06_
TECHNOLOGY

"Build, Don't Talk."
Ludwig Mies van der Rohe

06_1 Background

The project considers the synthesis of form, function and technology to create architecture (fig 164) and in doing so addresses the challenges of significance conservation presented at the WNR. To create this architecture, form, function and technology needed to be investigated. In chapter 2 the functional and formal considerations as derived from theoretical backgrounds were identified and utilized to create the architecture. In this chapter, technology is added to the design and the complete architecture (form, function and technology) is showcased.

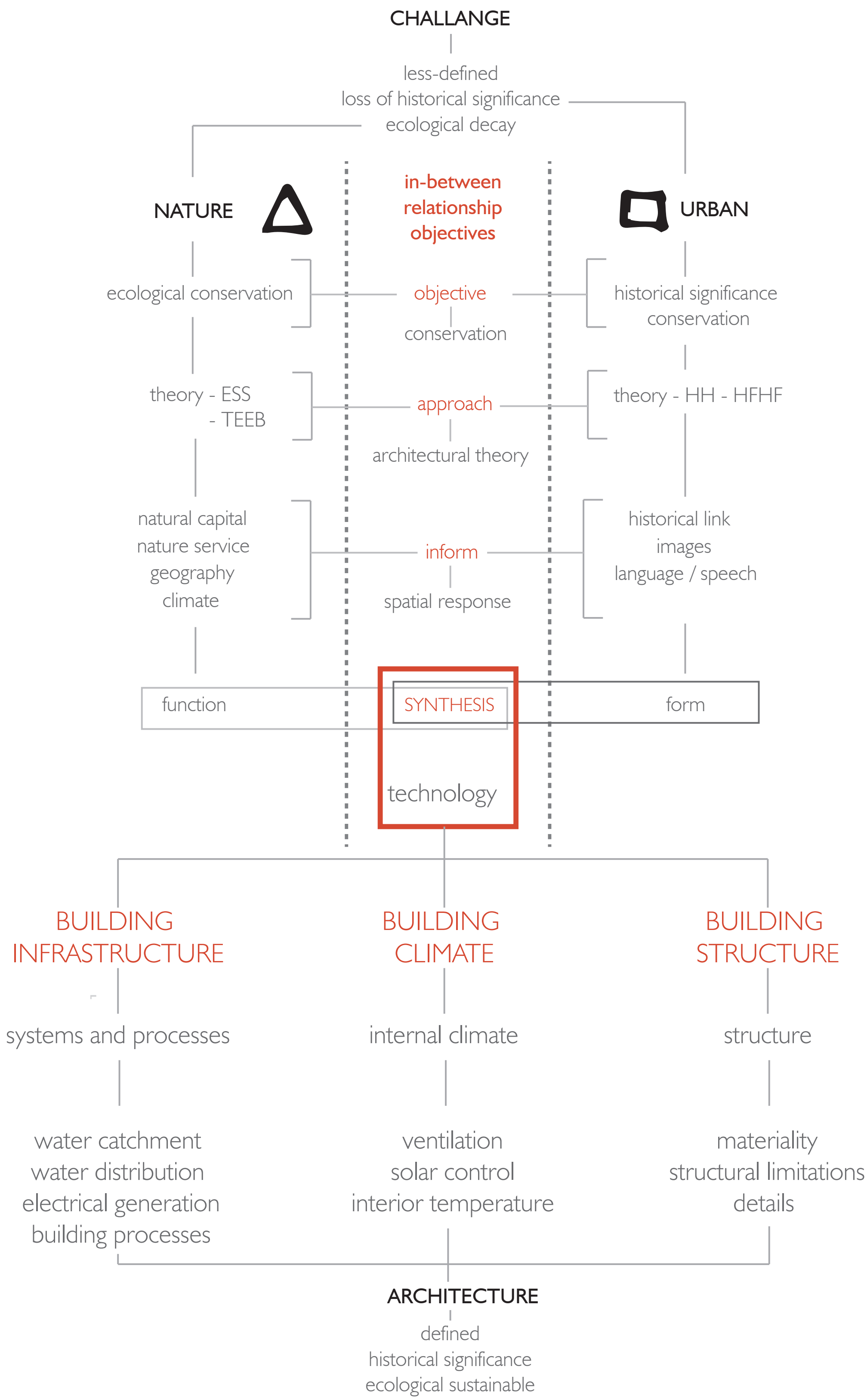
06_2 Technology Approach

The technological approach and conception can be seen as a derivative from the functional and formal informants as stated in previous chapters. The architectures technological aspects is approached in terms of a three part sub-categorical investigation to understand the building in the systems, climate and structure. These investigations are concluded into alterations of the design to enhance the systematic, comfortability and structure of the architecture. The three sub-categories are as follows; building infrastucture, building climate and building structure.

