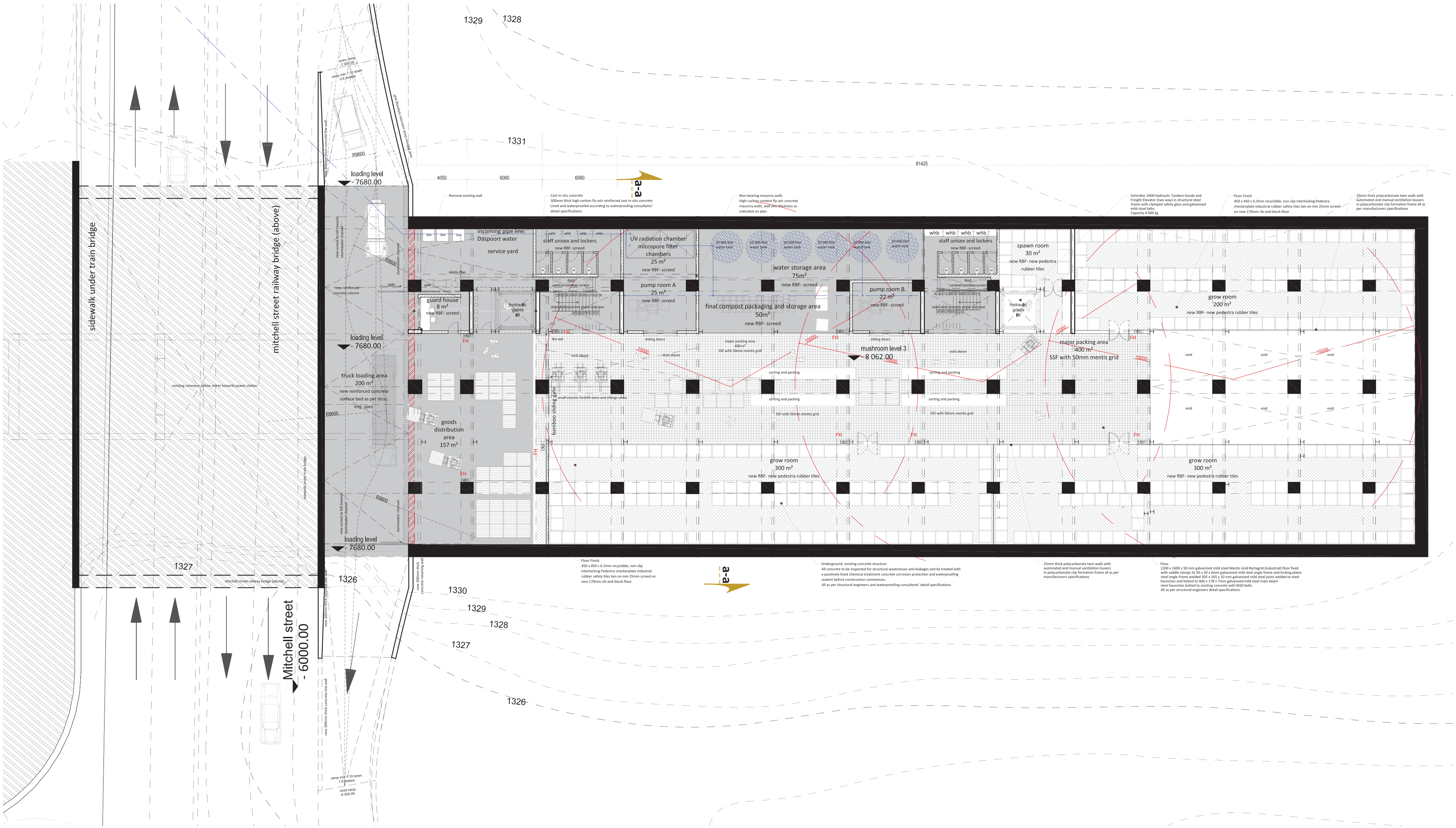


mushroom level one
n.t.s.



mushroom level two
n.t.s.

Figure 147: Basement plans part one [author, 2010].


sidewalk under train bridge
mitchell street railway bridge (above)
Mitchell street
- 6000.00
loading level
- 7680.00
truck loading area
200 m²
goods distribution area
157 m²
guard house
8 m²
new RBF- screed
incoming pipe line: Daspoort water
service yard
staff unisex and lockers
new RBF- screed
UV radiation chamber
micropore filter chambers
25 m²
pump room A
25 m²
water storage area
75m²
final compost packaging and storage area
50m²
pump room B
22 m²
spawn room
30 m²
grow room
200 m²
new RBF- new pedestra rubber tiles
major packing area
400 m²
SSF with 50mm mentis grid
mushroom level 3
- 8 062.00
grow room
300 m²
new RBF- new pedestra rubber tiles
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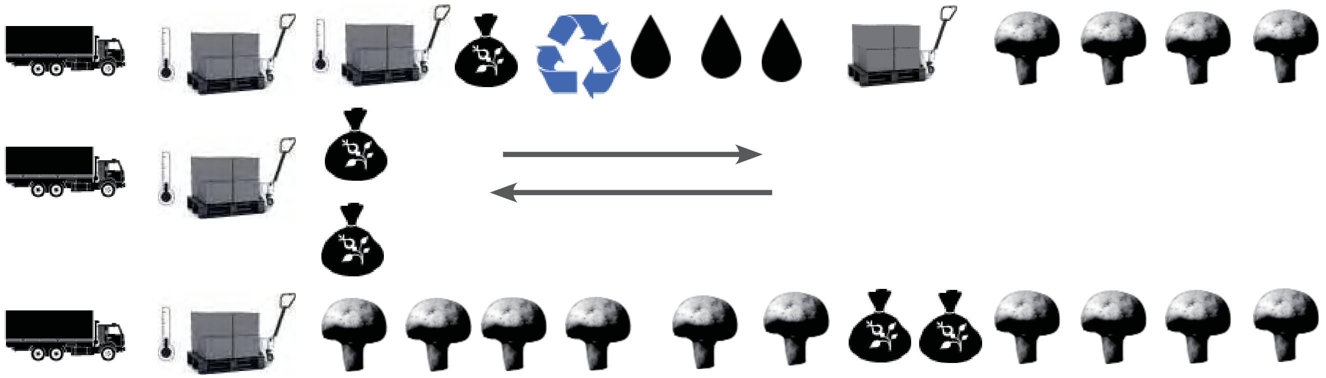
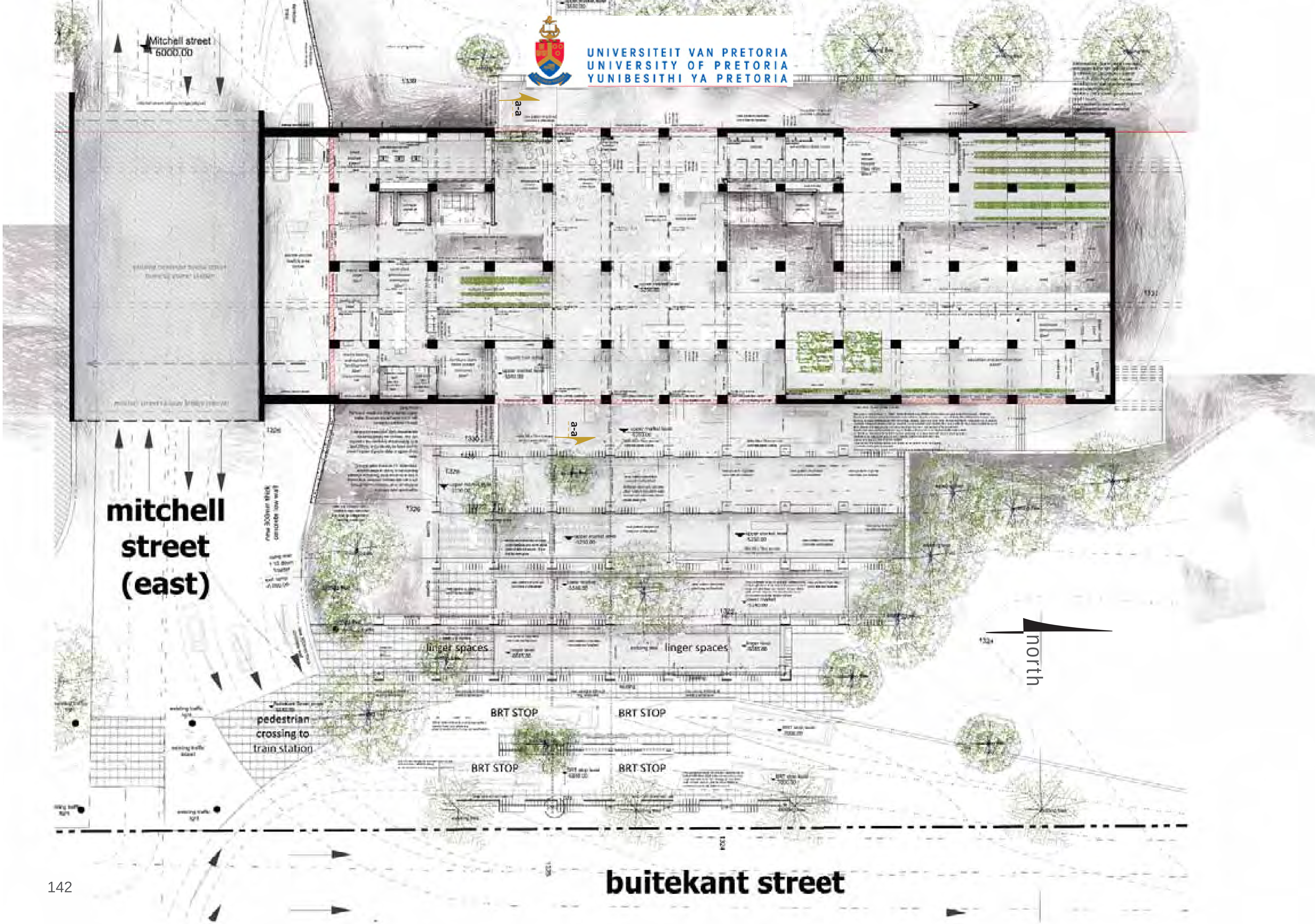


mushroom level three

n.t.s.

Figure 148: Basement plans part two [author, 2010].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Mitchell street
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mitchell
street
(east)
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linger spaces
pedestrian
crossing to
train station
BRT STOP
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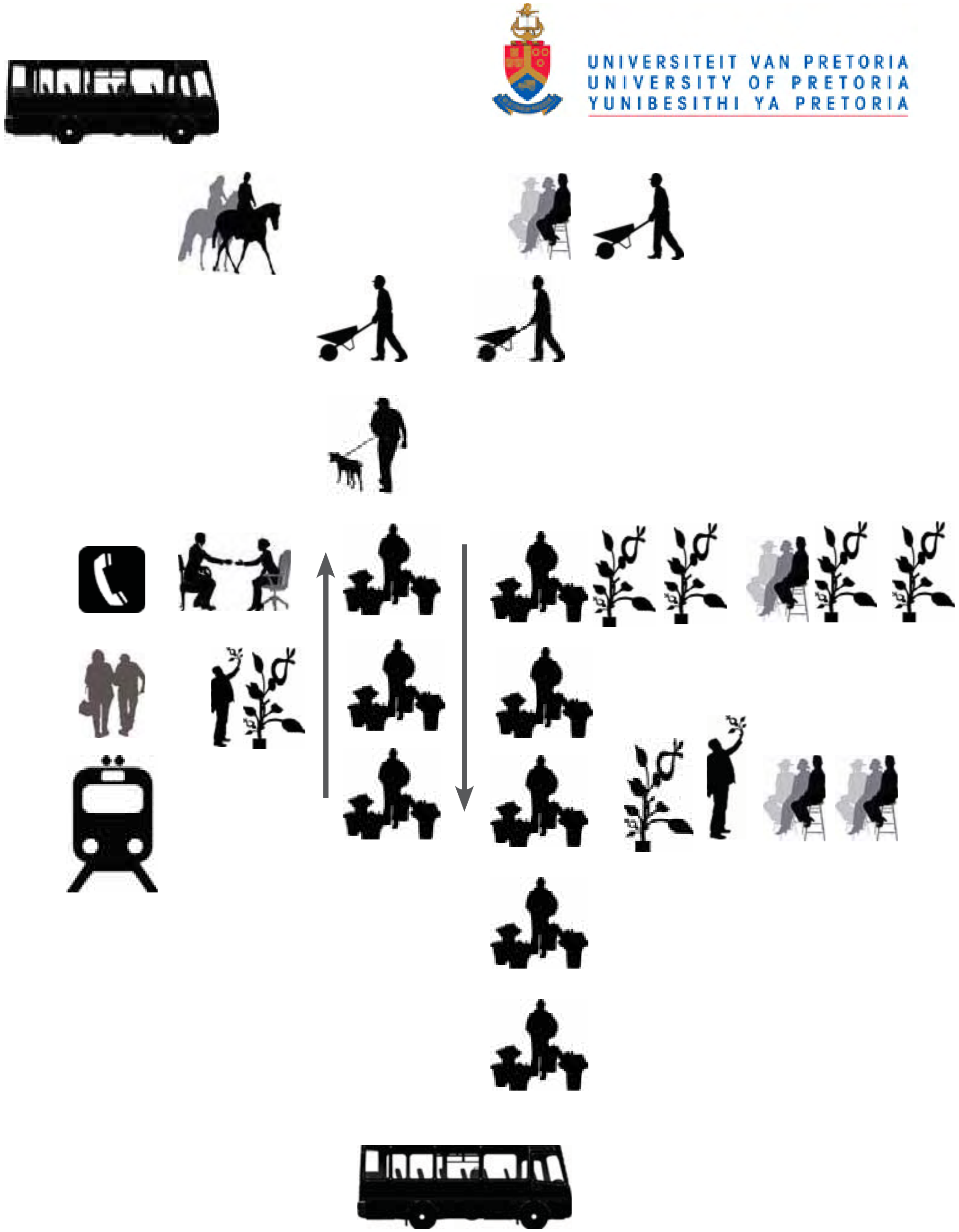
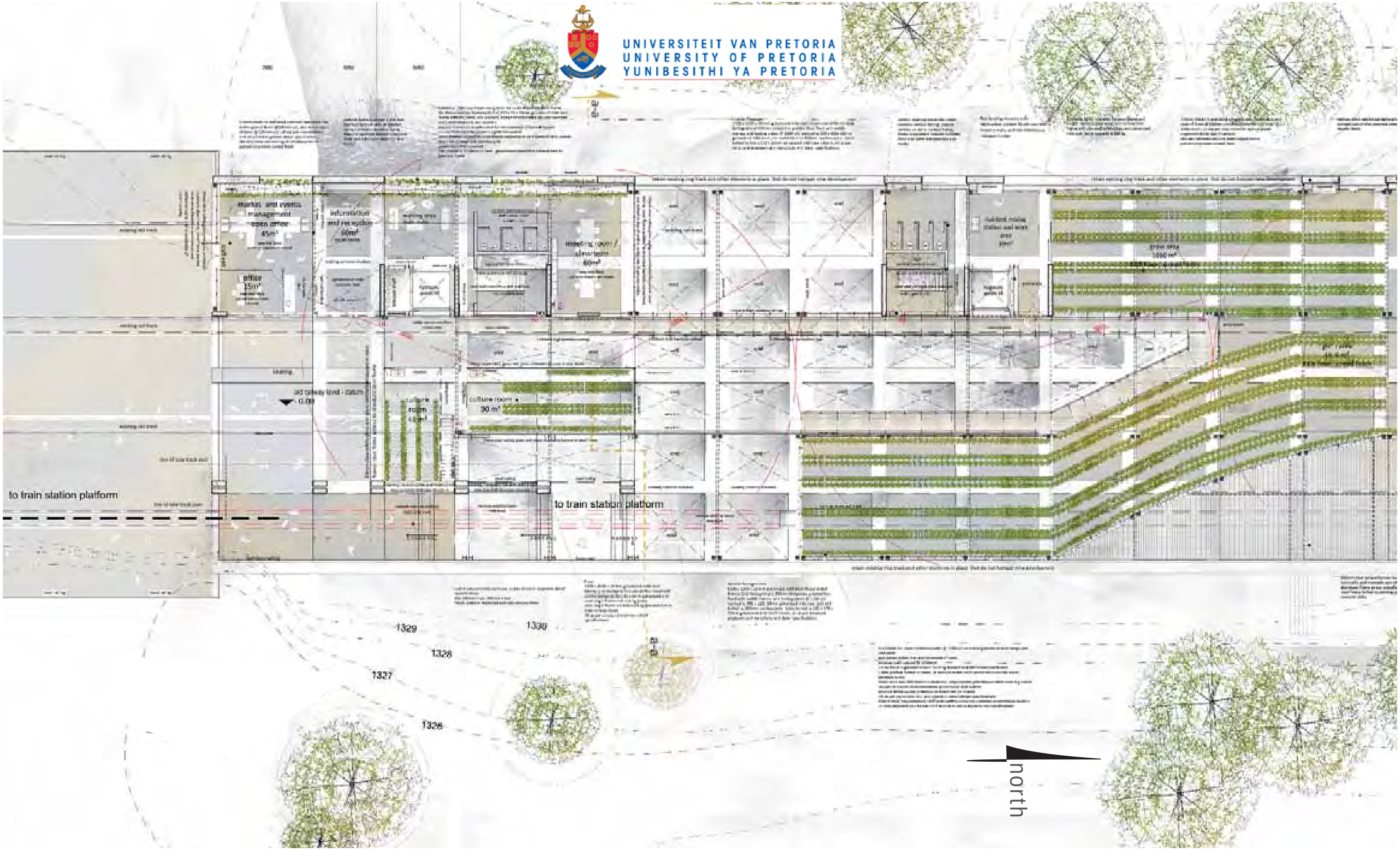
BRT STOP
BRT STOP
north
buitekant street