Under the sub-category of building infrastructure , the systems and process of the conservation facility are investigated. Calculations on the use and distribution of water and electricity are made and the design is altered to cater for these needs. The working of the internal flows is also investigated and revisions on the design to ease processes are applied. The next sub-category, building climate considers the internal climate and user comfort of the conservation facility. Under this sub-category investigation into solar control, ventilation systems and building climatic modelling are undertaken and the design is altered to reflect these results. The final sub-category, building structure considers the structure of the conservation facility. Investigations into materials, structural grids and constructability are done.

Together, these three sub-categories form the technological approach. This approach is implemented by means of a technical conceptual consideration.

Fig _164 (Right): Conceptual framework diagram (Author 2017).


CHALLANGE
less-defined
loss of historical significance
ecological decay
NATURE
in-between
relationship
objectives
URBAN
ecological conservation
objective
conservation
historical significance
conservation
theory - ESS
- TEEB
approach
architectural theory
theory - HH - HFHF
natural capital
nature service
geography
climate
inform
spatial response
historical link
images
language / speech
function
SYNTHESIS
form
technology
BUILDING
INFRASTRUCTURE
BUILDING
CLIMATE
BUILDING
STRUCTURE
systems and processes
internal climate
structure
water catchment
water distribution
electrical generation
building processes
ventilation
solar control
interior temperature
materiality
structural limitations
details
ARCHITECTURE
defined
historical significance
ecological sustainable

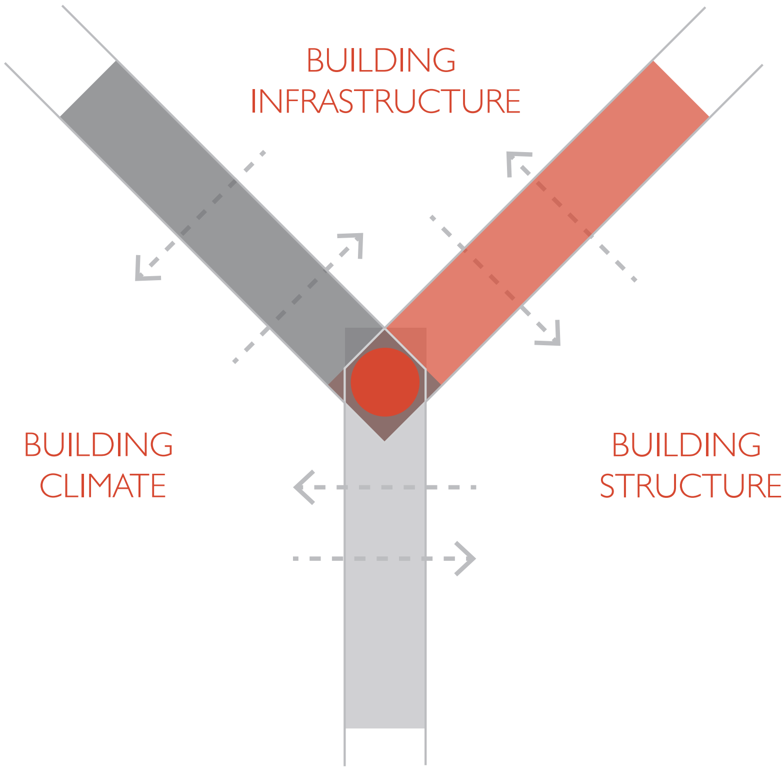
06_3 Technology Concept

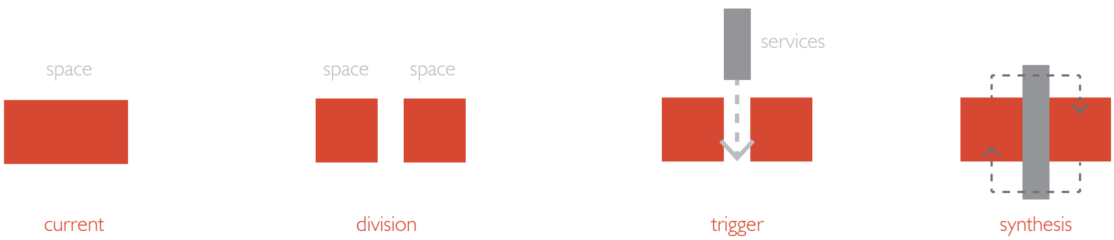
The conceptual consideration for the implementation of technology into the architecture is derived from the projects concept and builds on the same ideas. The prolific partition as explained in chapter 3 aims to intervene in the in-between and form a space that is productive in nature. The same consideration is implemented to form the concept for the implementation of technology where needed.

The three sub-categories as stated in the approach are the elements of technological consideration. Where they meet and share areas in-between programmed spaces presents the opportunity to situate these technologies thus making them function in the in-between . Considering this idea, the concept of intervention or placement of services in the facility is to, as far possible, be implemented in-between programmed spaces. This conceptual approach holds many advantages as no additional spaces need to be developed to house services. Where additional corridors are implemented, these areas will house multiple services for the surrounding and adjoining programmed spaces.

The technology concept is implemented in a similar manner as the projects design concept. The four-phased approached as explained in chapter 3 is altered to fit the requirements of the technology concept (fig 165). The first phase to implement the additions of services needed, is to determine the required services and the available spaces. The following phase identifies the possible in-between spaces

Fig _165 (Right): Conceptual framework diagram (Author 2017).


BUILDING
INFRASTRUCTURE
BUILDING
CLIMATE
BUILDING
STRUCTURE


space
space
space
services
current
division
trigger
synthesis

06_4 Building Infrastructure

The building infrastructure sub-category firstly focusses on the water usage and supply of the conservation facility. The objective of the water usage calculation is to determine if the facility will be able to be independent from municipal water supply for all its needs. The second part of the sub-category focusses on the electricity generation. It is proposed that the facility partially generates its own electricity by means of photo-voltaic panels but still stay connected to the municipal grid for possible emergency needs. The third segment of the building infrastructure sub-category focusses on the building processes and gives a visual interpretation of the working in terms of harvesting processes, the visitors' experience and office spaces.

Water Catchment - Yield

Water usage of the facility is deemed to be high due to its irrigation demand. Rain water harvesting was investigated to see if this can satisfy the water demand without resorting to the municipal water connection.

The first part of the investigation considered the rain water data from the Pretoria area as captured by Wonderboom Airport weather station, less than 2 km away from the site. With adequate yearly rainwater, the investigation identified areas of possible catchment and the annual yield of the facility could then be calculated.

Areas identified were the mountain run-off from south of the facility (fig 169 - area 1), the paved circulation surfaces (fig 170 - area 2) and the sheet metal roofs (fig 171- area 3). With the combined areas and the rainwater data, the annual yield was calculated at 9110m^3/yr. (see page 173)

Water - Demand

With the possible yield calculated, the investigation could then focus on the facility's water demand. The demand consideration was divided into two categories; irrigation demand and sanitary demand. The notion of dividing the two water demand calculations was to evaluate how much of a specific water quality will be needed and to structure the distribution areas accordingly.

The irrigation demand focused on all the grow beds, the test beds and the green roofs where the water that can be used may be of a lower quality. The sanitary demand included potable water and for this the water needed to be taken through a filtration process.

Considering the irrigation and sanitary water and the required filtration for different uses, a basic water distribution network was developed for the site. The water distribution network starts with the catchment pond for all rainwater harvested in the designated areas. The pond is used as a sediment filter. From the pond that is situated on the south-western corner of the facility, the water is directly used for irrigation purposes. The required water for sanitary purposes is pumped from the pond, through a three-part filtration system into a covered secondary water storage area. This storage tank is used to keep the filtered water clean and on demand for sanitary and potable uses. From the indoor storage tank, the water is pressurized and distributed to the areas for the different uses.

Water Budget

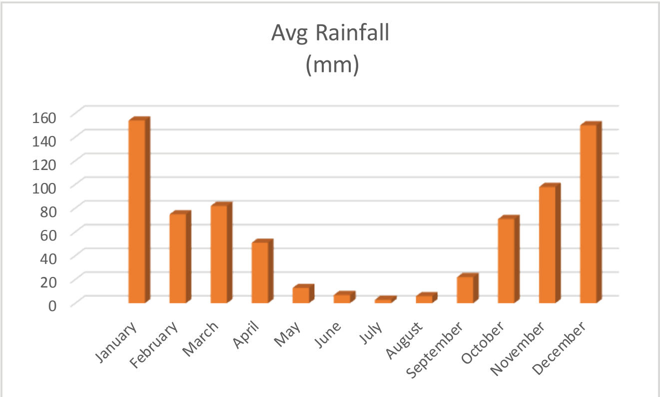
The water usage and distribution investigation concludes in the presentation of the water budget. The water budget (fig 178 - 179) showcases the yield and demand in comparison and results in the amount needed per month to keep the facility water self-sufficient. From the water budget the sizes of the catchment pond and the potable water storage network were developed to ensure that enough water was present at any needed time within the conservation facility.

Fig _167 (Right Top): Pretoria Avg Rainwater Yield Graph (Author 2017).
Fig _168 (Right Bottom): Areas considered for water chachment (Author 2017).