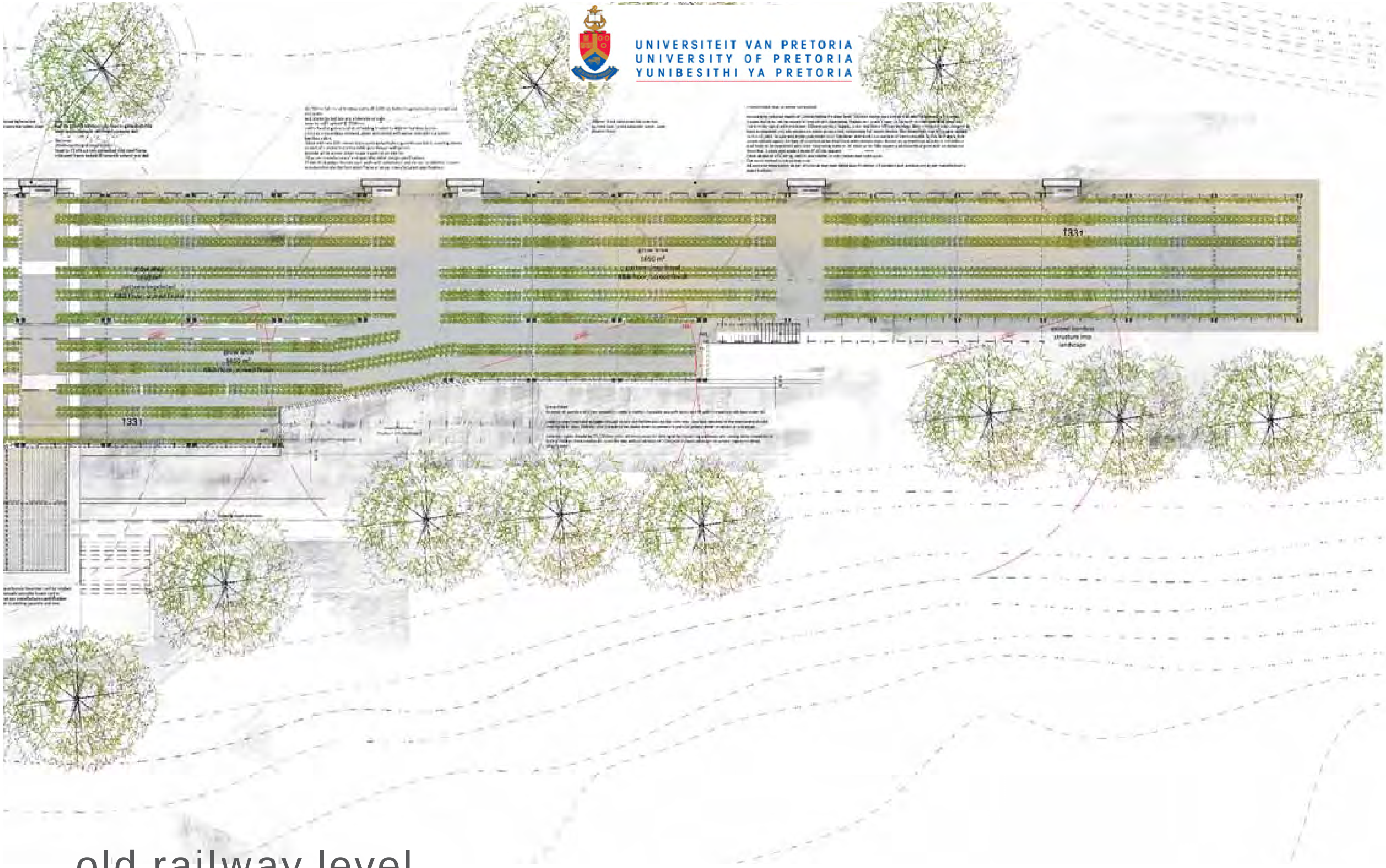


market level

n.t.s.

Figure 149: Public plane [author, 2010].

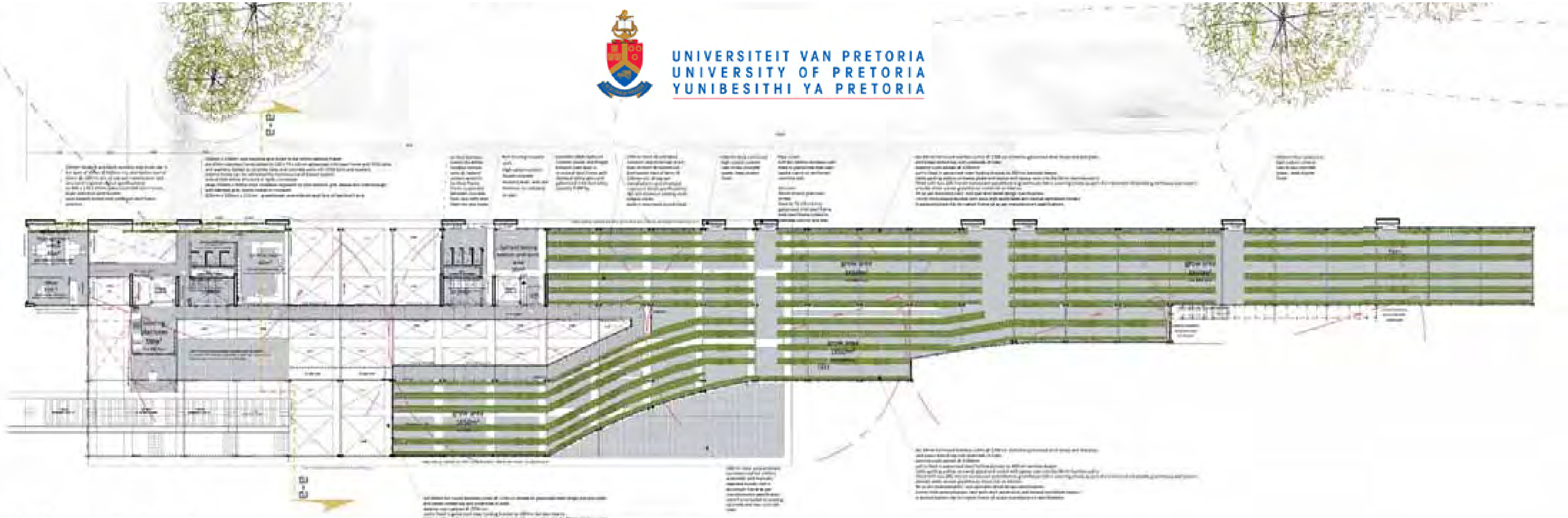

market and events management open office 45m²
office 15m²
information and reception 60m²
meeting room / classroom 60m²
culture room 90 m²
culture room 45m²
old railway level - datum
to train station platform
to train station platform
1329
1330
1328
1327
1326
north



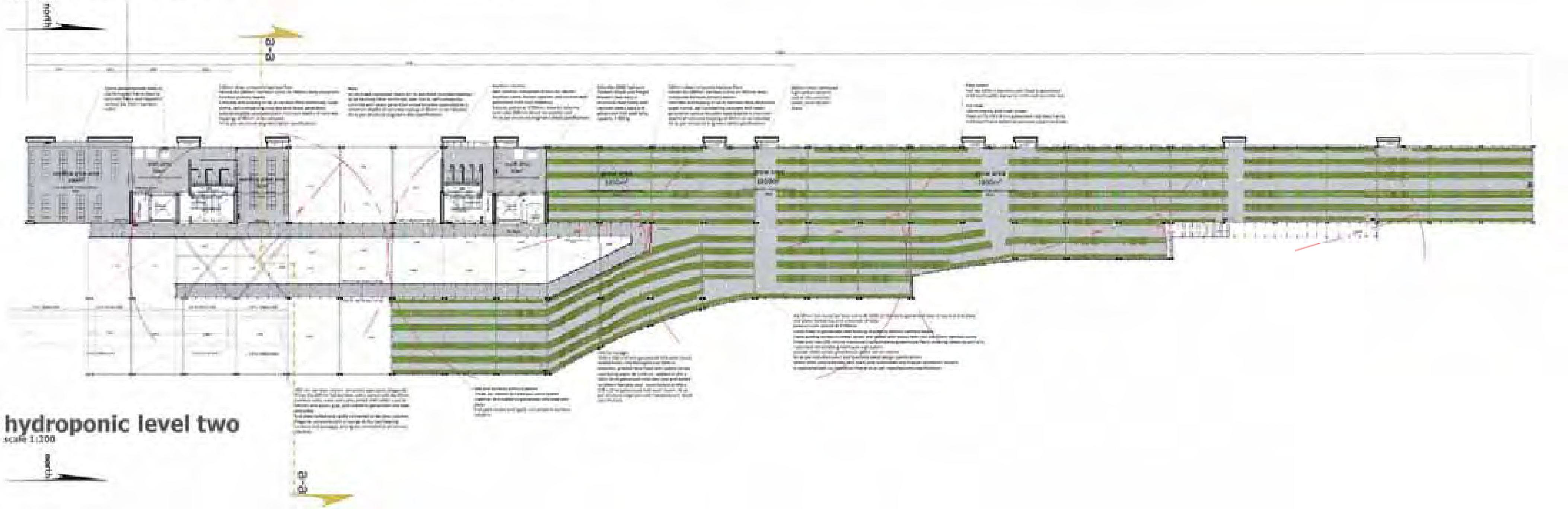
old railway level

n.t.s.

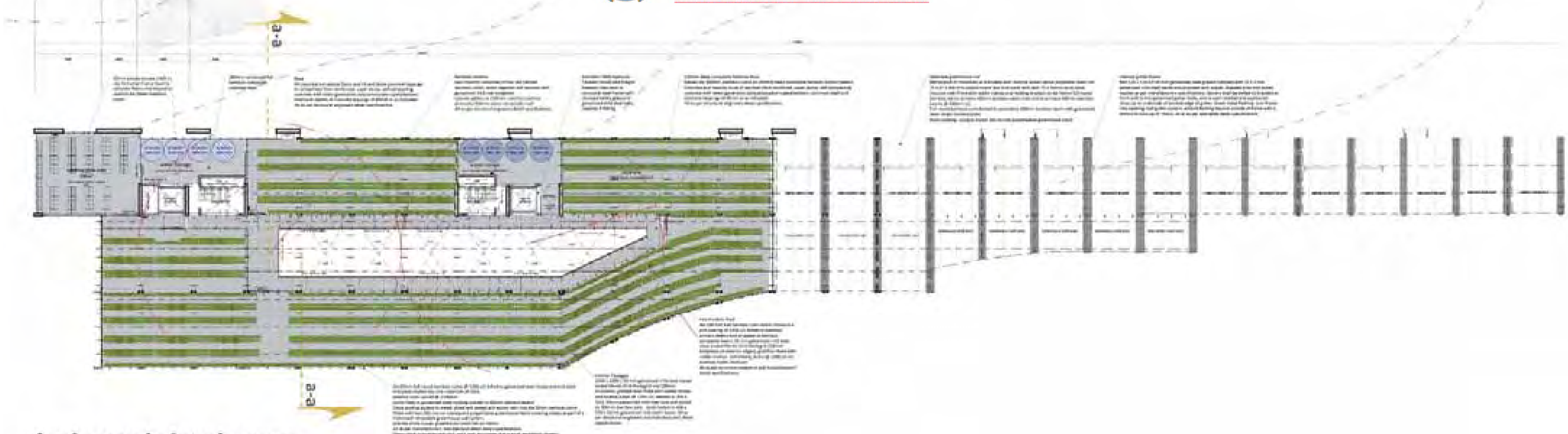
Figure 150: New plane part one. [Author, 2010].



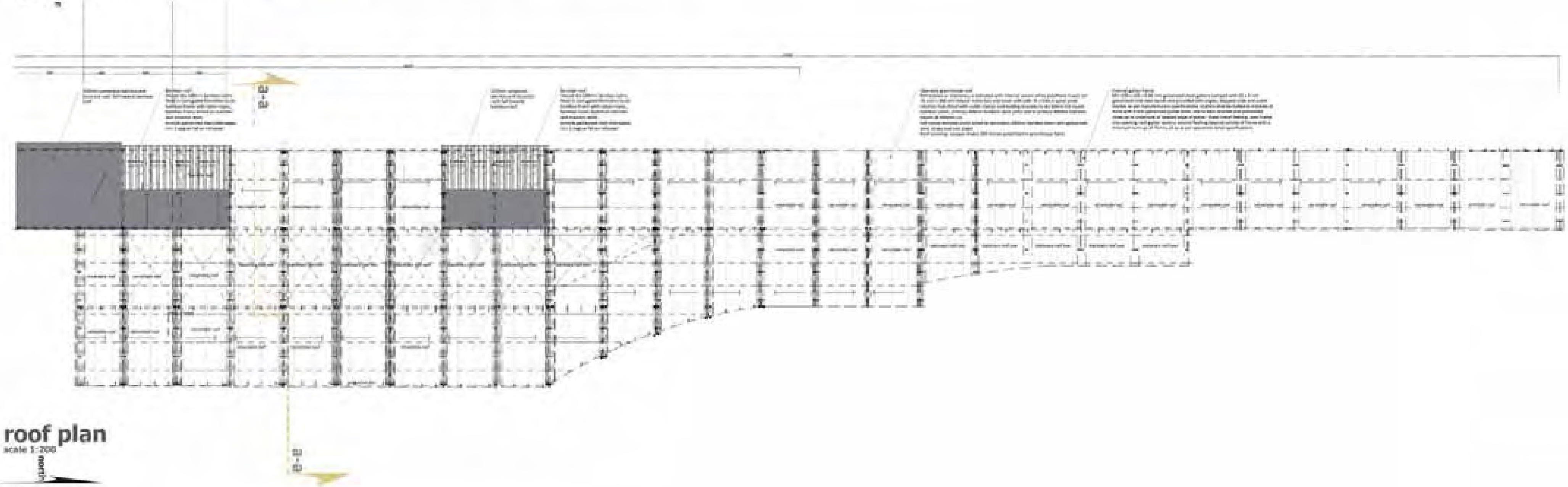
hydroponic level one
scale 1:200



hydroponic level two
scale 1:200



hydroponic level seven
scale 1:200



roof plan
scale 1:200

Figure 151a, 151b (opposite) and 152a, 152b (above): New plane part two. [Author, 2010].