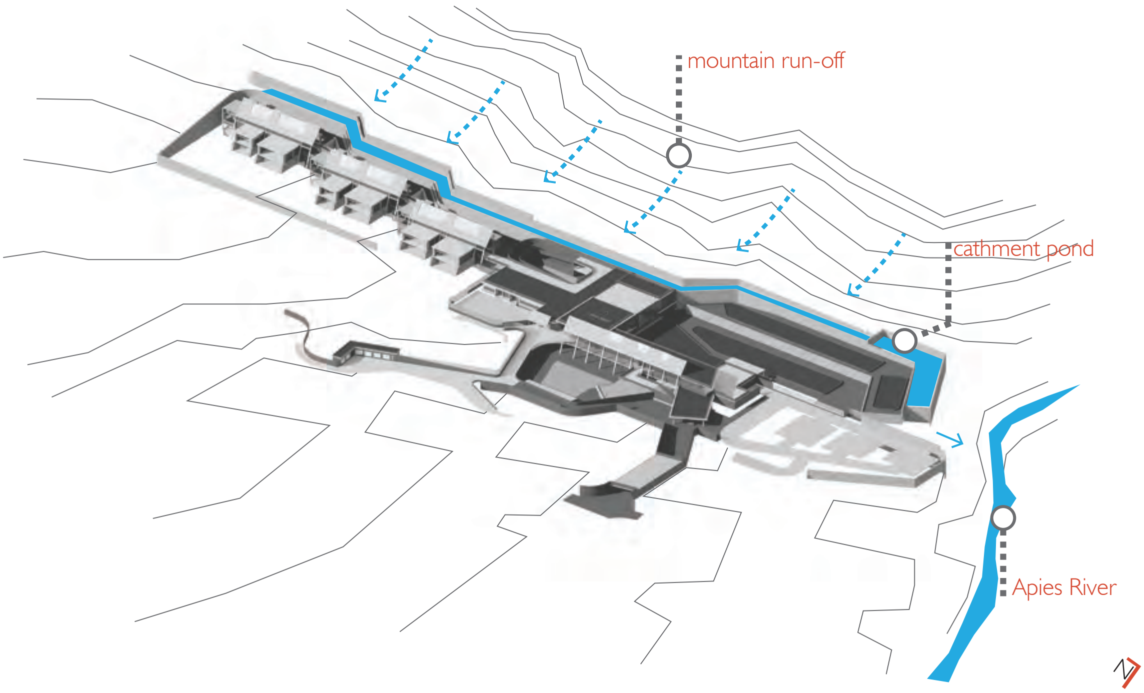
Water Catchment - Yield

Rainfall Data - Pretoria

January	154mm
February	75mm
March	82mm
April	51mm
May	13mm
June	7mm
July	3mm
August	6mm
September	22mm
October	71mm
Novemeber	98mm
December	150mm



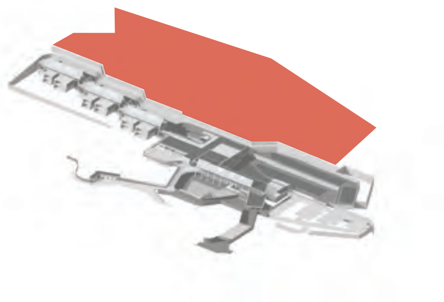
Water catchment consideration



Area of catchment

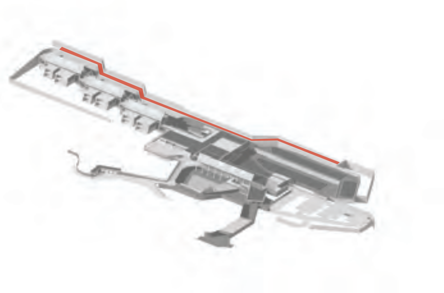
Area 1: Mountain

Total Area of cathment:	24300
Avg Runoff coeficient:	0.35



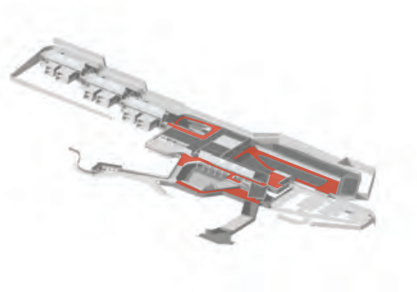
Area 2: Paths

Total Area of cathment:	926
Avg Runoff coeficient:	0.8



Area 3: Other

Total Area of cathment:	4000
Avg Runoff coeficient:	0.8



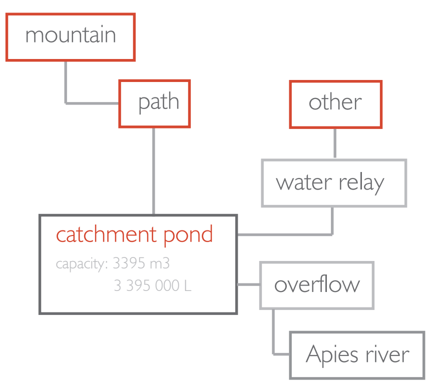
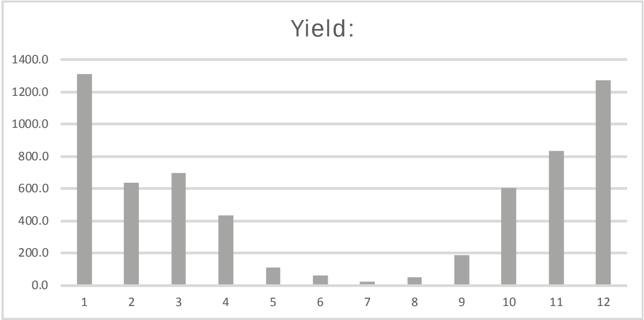
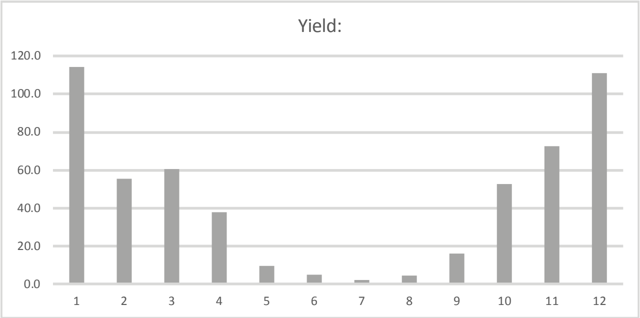


Fig _169 (Top Strip): Area 1 - Location and Yield of mountain run-off area. (Author 2017).
Fig _170 (Middle Strip): Area 2 - Location and Yield of paths (Author 2017).
Fig _171 (Bottom Strip): Area 3 - Location and Yield of other areas (Author 2017).
Fig _172 (Right): Diagram of water catchment and total yield. (Author 2017).

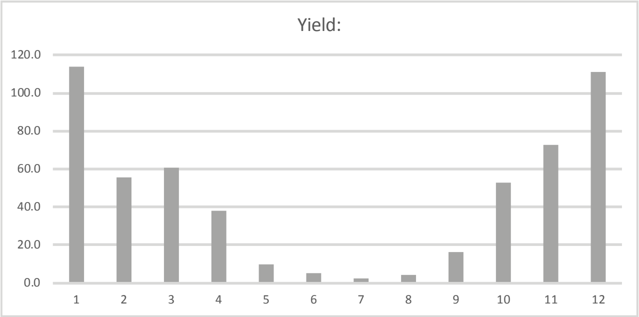
Yield Mountain			
Month	Avg Rainfall (mm)	Conversion:	Yield:
January	154	0.154	1309.8
February	75	0.075	637.9
March	82	0.082	697.4
April	51	0.051	433.8
May	13	0.013	110.6
June	7	0.007	59.5
July	3	0.003	25.5
August	6	0.006	51.0
September	22	0.022	187.1
October	71	0.071	603.9
November	98	0.098	833.5
December	150	0.15	1275.8
Avg Yearly	674		6225.7



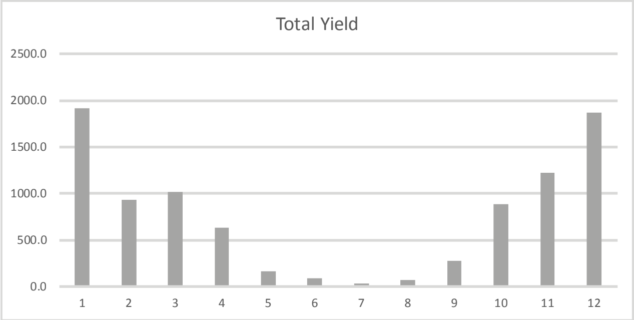
Yield Path			
Month	Avg Rainfall (mm)	Conversion:	Yield:
January	154	0.154	114.1
February	75	0.075	55.6
March	82	0.082	60.7
April	51	0.051	37.8
May	13	0.013	9.6
June	7	0.007	5.2
July	3	0.003	2.2
August	6	0.006	4.4
September	22	0.022	16.3
October	71	0.071	52.6
November	98	0.098	72.6
December	150	0.15	111.1
Avg Yearly	674		542.3



Yield Other			
Month	Avg Rainfall (mm)	Conversion:	Yield:
January	154	0.154	492.8
February	75	0.075	240.0
March	82	0.082	262.4
April	51	0.051	163.2
May	13	0.013	41.6
June	7	0.007	22.4
July	3	0.003	9.6
August	6	0.006	19.2
September	22	0.022	70.4
October	71	0.071	227.2
November	98	0.098	313.6
December	150	0.15	480.0
Avg Yearly	674		2342.4