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section a-a
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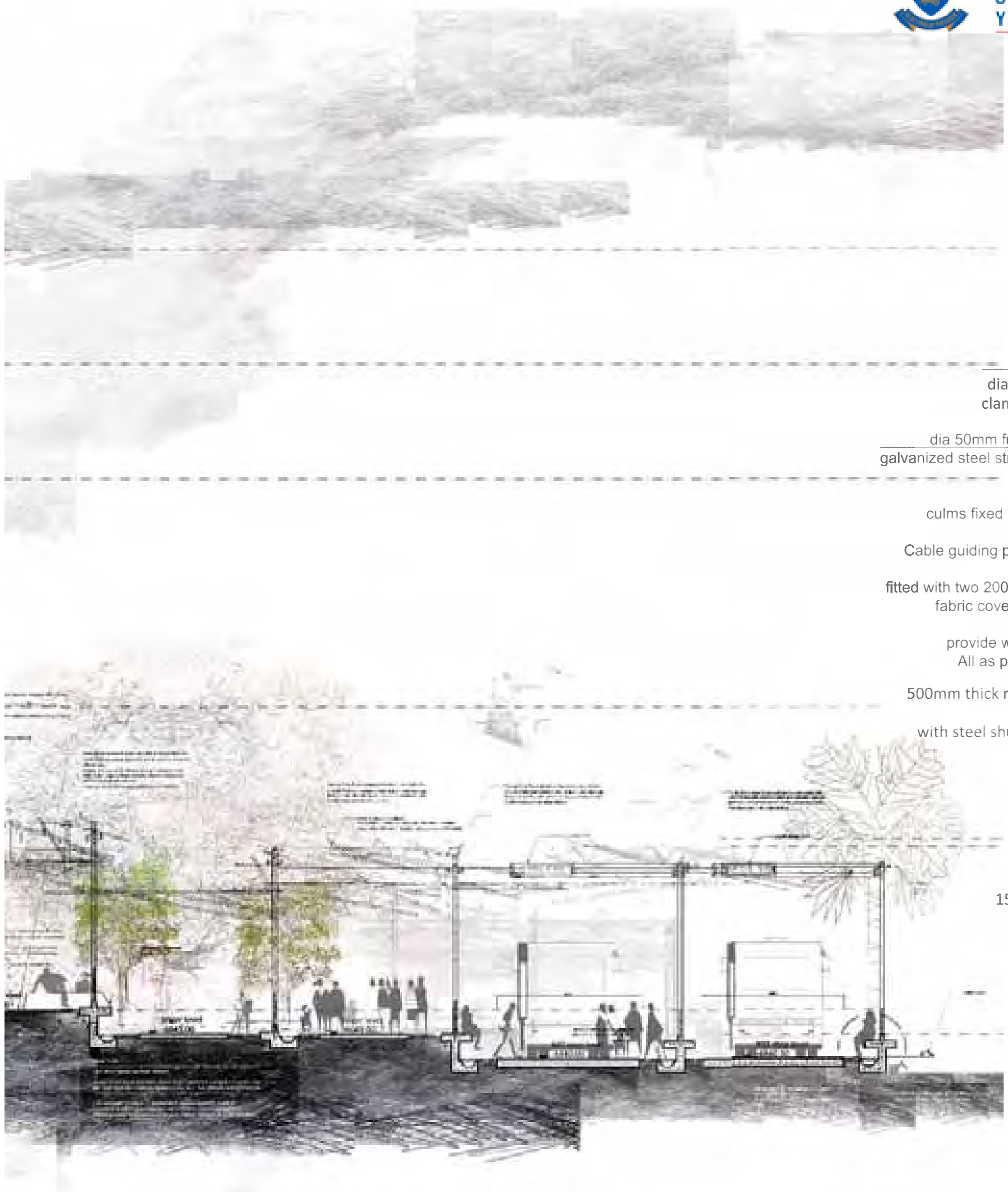
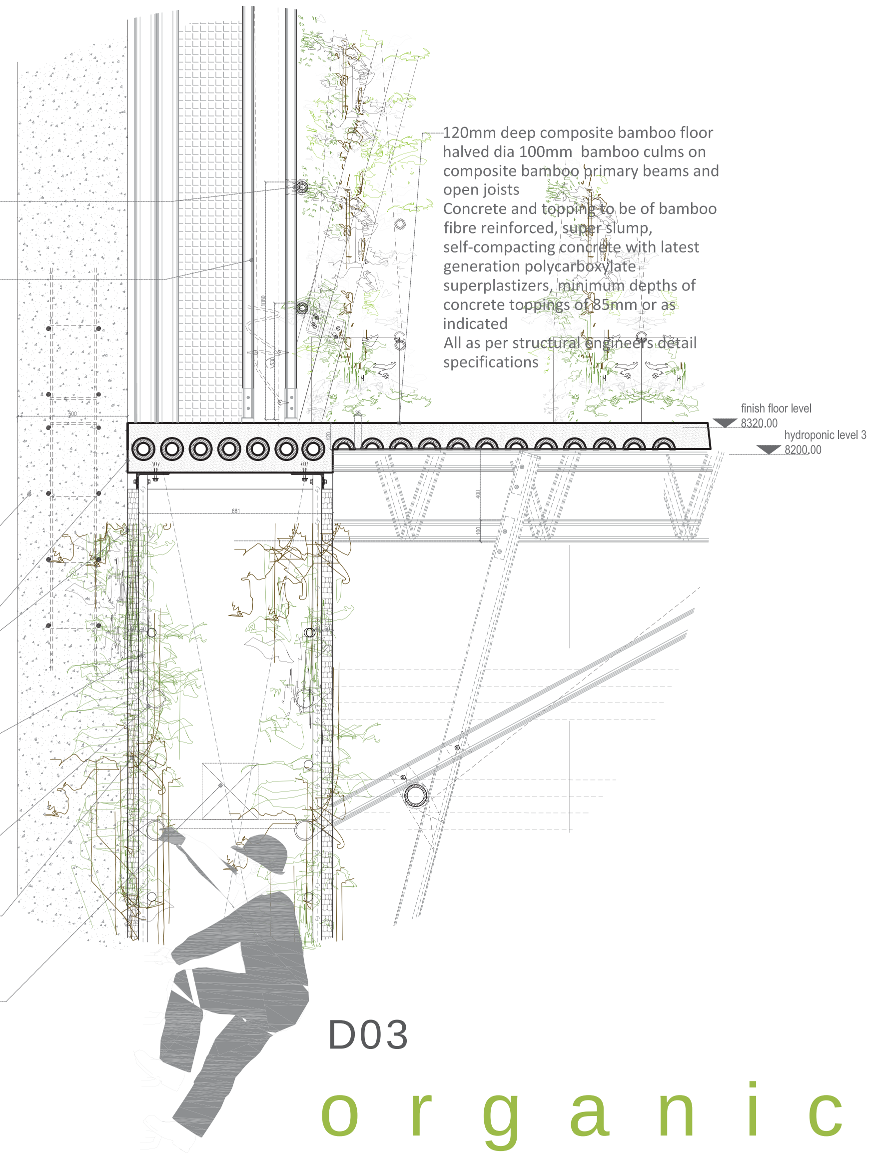
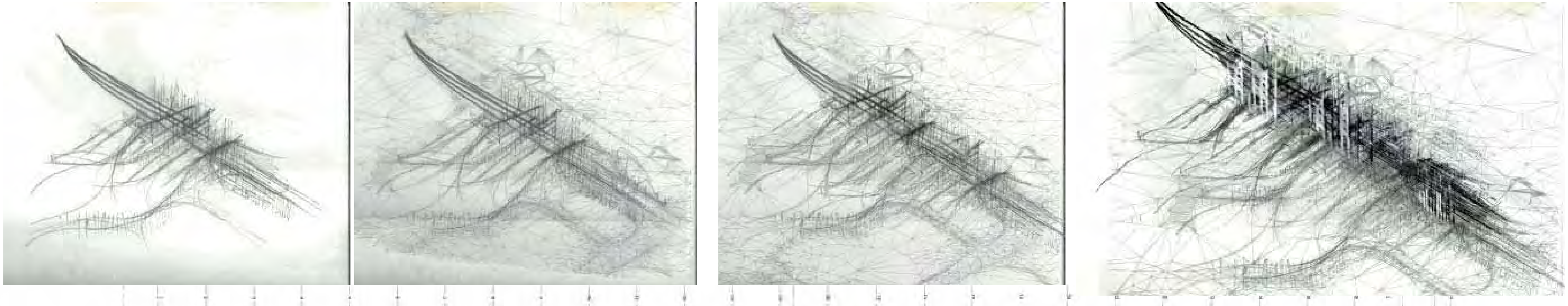
living building





D03

organic technology



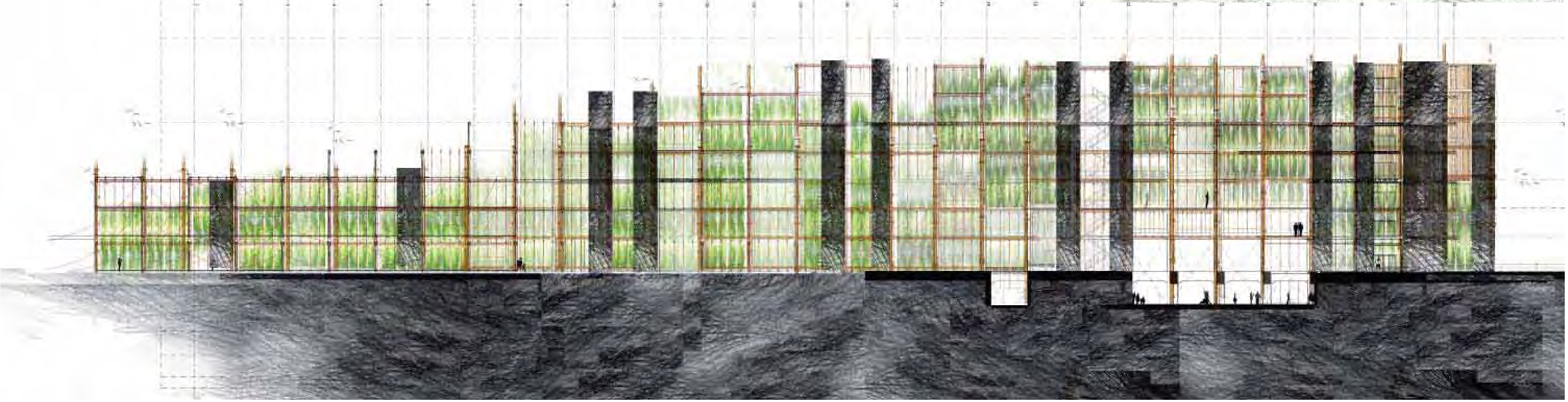
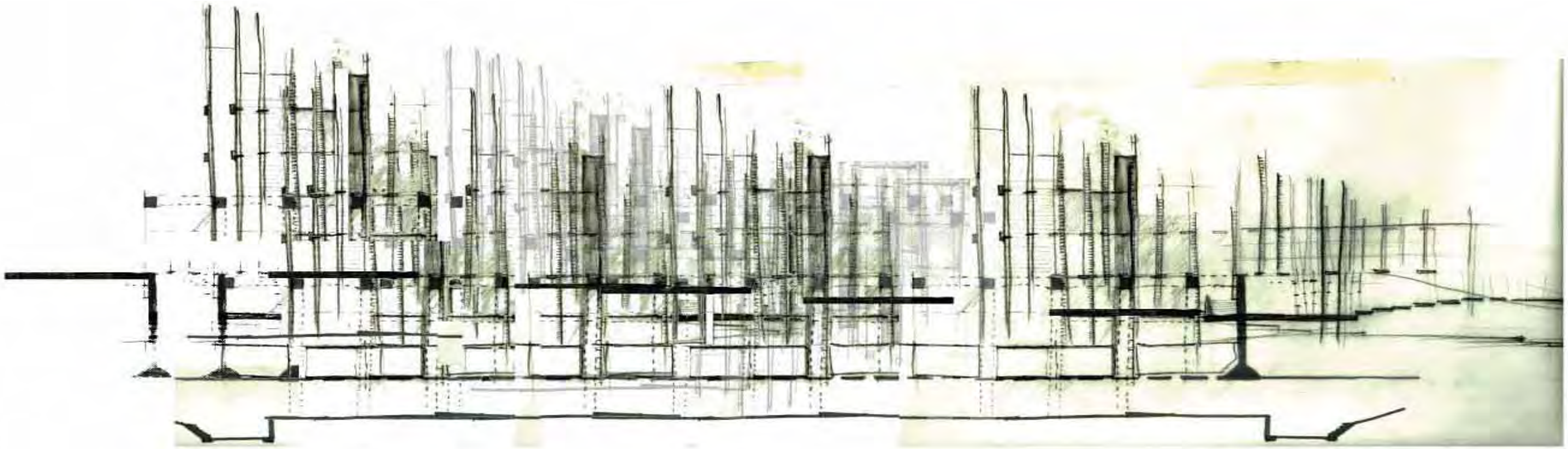
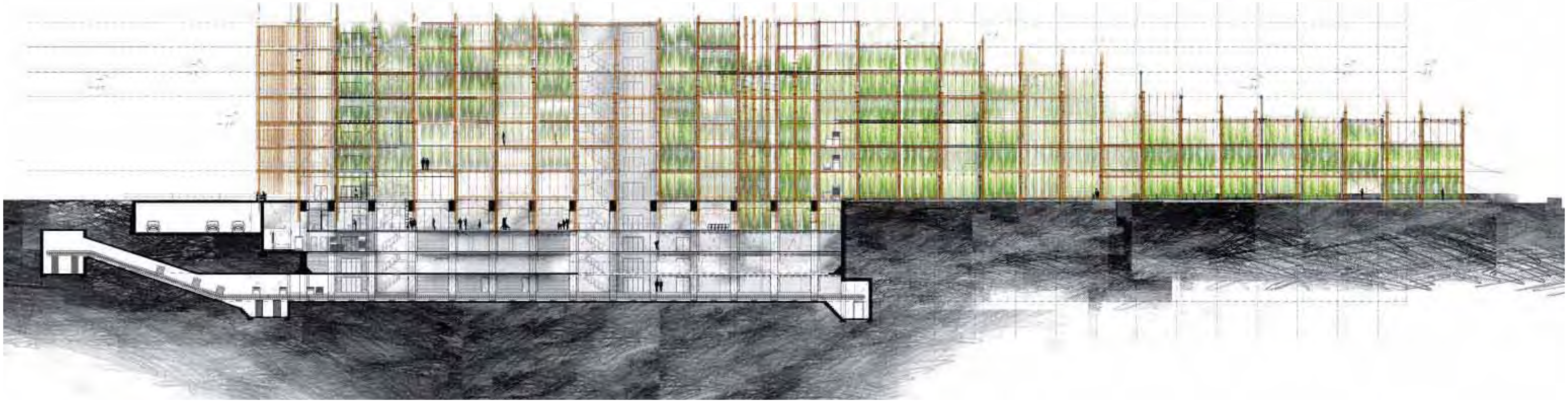


Figure 154 (top) and Figure 155 (middle): From concepts to result [author, 2010].

Development on the concept of the living building towards the resulting concrete expression of the research investigation and a singular form of architecture - the hydroponic food factory. Drawing above shows the heavier western facade.





concrete results

Figure 156 (top) and Figure 157 (middle): From concept to result [author, 2010].

Development on the concept of a building of light and frame and the resulting concrete expression of the research investigation on new building technologies into a singular form of architecture. Drawing above shows a typical section and the lighter eastern facade.