Yield Total				
Month	Yield Mountain:	Yield Path:	Yield Other:	Total Yield
January	1309.8	114.1	492.8	1916.7
February	637.9	55.6	240.0	933.4
March	697.4	60.7	262.4	1020.6
April	433.8	37.8	163.2	634.7
May	110.6	9.6	41.6	161.8
June	59.5	5.2	22.4	87.1
July	25.5	2.2	9.6	37.3
August	51.0	4.4	19.2	74.7
September	187.1	16.3	70.4	273.8
October	603.9	52.6	227.2	883.7
November	833.5	72.6	313.6	1219.7
December	1275.8	111.1	480.0	1866.9
Total Yield	6225.7	542.3	2342.4	**9110.3**
Avg Yearly	518.8	45.2	195.2	



Water Distribution - Demand

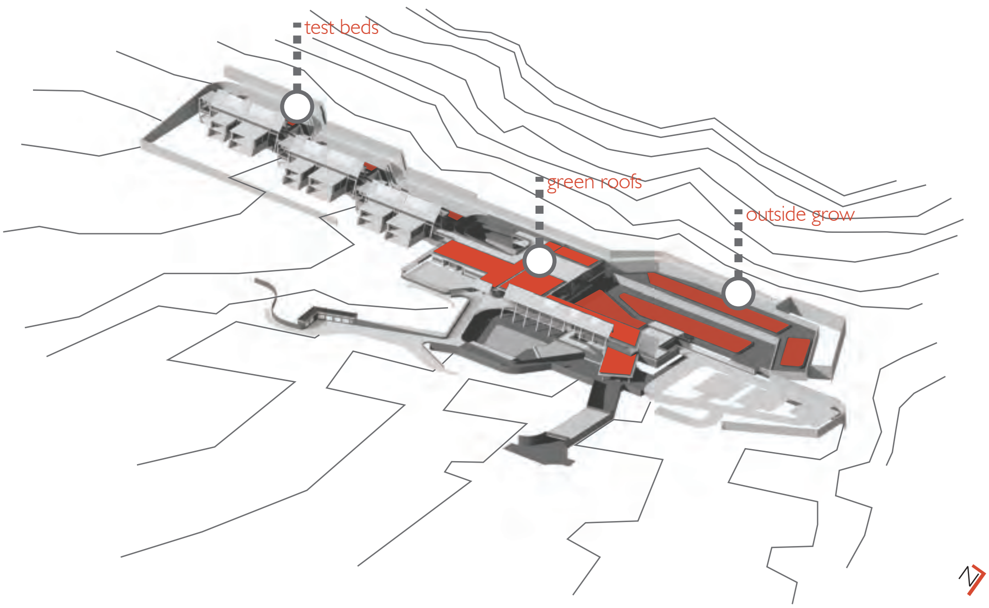


Fig _173 (Top): Irragation demand areas (Author 2017).

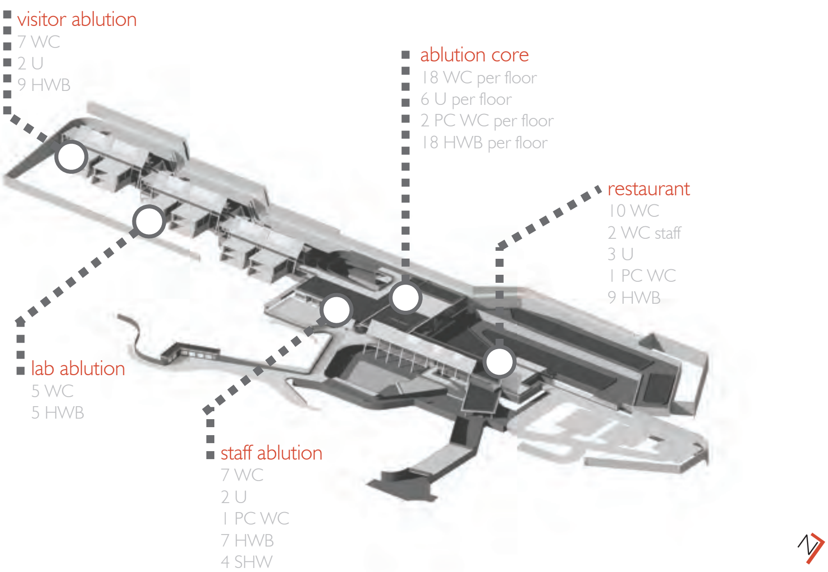


Fig _174 (Top): Sanitary demand (Author 2017).

Total Irrigation Demand				
Month	Irrigation Green Roof	Irrigation Test Beds	Irrigation Outside Grow Area	Total Irrigation Demand
January	289.728	102.08	358.288	750.096
February	289.728	102.08	358.288	750.096
March	289.728	102.08	358.288	750.096
April	217.296	76.56	268.716	562.572
May	144.864	51.04	179.144	375.048
June	144.864	51.04	179.144	375.048
July	144.864	51.04	179.144	375.048
August	144.864	51.04	179.144	375.048
September	217.296	76.56	268.716	562.572
October	217.296	76.56	268.716	562.572
November	289.728	102.08	358.288	750.096
December	289.728	358.288	358.288	1006.304
Total Yearly	2679.984	1200.448	3314.164	7194.596

Fig _175 (Top): Total irragation demand calculations (Author 2017).

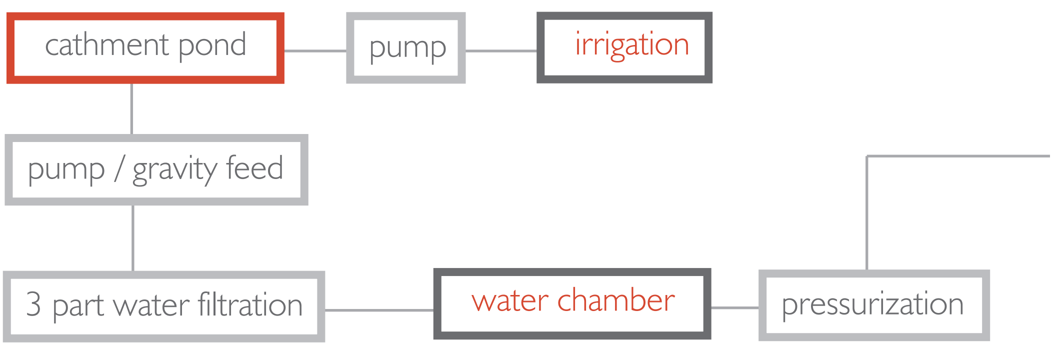
Sanitary Demand					
Month	Person	Amount use (L)	Water / capita / day (L)	Water / capita / month (L)	Domestic Demand (m³/month)
January	500	10	5000	155000	155
February	500	10	5000	140000	140
March	500	10	5000	155000	155
April	500	10	5000	150000	150
May	500	10	5000	155000	155
June	500	10	5000	150000	150
July	500	10	5000	155000	155
August	500	10	5000	155000	155
September	500	10	5000	150000	150
October	500	10	5000	155000	155
November	500	10	5000	150000	150
December	500	10	5000	155000	155
Total				1825000	1825
					155
			Safty Factor		1.5
			Tank Size		2325

Fig _176 (Top): Total sanitary demand calculations (Author 2017).

Water Budget

Yield And Demand						
Month	Demand	Yield	Monthly Balance	Vol. water in tank (m^3)	Year 2	Year 3
January	905.096	1916.6532	1011.5572	2203.031	2448.76	2694.49
February	890.096	933.435	43.339	2246.37	2492.1	2737.83
March	905.096	1020.5556	115.4596	2361.8296	2607.56	2853.29
April	712.572	634.7358	-77.8362	2283.9934	2529.72	2775.45
May	530.048	161.7954	-368.2526	1915.7408	2161.47	2407.2
June	525.048	87.1206	-437.9274	1477.8134	1723.54	1969.27
July	375.048	37.3374	-337.7106	1140.1028	1385.83	1631.56
August	530.048	74.6748	-455.3732	439	684.73	930.459
September	712.572	273.8076	-438.7644	0.2356	245.965	491.695
October	717.572	883.6518	166.0798	166.3154	412.045	657.775
November	900.096	1219.6884	319.5924	485.9078	731.637	977.367
December	1161.304	1866.87	705.566	1191.4738	1437.2	1682.93
Total	8865	9110	246	2361.8296	2607.56	2853.29
			Safty Factor	1.5		
			Needed	3542.7444		
			Tank Size	3543	3543	3543
					935	689

Fig _178 (Top): Water budget calculations (Author 2017).