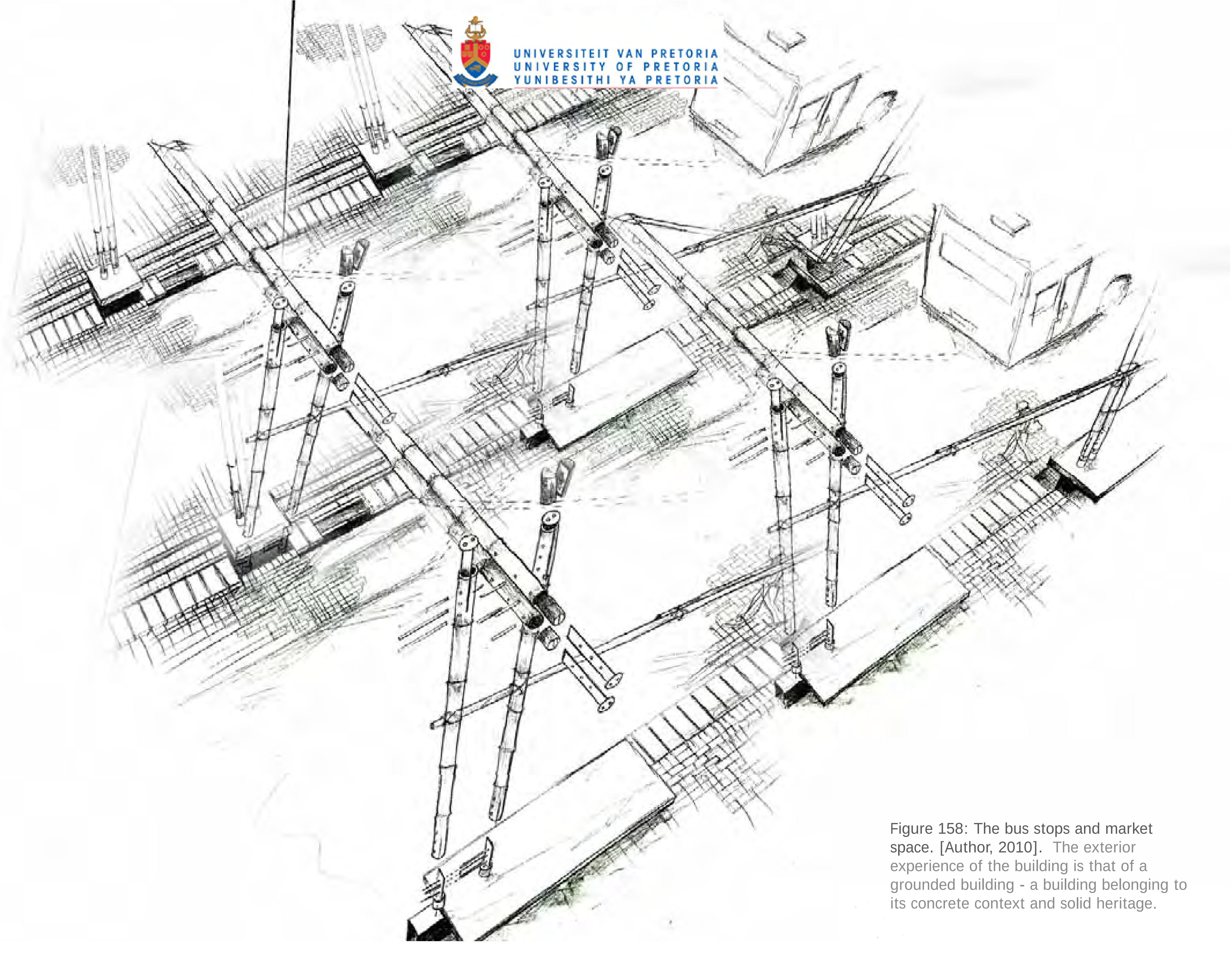


Figure 158: The bus stops and market space. [Author, 2010]. The exterior experience of the building is that of a grounded building - a building belonging to its concrete context and solid heritage.

suspended inside

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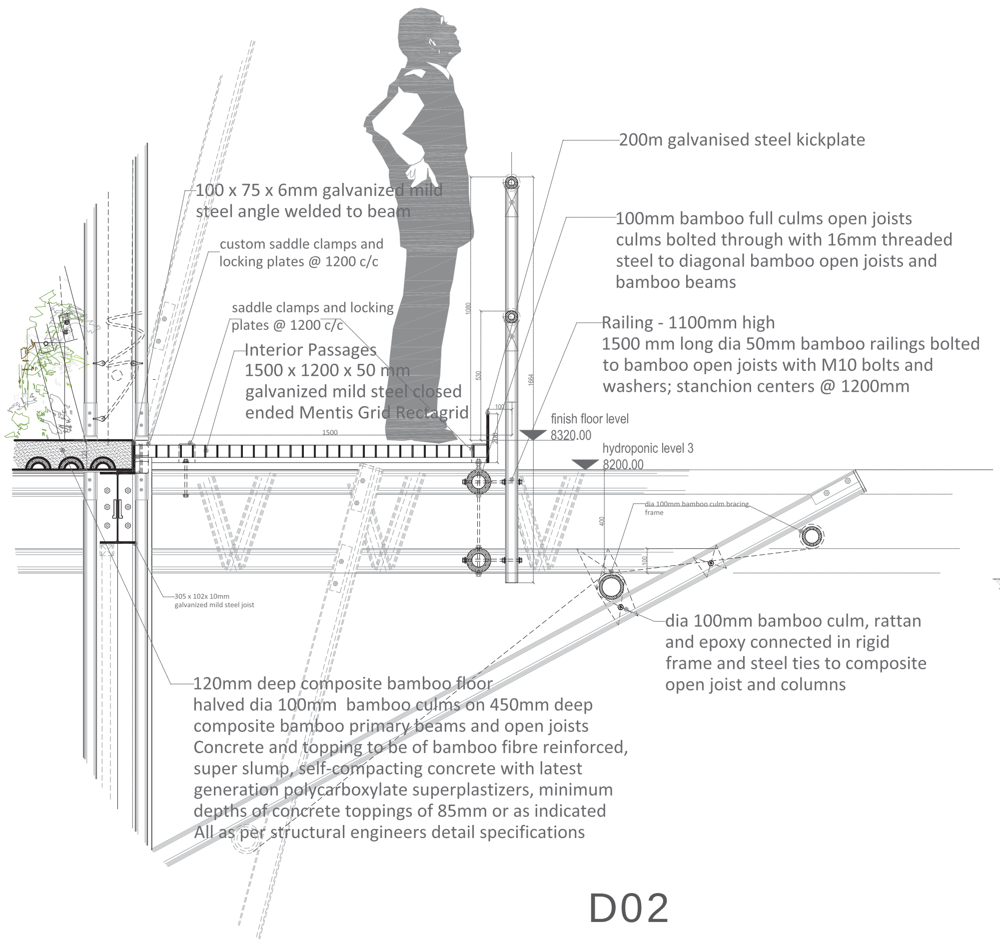
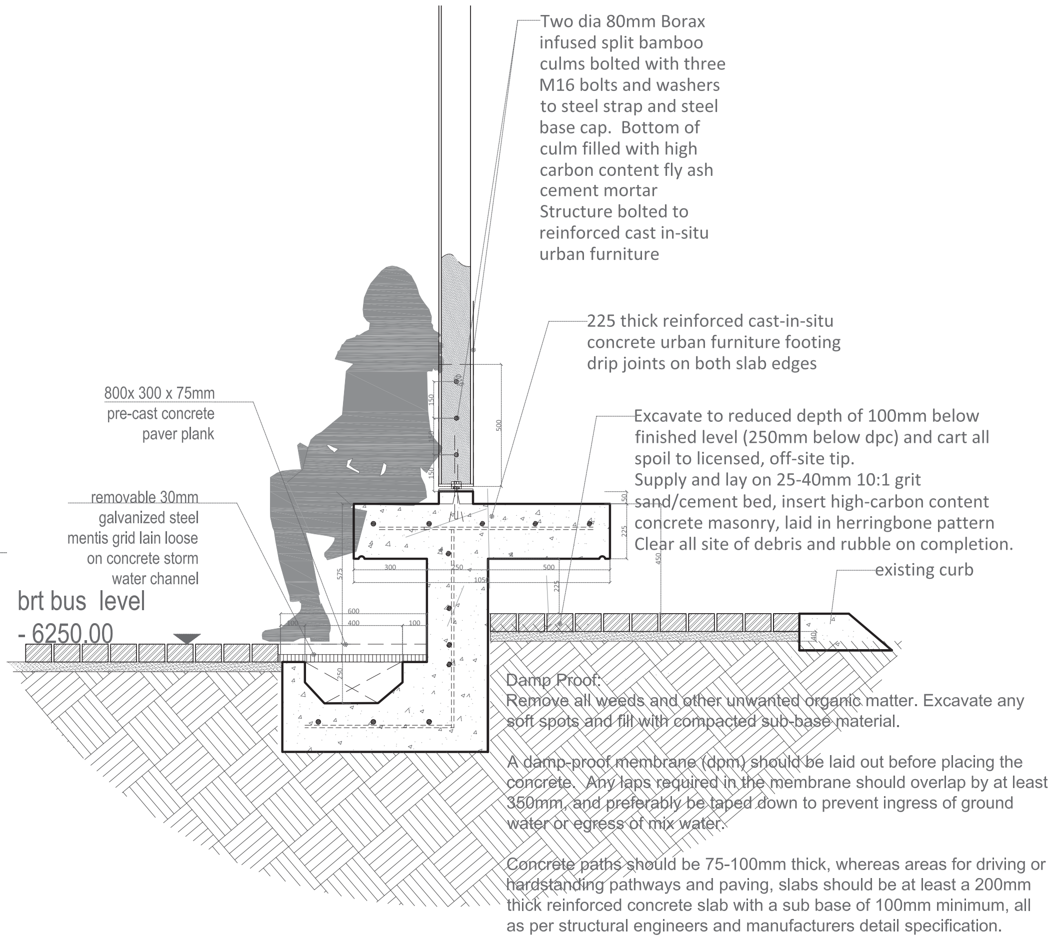
grounded outside



D02



D01

experience verticality

Figure 159 (left) and 160 (right): Typical details expressing experiences of verticality and assembly of the new living building [author, 2010]. The building interior is an experience of verticality and of suspension through a new building material: structural bamboo.

experience assembly

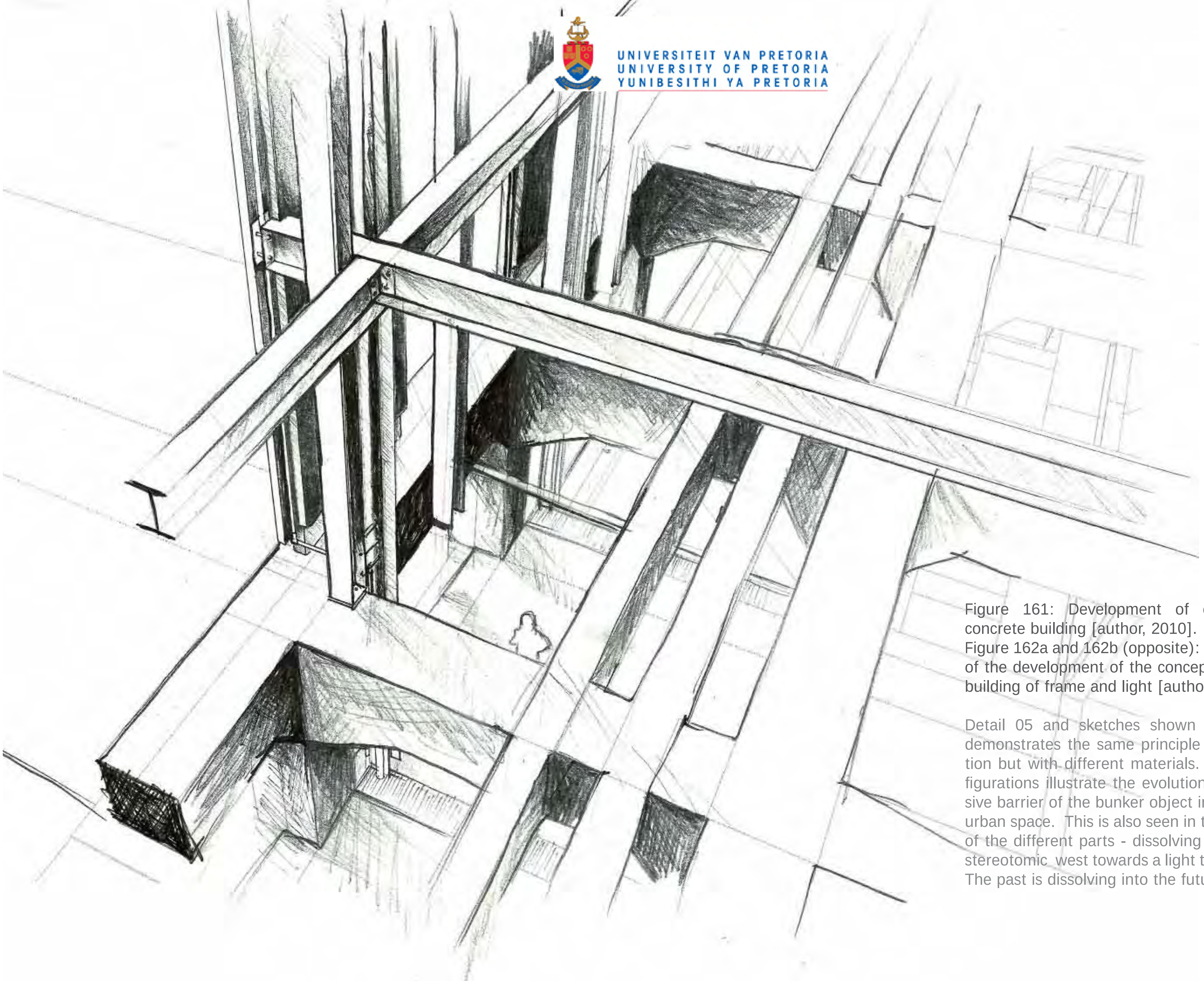
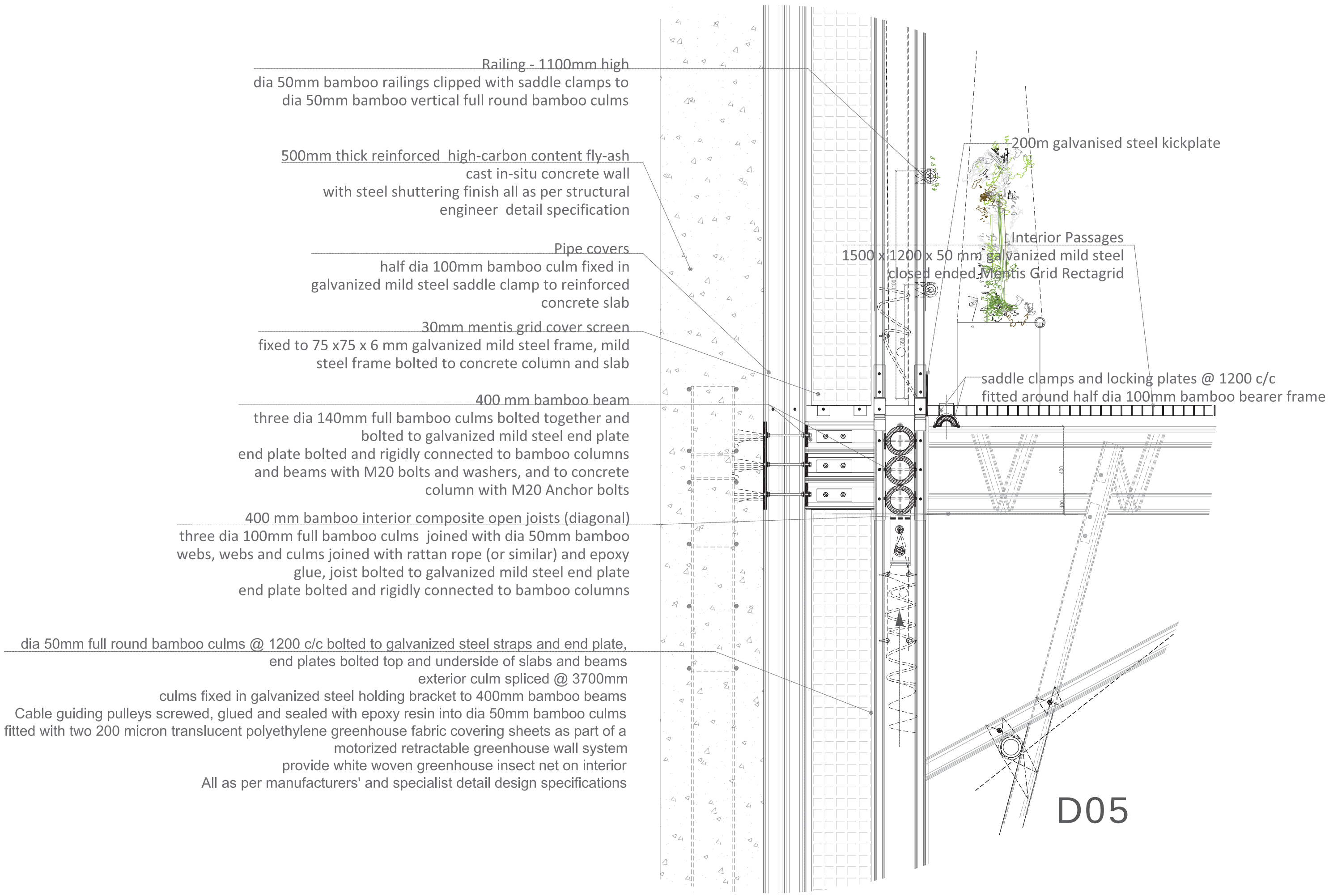


Figure 161: Development of concepts to concrete building [author, 2010].
Figure 162a and 162b (opposite): Photographs of the development of the concept model - a building of frame and light [author, 2010].

Detail 05 and sketches shown here (steel) demonstrates the same principle of construction but with different materials. These configurations illustrate the evolution of the passive barrier of the bunker object into an active urban space. This is also seen in the assembly of the different parts - dissolving from a solid stereotomic west towards a light tectonic east. The past is dissolving into the future.

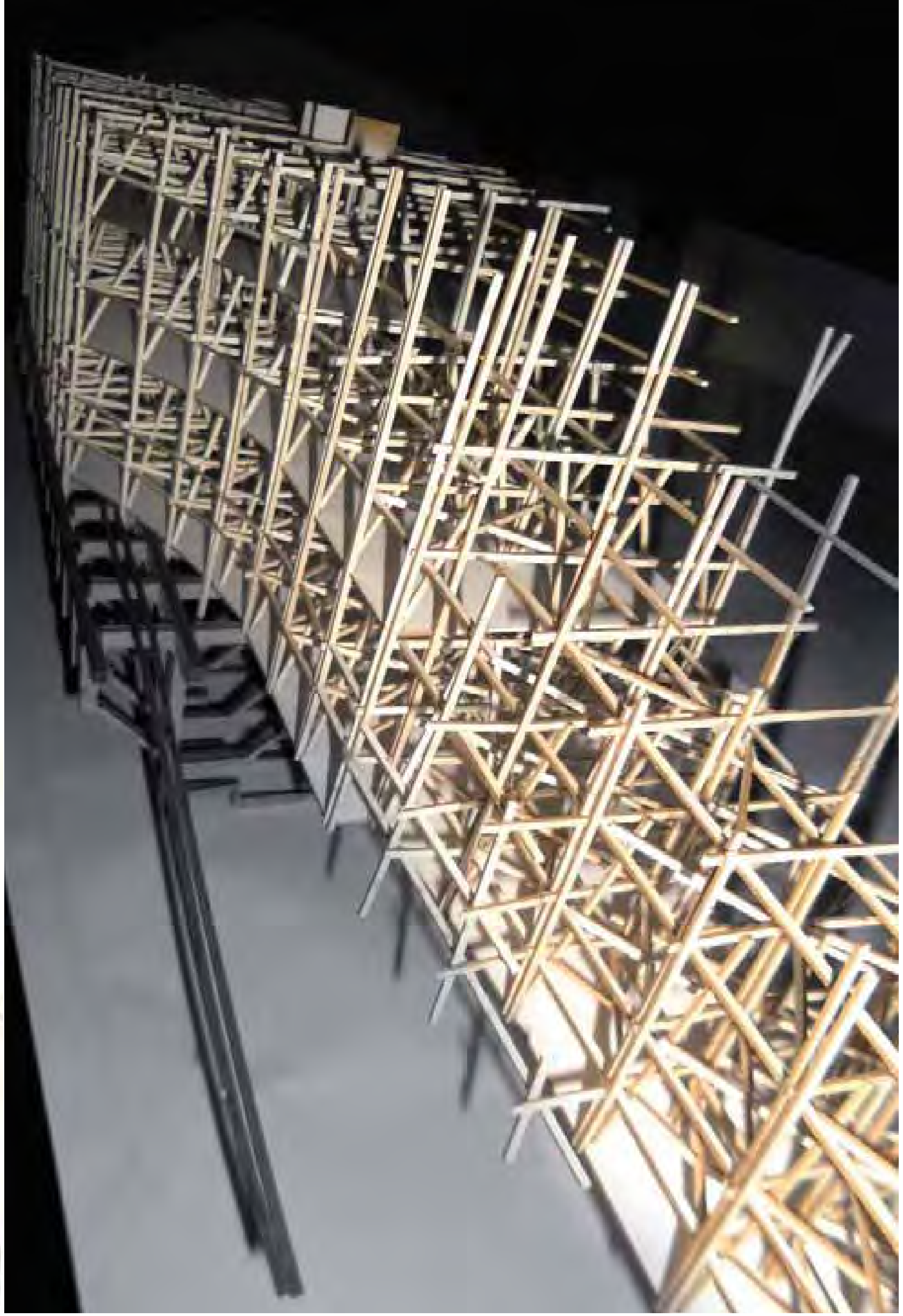
dissolving materiality



experience earth

Figure 163: Typical details expressing experiences of dissolving materials - elements of mass moving towards elements of light [author, 2010].

The dissolving elements of mass to elements of light enhances the experience of the underground sunken structure of the concrete bunker and the above ground suspended character of the bamboo in the hydroponic food factory. This shows the evolution of the bunker as a closed, introverted object into a open space of light and air.



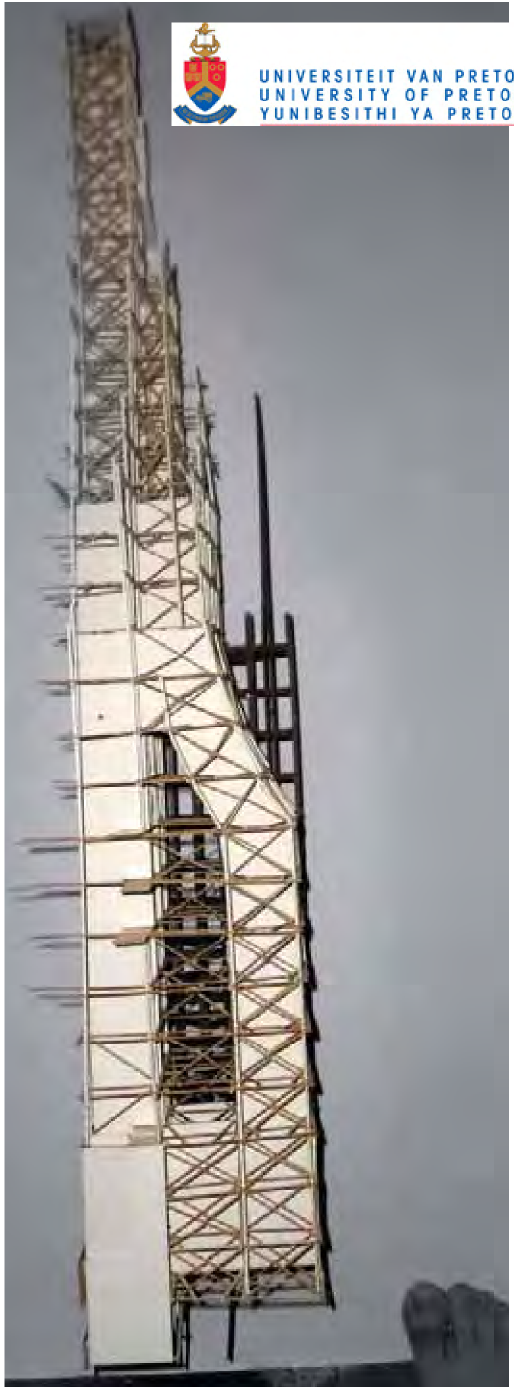
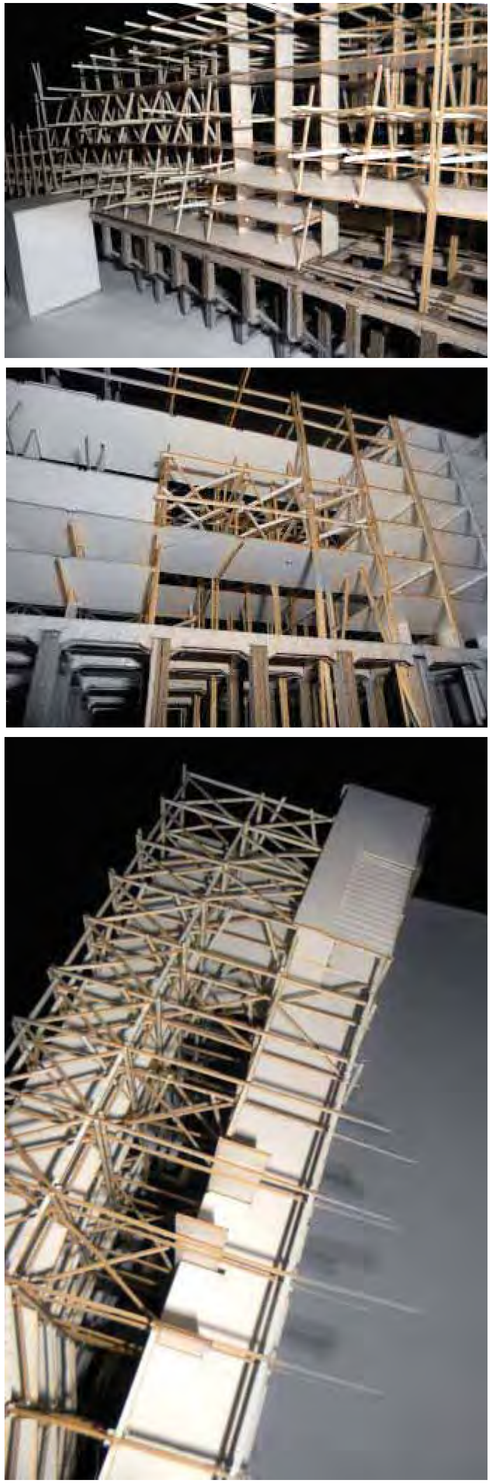
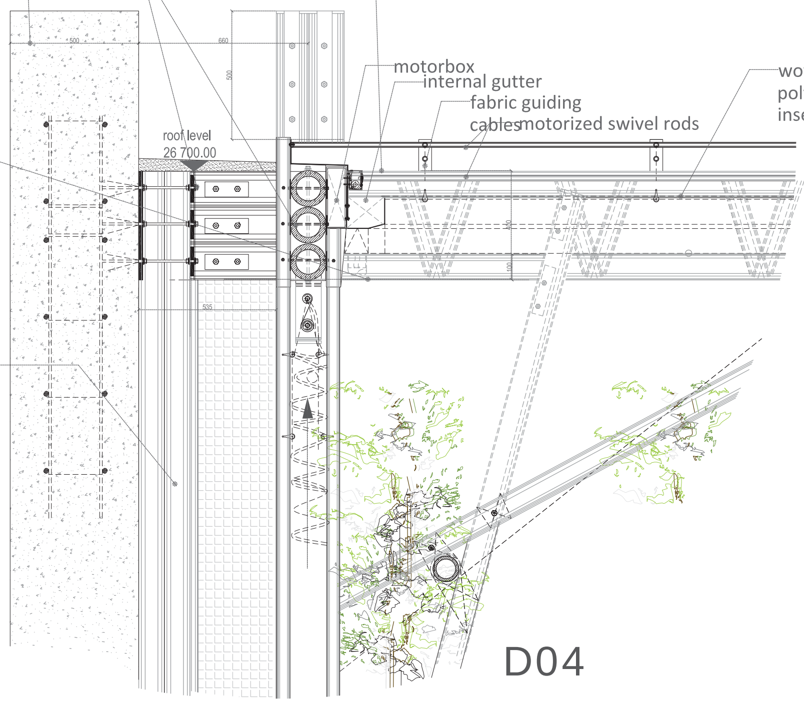


Figure 164 (left): Photograph of the working model [author, 2010].
Figure 165 (centre): Frame and construction of final model [author, 2010].
Figure 166 (right): Unfinished final model from above [author, 2010].

The agriculture program requires as much natural ventilation as possible, and retractable greenhouse walls and retractable greenhouse roofs are proposed. This further encourages the development of an open frame building - with moving, opening walls, translucent and transparent skin and an experience of edgelessness. The photos show the development of the models from the working model to the final design proposal.



o p e n b u i l d i n g



e x p e r i e n c e a i r

Figure 167a (top), 167b (middle) and 167c (bottom): Photographs of the construction of the final model [author, 2010]

Figure 168: Typical details of the new living building [author, 2010].

The building roofs are operable greenhouse screen roofs, allowing maximum air and light for crop production.

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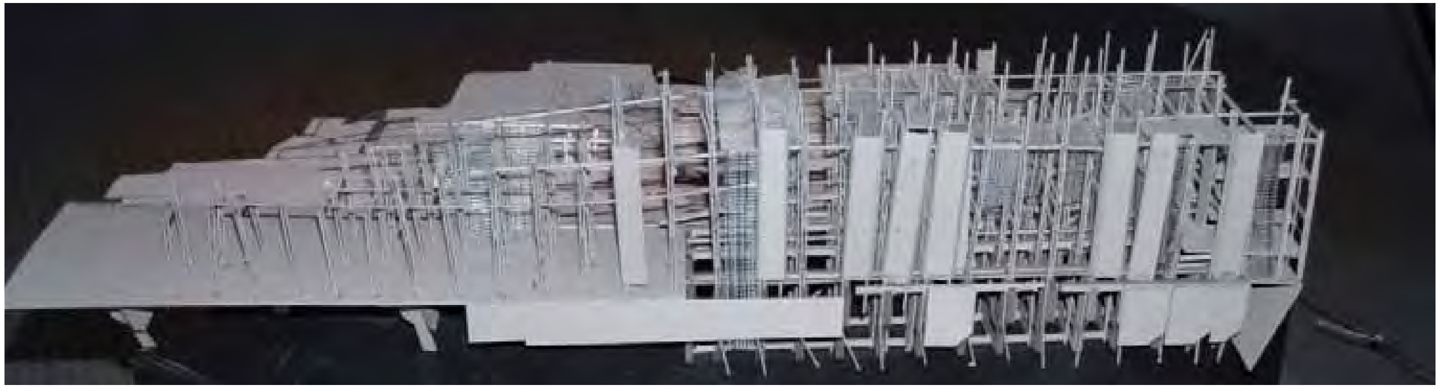


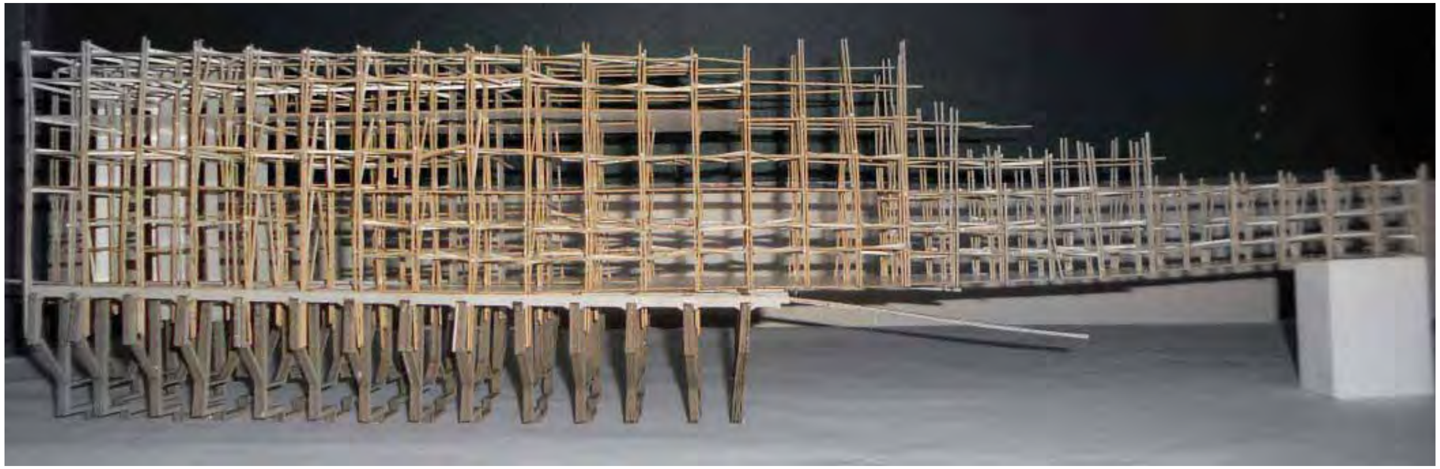


Figure 169a (top left), 169b (top middle) and 169c (bottom left): Working models [author, 2010].
The photographs show the evolution of the concept into the final building through physical models.

Figure 170 (below): Collection of photographs of the construction of the final model [author, 2010].
The images show the construction of the final model, illustrating the bamboo structure, concrete massing elements, open and closed retractable walls and roofs, concrete floors stopping short of each other and semi-transparent intermediate gridded floors - a dissolving, open, organic building.

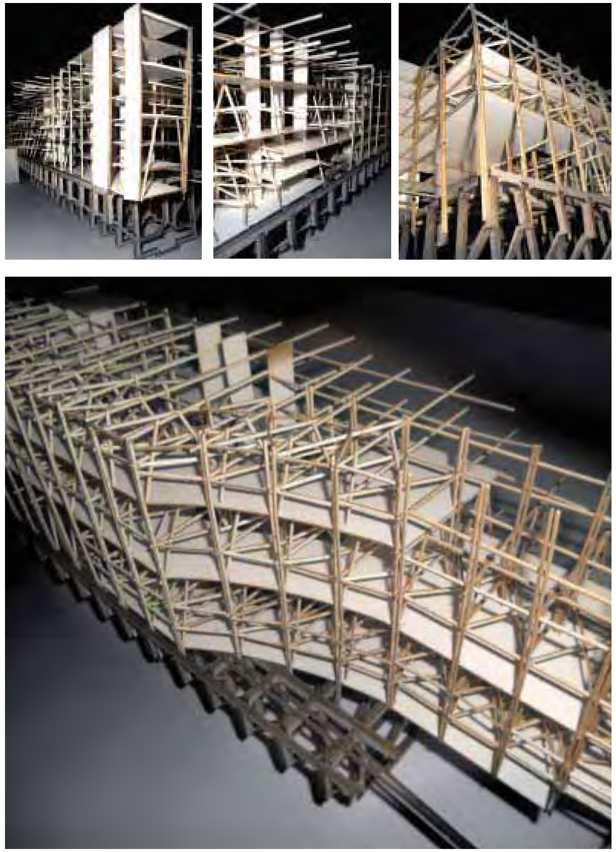


Figure 171 (top): Finished final model eastern elevation [author, 2010].

Figure 172 (far left): Finished final model western elevation [author, 2010].

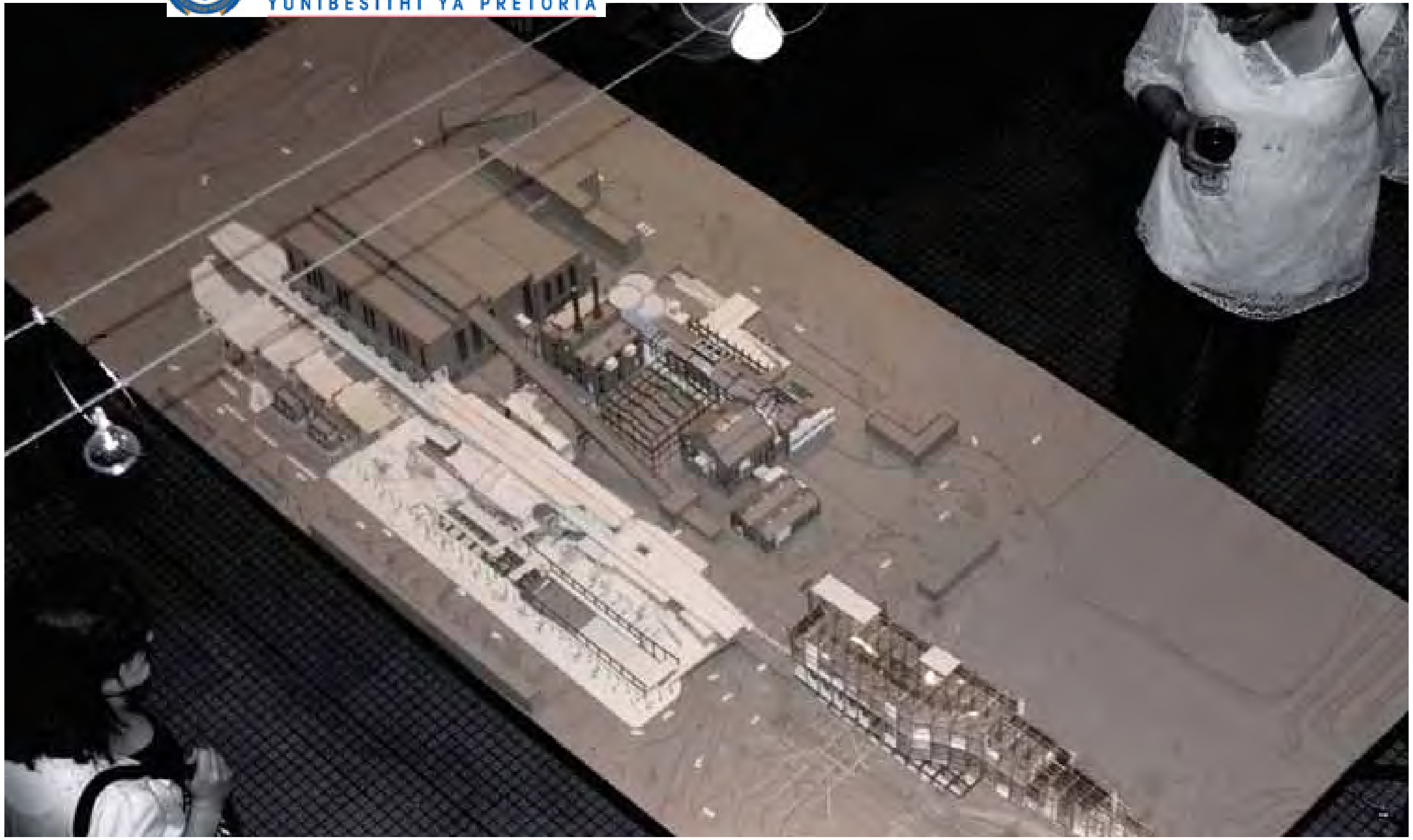
Figure 173 (left): Finished final model - view towards station [author, 2010].

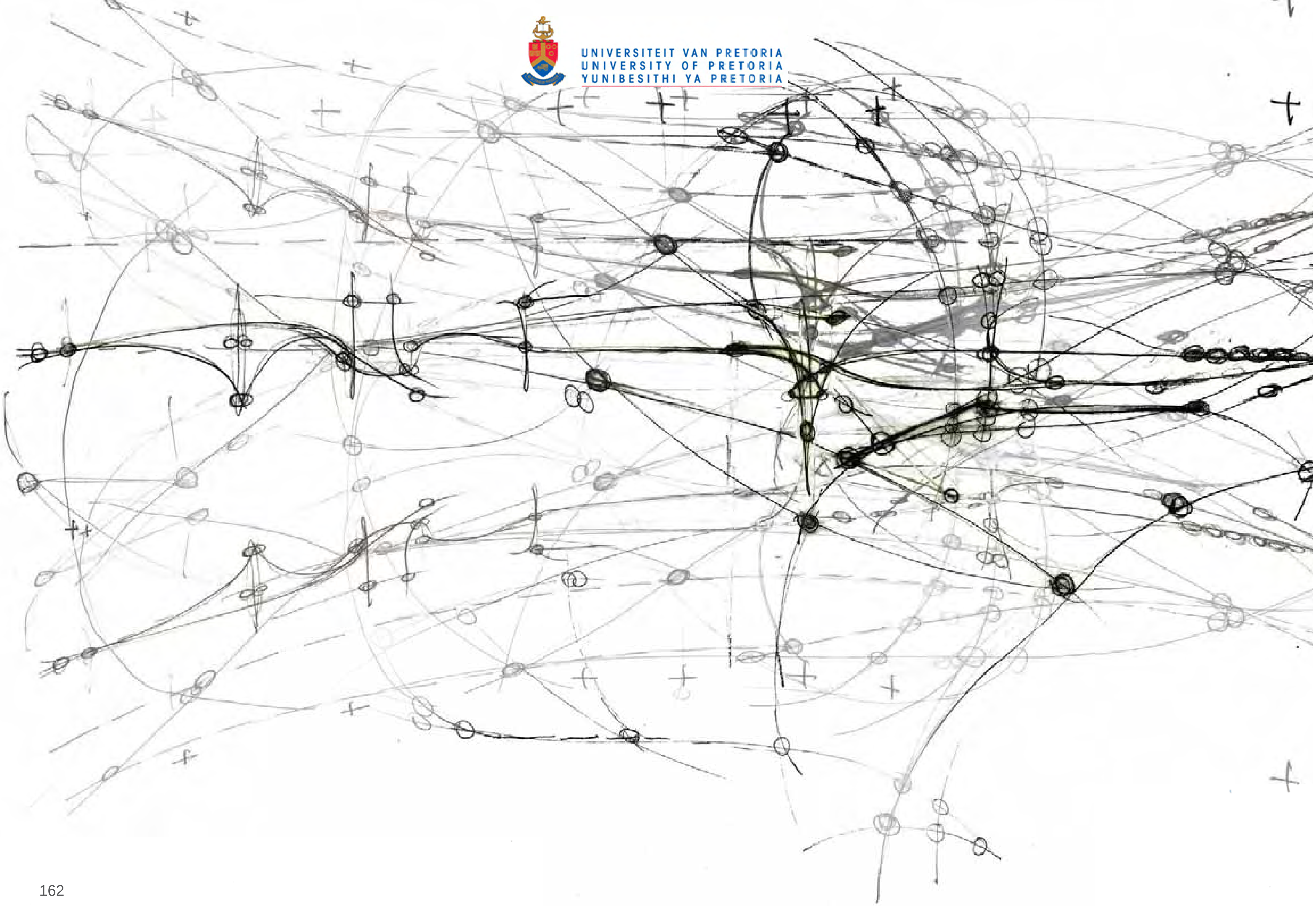
Figure 174 (right): Introducing new ideas - exhibition night 25th November 2010 [author, 2010].
Explaining to visitors the innovation potential in new materials and programs for 21st century architecture.

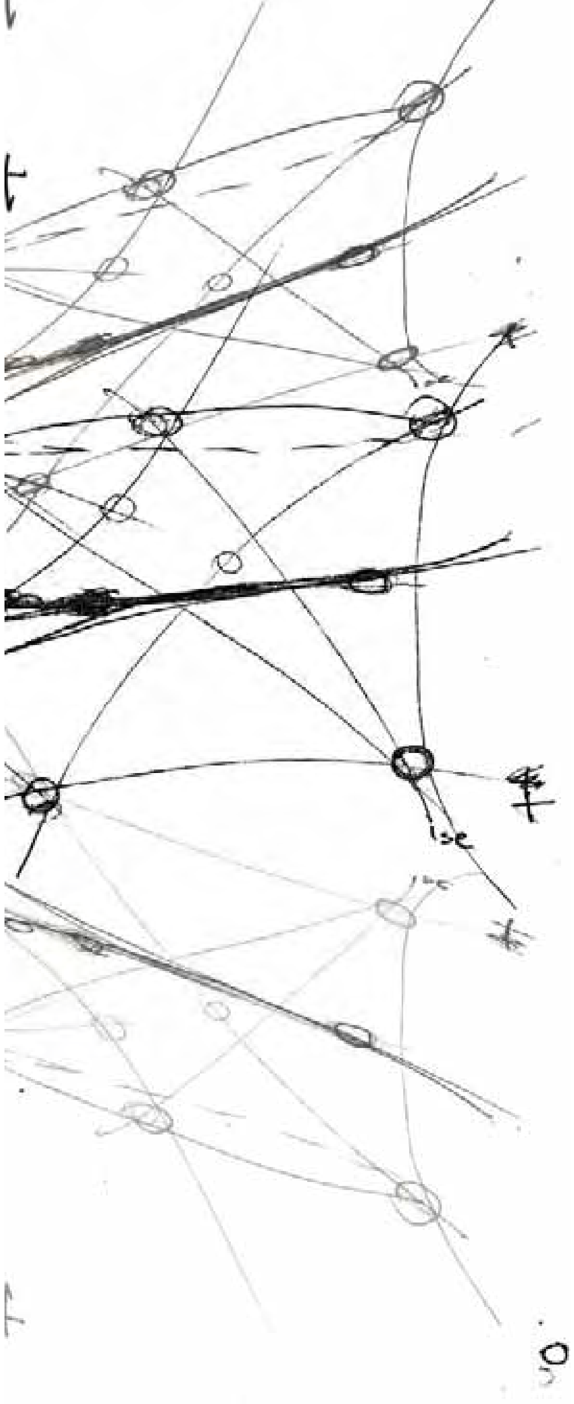
Figure 175 (below left) and 176 (below right): Collection of photographs of the group model - exhibition night, 25th November 2010 [author, 2010].
The photographs show the development potential of the site and the place of the hydroponic factory in the larger scheme. The hydroponic factory is a conceptual and literal acknowledgment of the legacy of the site, and now advocates the evolution of the 21st century building and urban environment by taking progressive steps towards the future. The industrial heritage of the site is now its productive future. The exhibition night drew attention to the new role of architecture in productive urban environments and new, resource-efficient building technologies. There was a great public interest in the concept and execution of vertical agriculture and bamboo technology for South Africa.

Figure 177 (opposite left), 178 (opposite right): Interest in Pretoria West [author, 2010]. A new public interest was created in the redevelopment of the Old Pretoria West Power Station and an awareness was created for the value of industrial heritage and industrial sites.

Figure 179 (opposite, middle), 180 (opposite right): Hydroponic food factory in context [author, 2010].







reflection

This thesis is an architectural response to the research topic and investigation and should be read as such. The calculations and estimates should be considered as a base and platform for development of the total project in all its various specialists fields. The resulting building of the research presented in this document is a conceptual model for vertical agriculture on the Old Pretoria West Power Station, Pretoria, South Africa. The project provides insight into the viability, probability and possibility of the concept of vertical agriculture - giving realistic direction for not only the global 21st century urban development, building typologies or programs, but more importantly, the project gives realistic direction in the application of future-orientated concepts and technologies in a local context for South Africa. The total project is ready for further research, exploration and resolution.

Let us learn not only from what we know already, but from what have yet to discover.

Figure 181 (opposite): Creating our future - looking towards a new legacy [author, 2010].

appendix

hydroponic crops

Abbreviated list
[Cox, 2010]

Berries
abbreviated list

Blueberry, hydrotaste.com
Cranberry, Lynette Morgan & suntec.co.nz
Raspberry, www.reeis.usda.gov
Strawberry, sunsetproduce.com

Bush Vegetables
abbreviated list

Tomato, eurofresh.com, villagefarms.com, sunsetproduce.com
(all varieties: beefsteak, campari, plum, cherry, globe, et cetera.)
Green Bean, hydrotaste.com

Grains

Barley, valcent.net
Corn, hydrotaste.com
Wheat, NASA
Rice, Pasona O2, Tokyo [underground production]

Herbs & Spices
abbreviated list

Banana Pepper, hydrotaste.com
Bay Leaves, freshzest.com
Chile Peppers, hydrotaste.com
Chives, freshzest.com
Cinnamon Basil, cahabaclub.com
Coriander, freshzest.com
Dill, Richard Stoner & grow-anywhere.com
French Tarragon, freshzest.com
Green Basil, freshzest.com
Lemon Basil, cahabaclub.com
Marjoram, freshzest.com
Mint, freshzest.com
Opal Basil, cahabaclub.com
Parsley, Big Red Strawberry Farm, Malaysia
Thai Basil, freshzest.com
Yellow Pea Shoots, cahabaclub.com

Leafy Greens
abbreviated list

Asparagus, asmith.id.au/index.html
Butterhead Lettuce, hydroserre.com/default.php
Broccoli, Richard Stoner & grow-anywhere.com
Brussels Sprout, hydrotaste.com
Cauliflower, hydrotaste.com
Celery, Richard Stoner & grow-anywhere.com, aeroponic
Charita Lettuce, valcent.net
Chinese Cabbage, Cornell University CEA,
Estelle Lettuce, valcent.net
Garlic Chives, Blue Harbor Plantation, Honduras
Green Coral Lettuce, Big Red Strawberry Farm, Malaysia
Peas, cahabaclub.com
Romaine Lettuce, Big Red Strawberry Farm, Malaysia
Spinach, Cornell University CEA
Swiss Chard, cahabaclub.com

Legumes

Peanuts, Lynette Morgan & Lynette Morgan & suntec.co.nz
Pistachios, Dr. Hillel Soffer @ UC Davis

Melons

Cantaloupe, nysunworks.org
Muskamelon, Taiwan Agricultural Research Center
Watermelon, Almeria, Spain

Root Vegetables

Beet, Richard Stoner & grow-anywhere.com
Belgian Endive, greenhousegrown.com
Carrot, Richard Stoner & grow-anywhere.com
Onions, Richard Stoner & grow-anywhere.com
Potato, hydrotaste.com
Radish, cahabaclub.com
Sweet Potato, NNT Urban Development, Japan

Shrubs & Trees
abbreviated list

Avocado, Lynette Morgan & suntec.co.nz
Banana, hydrotaste.com
Guava, Lynette Morgan & suntec.co.nz
Lemon, Disney's EPCOT
Lime, Lynette Morgan & suntec.co.nz
Nectarine, Lynette Morgan & suntec.o.nz
Peach, hydrotaste.com
Pepino Fruit, hydrotaste.com
Pineapple, Disney's EPCOT

Specialty Crops

Coffee, Lynette Morgan & suntec.co.nz
Grapes, Lynette Morgan & suntec.co.nz
Luffa Sponge, hydrotaste.com
Olives, Lynette Morgan & suntec.co.nz
Sunflower, hydrotaste.com
Tobacco, University of Kentucky
Wheat Grass, Richard Stoner & grow-anywhere.com

Vine Vegetables

Cucumber, University of Arizona CEA, hydroponic
Eggplant, greenhousegrown.com,
Okra, U. of Florida Institute of Food and Agricultural Sciences
Squash, hydrotaste.com
Sweet Bell Pepper, sunsetproduce.com
Zucchini, hydrotaste.com
Pineapple, Disney's EPCOT

It is also possible to grow cultivars of flowers, seeds and many other varieties of non-edible crop such as bamboo etc.

Business

Retail Value / Kg

	Crop type	Pick and Pay	Woolworths	Checkers	Spar	Fruit and Veg	Fresh Fruit Market	Plant Land	Average
1	**Compost**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	20.00	R 20.00
2	**Mushrooms**	R 51.96	R 80.00	R 55.96	R 50.00	R 50.00	R 51.09		R 51.80
3	**Hydroponics (Tomato Prices)**	R 20.00	R 20.00	R 20.00	R 20.00	R 20.00	R 22.88		R 20.58

Farmers Prices

		Farmers Prices (25% Retail Value)	Price Per Ha	tons per year	Annual Estimated Commercial Value
1	**Compost**	R 4.50	n.a	1 914.53	**R 8 615 390.52**
2	**Mushrooms**	R 12.95	n.a	3 130.40	**R 40 539 971.29**
3	**Hydroponics (Tomato Prices)**	R 5.14	n.a	2 080.00	**R 10 699 549.67**

Commercial Target			
	Tons per year		
Hydroponic Target	2 000.00		
Mushrooms	3 130.40		
Hydroponic Production	2 080.00		
Total	2 080.00		
Target Reached	**YES**	Grosse Annual Income	**R 59 854 911.48**
Less: Operating Income (12.5%)			R 7 481 863.94
Less: Labour	Mushrooms	R 505 700.00	
	Hydroponic	R 440 700.00	R 440 700.00
Upkeep		R 550 000.00	R 550 000.00
		Nett Annual Income	**R 51 382 347.55**
Esitmated Final Building Cost			**R 221 860 464.20**
Return on Investment (First Year)			**23.16%**

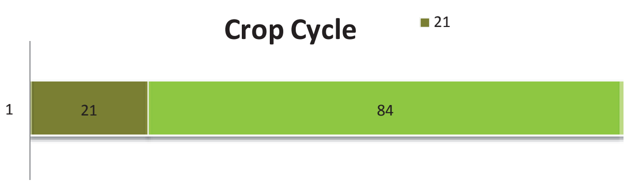
Figure 182: Preliminary profits and building cost estimates [author, 2010].

The estimated production capabilities and current prices for these crops are estimated to determine if there is any actual economic value in the project. The building costs were estimated as if the design is on a high end of the scale of commercial construction because of the various unknown factors of the inherent systems and components of hydroponic farming and bamboo construction. This estimate is also for a current scenario (the year 2010) and the return on investment and profit margins, but these do not include any escalations for the 15 year window before the building is finally completed. The aim is merely to determine the possibility of the project to be a real business opportunity. The final figures will have to be determined by a specialist and some variation is expected.

Phases		Days	notes
A	Production of substrate (compost)	14	away from public (odours)
B	Peak Heating or Pasteurisation (compost)	7	
C	Spawning Process	10	
D	Growing Process	21	first flush: 21 days thereafter 7 day
E	Packing Process	na	
F	Store/Refrigerate (max)	7	

Processes

non harvest days per year per crop	50
annual non-harvest factor	14%
Crop Cycle (days)	84
Harvest Cycle (days)	7
Harvests per crop	6
crops per year	3
Rooms Required per year for daily harvests	5
Compost Required Every (X) Weeks	12
Loss Factor for non-harvest period	14%
(21 days growing per crop until first flush)	
Yield kg/day/m² from crop land	3
Worker can harvest kg / day	16
Yield per week per m² (kg/m² per 7 working days)	112.00



Minimum Spacial Requirements

Requirements

Composting and Pasturising Areas

Compost Provided every 21 days	tons	*l (mm)*	*area (m²)*	*volume (m³)*	notes
Required depth of compost		150.00			
Total Compost Required per Growing Room (crop area per growing room)			400.00	10.00	1m³ organic waste : 0.58 m³ compost material
total tons required per growing room ((@475 kg compost / organic matter = m³)	5				20.00
Total Pasturising Area required for composting (0.475m³ = 1 ton compost)	**5.00**		**5.00**		

Spawning Areas

	units	mm	m²	m³	
Spawn required per growing room (crop area per growing room)			400.00		
Fully Grown Spawn Storage required per growing room (shelf spacing @300mm)			50.00		
% m² spawn area required per m² growing area	**12.5%**				
total crop area (shelves) provided	1 100.00		4 400.00		
total spawn room area (shelves) required	**137.50**		**550.00**		

Packing Areas

	kg	mm	m²	m³	
Harvest area per day	9 460.00		3 784.00		
Kg packed per day = Kg harvest per day	9 460.00				
Kg per worker packed per day (180kg/hour)	1 440.00				
Harvest area packed per day			360.00		
Paking Area Required (360m² harvest packed per day per worker)			**10.51**		

Refridgeration Areas

		mm	m²	m³	
Kg per worker packed per day (180kg/hour)	1 440				
punnets packed per day (250g per punnet)	2 880				
number of punnets to 1 kg	4	0.12	0.03	0.01	
Space Required per day (kg packed x punnet per kg)			7.68	20.74	(ceiling height 2.7m)
Max number of days to be stored	10				
Max refridgerated space required			**76.80**	**207.36**	(ceiling height 2.7m)

Figure 183: Mushroom occupation - part one [author, 2010].
The expected occupation schedule for the mushroom crop.

Occupation

SANS 0400 Classification	Area	Code	Name	Description	Occupation m²	Rooms	subtotal	m² no rooms x m² per room	Workers Required per room	subtotal	total	notes
D2	Composting	A	Prewetting area	Water tank: For keeping fresh water and soaking of straw.	60.00	1	60.00		2	2		
		A	Composting yard	Required for compost preparation	40.00	1	40.00	100.00	2	2	4	
	Pasturising	B	Boiler room	Required for pasteurization of compost.	14.00	1	14.00		1	1		
		B	Pasteurization tunnel	Required for pasteurization and conditioning of composting	5.00	1	5.00		1	1		
		B	Casing soil chamber	For pasteurization of casing soil.	9.00	1	9.00	28.00	1	1	3	
	Spawning	C	Boiling and Sterilzation	Washing, boiling and sterilization of grains are performed in this room. For this purpose, boiling cattle and autoclave is required.	16.00	1	16.00		1	1		
		C	Spawn Lab :Inoculation	laminar flow is placed which is used for inoculation of pure culture into bottles for preparation of master spawn and further multiplication of master spawn into commercial one	25.00	1	25.00		1	1		
		C	Spawn Lab: Incubation	After inoculation, master and commercial spawn are shifted to incubation room for growth and colonization of fungal mycelium. This room is fitted with air conditioner. Therefore, temperature of this room could be adjusted as per requirement of mushroom species.	25.00	1	25.00		1	1		
		C	Spawn storage	Fully colonized mushroom spawn is shifted to storage room where temperature is maintained to 40C.	50.00	1	50.00		1	1		
		C	Spawn lab.		20.00	1	20.00	136.00	1	1	5	80m² per worker x shelves x floors
	Growing	D	Growing room	For growing of Mushroom crops (yield determined by this area)	80.00	4	320.00	1 280.00	1	4	60	
	Packing	E	Packing room	For packing of mushrooms	10.00	1	10.00		4	4		
		E	Packaging store room	Storage of packaging materials	6.00		0.00					
								10.00			4	
	Refridgerate / Store	F	Refridgerated room	Storing of final product: packed fresh mushrooms, 10 days max	76.80	1	76.80		0	0		
		F				1	0.00	76.80	0	0	0	
	Management	G	Office	Open plan management and marketing office; computer control room	15.00	1	15.00		3	3		
		G	Staff Ablutions and Lockers	Male, Female		1	0.00	15.00	2	2		
G1	General Amenities					1	0.00		0	0		
		G	Stores/tool room	To keep the hand tools and equipments required for mushroom farm.	9.00	1	9.00		0	0		
		G	General Stores		9.00	1	9.00		0	0		
		G	AC compressor room/generator	For keeping compressor, cooling tank, motor and electric panel, gen-set and diesel.	34.00				0	0	5	
											20.00	
							Total Factory Floor	1 645.80	Total Workforce		108.00	

Accommodation Schedule

Figure 184: Mushroom occupation - part two [author, 2010].
The expected occupation schedule for the mushroom crop.

Processes

	Phases	Days	notes
A	Compost Provision	21	
B	Growing Process	56	12 weeks per crop
C	Packing Process	1	
D	Store/Refrigerate (max)	na	

Maximums		Source
crops per year	3.60	Vertical Farm
harvest index	30%	
Crop Cycle (days)	56	
Harvest Cycle (days)	21	
hydroponic ton / hectare / year	750.00	Vertical Farm
Kg per m² per crop season	50.00	Vertical Farm, Morkel Combrink
Worker can harvest kg / week	3 360	
Workers required	11.90	
area picked per worker per week	168.00	
per day	33.60	
persons fed per year / ton	18.20	Vertical Farm
persons fed per year / hectare	13 650.00	
tons / month / hectare	62.50	
If I provide (X) per year	2 080.00	
I feed (X) people per year	37 856.00	
distance between plants (mm)	400.00	
space per plant (m²)	0.20	

Requirements

Minimum Spacial Requirements

							notes
Composting Provision							
Compost Provided Every 56 Days	**tons**	**units**	***d* (mm)**	***d* (m)**	***area* (m²)**	***volume* (m³)**	1m³ organic waste : 0.58 m³ compost material
Weekly biomass provided (Harvest Index)	74.29						
total compost matter provided per week						156.39	475 kg compost = org matter m³
1m³ organic waste : 0.58 m³ compost material	90.71			4.00	39.10	0.50	
Total compost provided 8 weeks	**90.71**			0.50	39.10	0.86	depth of 500mm
Growing Process							
Typical	**units**	***d* (mm)**	***b* (mm)**	***h* (mm)**	***area* (m²)**	***volume* (m³)**	I want to provide X tons a week
Ton per m²	0.05				1.00		
m² required per ton per week					800.00		40.00
harvest area (area required for ton required per week x 52 / crop cycle)					11 555.56		
							160.00
levels of building	7.00				1 650.79		**2 080.00**
number of crops	14.44						
number of summer crops	7.22						
Total Production area Hydroponic Building					**11 555.56**		
Packing Areas							
	tons	**units**	***d* (mm)**	***d* (m)**	***area* (m²)**	***volume* (m³)**	need to process X tons a week
pallet size	2.00			1.10	1.20	1.32	
stacked pallets required		20.00			24.00	26.40	40.00
number of 6m containers (approx 9 tons) per week		18.00					stacking space + 2m² workspace x nr of workers
Washing Process Automated							
Workers required (750kg per day)		54.00					
Total Packing Space					**108.00**		
Refridgeration / Store Areas							
			mm	**m**	**m²**	**m³**	
stacked pallets required		20.00			24.00		pallets stacked 3 high
Store room Areas Per Week (pallets per day)					**24.00**		

Figure 185: Tomato occupation - part one [author, 2010].
The expected occupation schedule for the hydroponic tomato crop.

Accommodation Schedule

Occupation

SANS 0400 Classification	Area	Code	Name	Description	m²	Number of Rooms	subtotals	m² no rooms x m² per room	Workers Required per room	subtotals	total
D2	Growing	D	Crop Area	Weekly m² harvested	800.00	1			na	12	
							11 555.56	11 555.56			12
	Packing	E	Packing room	For packing and washing of hydroponic crops	108.00	1	108.00		2	2	
		E						108.00			54
	Refridgerate / Store	F	Refridgerated room	Storing of final product	24.00	1	24.00		1	1	
		F				1	0.00	24.00	1	1	2
	Management	G	Office	Open plan management and marketing office; computer control room	12.00	1	12.00		3	3	
		G	Staff Ablutions and Lockers	Male, Female	0.00	2	0.00	12.00	1	2	
G1	General Amenities	G	Stores/tool room	To keep the hand tools and equipments required	9.00	1	9.00		0	0	
		G	General Stores		9.00	1	9.00		0	0	
		G	Public Sales Point		4.00	1	4.00	22.00	1	1	
		G	AC compressor room/generator room/Electric cabin.	For keeping compressor, cooling tank, motor and electric panel, gen-set and diesel.	34.00	1	34.00	34.00	0	0	
											6
									extra staff		20.00
						Total Floor Area		11 755.56	Total Workforce		93.90

Figure 186: Tomato occupation - part two[author, 2010].
The expected occupation schedule for the hydroponic tomato crop.

Consumption, Requirements and Potential

Water Energy

1 Food Factory — NBR Sanitary Requirements

	Population	Male WC	Male WHB	Male Urinals	Male Showers	Female WC	Female WHB	Female Showers	notes
Factory Workforce	300	WC	WHB	Urinals	Showers	WC	WHB	Showers	Building Classification : D 2 - Moderate Risk Industrial (SABS 0400-1990:34)
NBR Requirements		3	6	5	n.a	9	5	n.a	population 120+: +1 for every 50 people
Min Total Required		7	10	9	n.a	13	9	n.a	
	Population	WC	WHB	Urinals	Showers				
Required Total	300	20.00	19.00	9.00	0.00				
Provided Total		**30.00**	**30.00**	**0.00**	**0.00**				

1 Food Factory — Consumption

Non-Production Orientated Requirements	Purpose	No. of Fixtures	Litres Used per Fixture	Est. No. of Times Used Daily	Est. Total Daily (Litres)	Daily 1000 Litres	Monthly 1000 Litres
Cloakrooms	WC	30	7.00	5.00	1 050.00	1.05	31.50
	WHB	30	4.00	3.00	360.00	0.36	10.80
	Urinals	0	1.00	3.00	0.00	0.00	0.00
	Showers	0	100.00	2.00	0.00	0.00	0.00
Other (Kitchen, Laundry, Scullery)	Sink (Kitchen)	3	7.00	4.00	84.00	0.08	2.52
	Sink (Other)	10	7.00	4.00	280.00	0.28	8.40
	Dishwasher	2	20.00	5.00	200.00	0.20	6.00
				Subtotal	1 974.00	1.97	59.22
Production Orientated Requirements							
Food Factory	Mushrooms	n.a	n.a	n.a	56 000.00		
	Hydroponic Factory	n.a	n.a	n.a	145 600.00		
				Subtotal	201 600.00	201.60	6 048.00

Tank Sizes

Min Monthly Requirement (1000	Max Monthly Catchment (1000	Max Value (1000 Litres)	notes
59.22	346.80	**346.80**	Daily Requirements used to calculate tank sizes
Min Daily Requirement (1000	**Max Daily Requirement (1000**	**Max Value (1000 Litres)**	Use the Maximum value to determine minimum tank size (for Rainfall)
1.97	205.55	**205.55**	
Typical Tank Capacity	**number required**	**Diameter (mm)**	Tanks to be pumped full daily
Slimline (750 litre)	462.40	750.00	Slimline Stacked (two rows heigh)
5 500 Litre Tanks	63.10	1 800.00	
10 000 Litre Tanks	34.70	2 200.00	
15 000 Litre Tanks	23.20	2 600.00	
20 000 Litre Tanks	17.40	2 600.00	
50 000 Litre Tanks	10.00	custom	

Daily Requirements used to calculate tank sizes

Landscape irrigation to be determined by specialist

	Daily 1000 Litres	Monthly 1000 Litres	Yearly 1000 Litres
Total Consumption Requirements	**205.55**	6 166.44	73 997.28

Figure 187: Water energy - part one [author, 2010].
The expected water energy in consumption and storage facilitation.

Rainfall Chart

Pretoria	Annual Rainfall Statistics								Annual Rainfall Statistics				
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Ave Rainfall (mm)	136.00	75.00	82.00	51.00	13.00	7.00	3.00	6.00	22.00	71.00	98.00	110.00	56.17
Ave Rainfall (m)	0.14	0.08	0.08	0.05	0.01	0.007	0.003	0.01	0.02	0.07	0.10	0.11	0.06

	Monthly Catchment Potential								Monthly Catchment Potential				Annual Average
Roof Area Name	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres
Hydroponic Roof Area	346.80	191.25	209.10	130.05	33.15	17.85	7.65	15.30	56.10	181.05	249.90	280.50	143.23
Total Roof x Litres/month	**346.80**	**191.25**	**209.10**	**130.05**	**33.15**	**17.85**	**7.65**	**15.30**	**56.10**	**181.05**	**249.90**	**280.50**	**143.23**

Monthly Catchment Potential														Annual Average
		1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres	1000 Litres
Total building water requirements (Productive Processes and Non-Productive Processes)	Total Monthly Requirements of factory Met?	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Difference	-5 819.64	-5 975.19	-5 957.34	-6 036.39	-6 133.29	-6 148.59	-6 158.79	-6 151.14	-6 110.34	-5 985.39	-5 916.54	-5 885.94	-6 023.21
ONLY Non-Productive Processes (grey water)	Non-Productive Monthly Requirements of factory met?	59.22	59.22	59.22	59.22	59.22	59.22	59.22	59.22	59.22	59.22	59.22	59.22	
		YES	YES	YES	YES	NO	NO	NO	NO	NO	YES	YES	YES	
	Surplus Per month	287.58	132.03	149.88	70.83	-26.07	-41.37	-51.57	-43.92	-3.12	121.83	190.68	221.28	84.01
	Surplus Carried over to next month	287.58	360.39	451.05	462.66	403.44	344.22	243.63	184.41	125.19	187.80	319.26	481.32	74.36
	Can it sustain?	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	

Self-Sustaining Grey water Recycling System

				Gutter Size		Min Standard Size	Recommended	Down pipe Size		Recommended
				Max Area Served / Gutter	Gutter Size (140mm²/m²)	Pipe Size Ømm	Pipe Size Ømm	Area Served / Down pipe	Down pipe Size (100mm²/m²)	Ømm
How much can Rainwater Catchment meet the daily requirements of the non-productive processes of the building?	**YES**	**108%**	of monthly non-productive processes can be sustained by RAINWATER	54.54	87.38	round up value to meet nearest standard	100.00	64.80	80.50	100.00
Can Rainwater Catchment sufficiently sustain TOTAL grey water Requirements of the building?	**NO**		The total building cannot be fulfilled by rainwater catchment of							

Figure 188: Water energy - part two [author, 2010].
The expected water energy in consumption and storage facilitation.

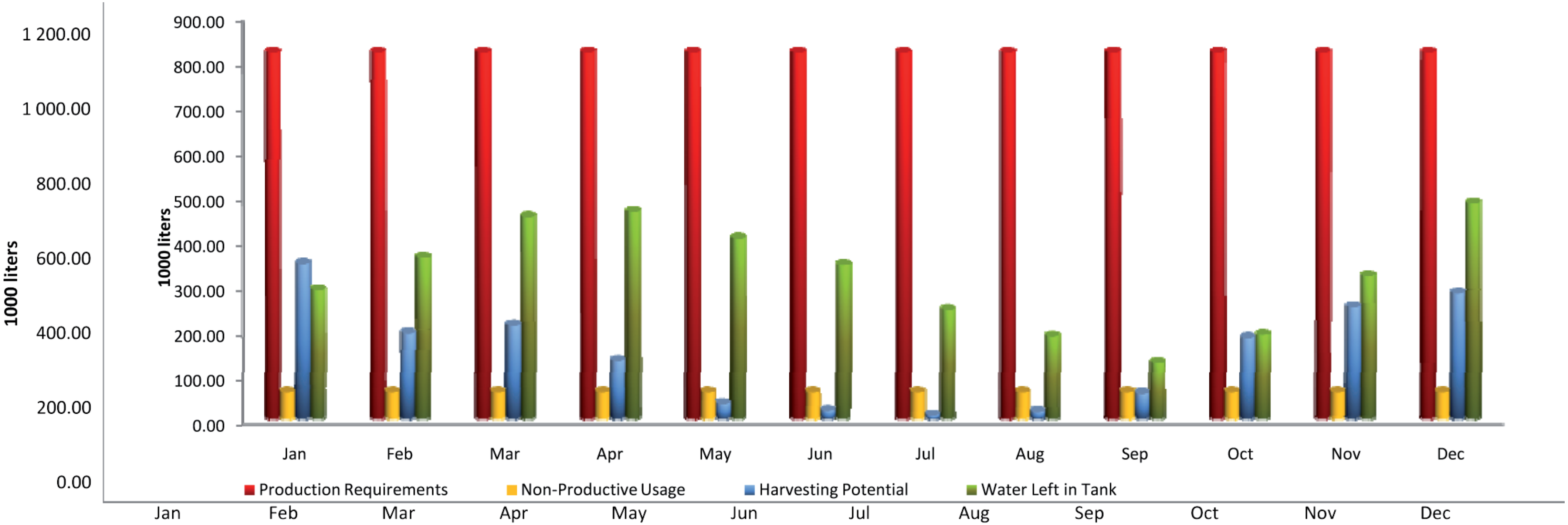


Figure 189: Figure illustrating water consumption pattern [author, 2010].
The expected water energy in consumption

Methane and Organic Storing Facilities, Composting

Biomass

Required by System	Crop	Cycle	tons per cycle	tons per week	Weekly	notes
Composte Required (Mushrooms)	Mushrooms	every 3 weeks	5	1.67	every week	The composting process takes 3 weeks, storage wil be calculated according to 3 week cycles
Compost Required (seedlings)	Seedlings	every week	6	6.00	every week	
Total Required		every 3 weeks	23.00	7.67	every week	475 kg organic matter = 1 m³ organic matter
Provided by System		**Cycle**	**tons per cycle**	**tons per week**	**Weekly**	
Organinc Waste Processed (every 3 weeks)		every 3 weeks	**396.71**	76.70	every week	
Compost Provided (every 3 weeks)		every 3 weeks	230.09	44.48	every week	1m³ organic waste : 0.58 m³ compost material
Surplus		every 3 weeks	207.09	**36.82**	every week	

Organic Waste Storage Space

every 3 weeks	*number of towers*	*h* (mm) per bin	*area* (m²) per bin	*volume required* (m³)	notes
Compost Towers	14.00	1.40	1.20	188.44	For every 1500 ton organic waste, 105 ton = methane gas (10%)
total area required @ height 1.2 m bins		volume per tower	157.03		
number of bins (bin @ 1.5m², / number of floors)		11.76	20.94	164.64	The composting process takes 3 weeks, storage wil be calculated according to 3 week cycles
Storage Space for surplus compost		3.00	**32.79**	98.37	Surplus compost can also be worked into the landscape park

Methane Gas Storage Space

Weekly	*liters*	*area* (m²)	*volume* (m³)	notes
Liters Consumption	14 362.80	7.18	14.36	1ton = 150m³ (65-75% methane) = 3.15 kWh per m³
Liters Provided	19 835.57	9.92	19.84	1000 liters per m³
Methane Storage Area Required		**9.92**		Gas Sent to Methane Reactor converted into Electricity (normal Diesel Generator can be transformed to process gas)
Methane Processing Area required		**9.92**		
Weekly	*liters*	*area* (m²)	*volume* (m³)	Gas either consumed on site, retailed or electricity replace into city grid
Daily Gas Use	2 051.83	1.03	2.05	
Daily Gas Consumption	2 833.65	1.42	2.83	

Sustainable Composting Conditions Met **YES**

Figure 190: Compost requirements [author, 2010].
The expected biomass energy and compost requirements.

Resource Schedule

Mushrooms

Energy Requirements

Electric Energy	Crop area	Lighting Hours	W / m^2 (1 W/f^2 = 25 W / m^2)	KWh (kWh/m^2/Hours)	Type of Light	notes	notes
m^2 energy needed	4 000.00		100 000.00	100.00	flourescent	Vertical Farm	Aerobic process, can be aided by sunlight or artificial means to reach 62ºC
lighting hours		8.00				crop area (m^2) x W per m^2 x number of ligthing hours	
Daily			800 000.00	800.00			Requires auger or similar machinesed turning device (every 2 days)
Weekly			5 600 000.00	5 600.00			
Montly			22 400 000.00	22 400.00			**Method 1**: 6 hours @ 62ºC, 7th hour cool down with 2ºC (day1), thereafter cooldown till 23ºC is reached by day 14
Annual			**268 800 000.00**	**268 800.00**			
Water	Crop area	Water (liters / m^2 / day)					
	4 000.00	2.00					**Method 2**: 50ºC for 5 days, thereafter cooldown till 23ºC is reached by day 14
Daily		56 000.00					
Montly		224 000.00					
Annual		2 688 000.00					
Waste	Tons	Harvest Index	Biomass Produced (tons)	Methane (m^3)	Potential (kWh)		
Weekly	8.60	0.35	15.97	10 780.71	2 997.04	1 m^3 methane gas = 0.278 kWh	
Montly	34.40		63.89	43 122.86	11 988.15		
Annual	412.80		766.63	517 474.29	143 857.85	kg per week *150 liters per kg (conservative)* 0.5	

Resource Schedule

Tomatoes

Energy Requirements

Electric Energy	Crop area	Lighting Hours	W / m^2 (1 W/f^2 = 25 W / m^2)	KWh (kWh/m^2/Hours)	Type of Light	notes
m^2 energy needed	11 555.56		124 511.11	124.51	LED	lighting hours per m^2
lighting hours		12.00				crop area (m^2) x W per m^2 x number of ligthing hours
Daily			1 494 133.33	1 494.13		
Weekly			10 458 933.33	10 458.93		
Montly			41 835 733.33	41 835.73		
Annual			**502 028 800.00**	**502 028.80**		
Water	Crop area	Water (liters / m^2 / day)				
	11 555.56	1.80				
Daily		145 600.00				
Montly		582 400.00				
Annual		6 988 800.00				
Waste	Tons	Harvest Index	Biomass Produced (tons)	Methane (m^3)	Potential (kWh)	
Weekly	40.00	0.35	74.29	50 142.86	13 939.71	1 m^3 methane gas = 0.278 kWh
Montly	160.00		297.14	200 571.43	55 758.86	kg per week x 150 liters per kg (conservative) x 0. effieciency (Vertical Farm)
Annual	2 080.00		3 862.86	2 607 428.57	724 865.14	

Figure 191: Resource schedule [author, 2010].
The expected resource consumptions.

Energy Potential

Electric Energy Required / Electric Energy Provided

1 Food Factory	Excess Biomass Produced (ton per week)	Weekly Operational Energy Required (kWh)	Montly Operational Energy Required (kWh)	Yearly Operational Energy Required (kWh)	Weekly Potential: Methane (m³)	Weekly Potential: Potential (kWh)	Monthly Potential (kWh)	Yearly Potential (kWh)	Weekly Remainder (kWh)	Montly Remainder (kWh)	Yearly Remainder (kWh)
Mushrooms	15.97	5 600.00	22 400.00	268 800.00	2 395.71	7 546.50	30 186.00	362 232.00	1 946.50	7 786.00	93 432.00
Hydroponic Factory (Tomato Calculations)	74.29	10 458.93	41 835.73	502 028.80	11 142.86	35 100.00	140 400.00	1 684 800.00	24 641.07	98 564.27	1 182 771.20
Offices and Laboratories	3.00	4 183.90	16 735.60	200 827.20	450.00	1 417.50	5 670.00	68 040.00	-2 766.40	-11 065.60	-132 787.20
Est. HVAC Requirements	0.00	20 000.00	80 000.00	960 000.00	0.00	0.00	0.00	0.00	-20 000.00	-80 000.00	-960 000.00
subtotal	**93.26**	**40 242.83**	**160 971.33**	**1 931 656.00**	**13 988.57**	**44 064.00**	**176 256.00**	**2 115 072.00**	**3 821.17**	**15 284.67**	**183 416.00**

2 On-site organic resources	Excess Biomass Produced (ton per week)	Weekly Operational Energy Required (kWh)	Montly Operational Energy Required (kWh)	Yearly Operational Energy Required (kWh)	Weekly Potential: Methane (m³)	Weekly Potential: Potential (kWh)	Weekly Remainder (kWh)	Montly Remainder (kWh)	Yearly Remainder (kWh)
Landscape Maintanance	1.00	2 500.00	10 000.00	120 000.00	150.00	472.50	-2 027.50	-8 110.00	-97 320.00
Human Organic Waste (Factory Employees)	31.50	2 500.00	10 000.00	120 000.00	4 725.00	14 883.75	12 383.75	49 535.00	594 420.00
Animal Manure (Horses)	6.48	0.00	0.00	0.00	972.00	3 061.80	3 061.80	12 247.20	146 966.40
subtotal	39	5 000	20 000	240 000	5 847	18 418	13 418	53 672	644 066

	Excess Biomass Produced (ton per week)	Weekly Operational Energy Required (kWh)	Montly Operational Energy Required (kWh)	Yearly Operational Energy Required (kWh)	Methane (m³)	Potential (kWh)	Weekly	Montly	Yearly
subtotal	**132.24**	**45 242.83**	**180 971.33**	**2 171 656.00**	**19 835.57**	**62 482.05**	**17 239.22**	**68 956.87**	**827 482.40**

Total

	Remainder	Remainder	Remainder (MWh)
MWh Required	45	181	2 172
MWh Potential	62	250	2 999
Methane Required	14 363	57 451	689 415
Methane Provided	19 836	79 342	952 107
MWh Surplus	**17**	**69**	**827**
Methane (m³)	5 473	21 891	262 693
Liters	5 473	21 891	262 693

Potential Electrical Conditions Met **YES**

% Potential Electrical **138.10%**

Figure 192: Latent energy potential [author, 2010].
The expected energy potential from bio-gas production.

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