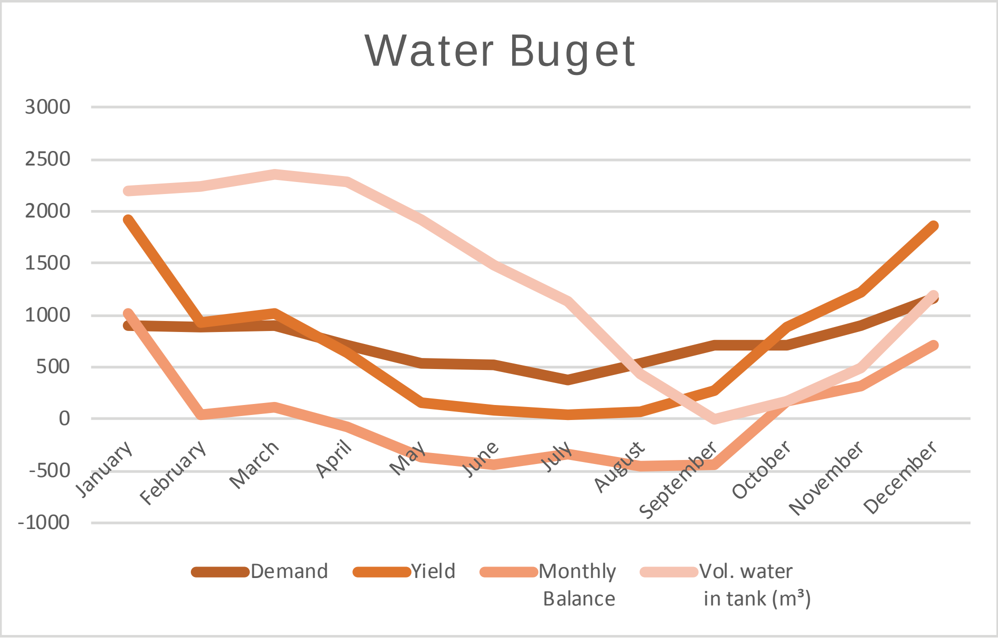


Fig _179 (Top): Water budget graph (Author 2017).

Fig _180 (Top Strip): Water distribution diagram (Author 2017).

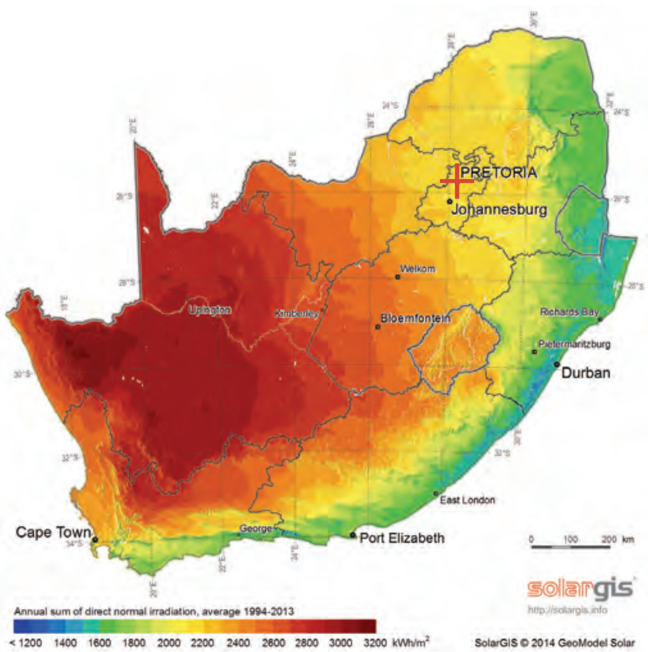
Electricity

The second investigation of building infrastructure focusses on electricity generation. This aspect is approached by means of a grid-tied electricity generation system that incorporates photovoltaic (PV) panels with the electricity grid of the City of Tshwane.

The consideration of a grid tied system is based on several aspects. Firstly, in the event of a fault in power generation from the PV-panels, the facility will still be able to run without any loss of power. The second argument for the grid tied system is to keep the governmental infrastructure economy on electrical generation operational. It is argued that if all building infrastructure is completely removed from municipal grids, the economy of these networks and the funds invested in them will completely be dismantled. The facilities electricity generation network was developed to keep the need for a municipal generation element present. When the municipality does dismantle the electricity infrastructure, the facility will be able to install additional panels to compensate for the loss in power.

Solar Investigation

The investigation into the electricity PV-panel systems started off by considering the solar generated electricity capacity of South Africa, and especially that of the City of Tshwane. The data were used to see if the adequate number of days and sunlight hours would suffice for the generation and installation of PV-panels. The investigation found that the Tshwane area has a solar capacity of 2200 kW/h/m^2 (Solar GIS 2017) based on annual averages from 1994 to 2013 and a daylight hour count on the shortest day (21 June) at a total of 8 hours. These statistics are deemed adequate for efficient solar generation (Solar365, 2017).



Pretoria:
Annual sum of direct normal radiation (avg1994-2013)

2200 kWh/m2

Hours of sunlight on the shortest day (June 21)

10 hours
2 hour SF

8 hours

Fig _181 (Above): South Africa solar data (Solar365, 2017).

Electrical Demand

The electricity demand was calculated by means of lights demand and plugs load demand. The lights demand was calculated on the bases of space use and the required lux levels of light for the space. The conservation facility was divided into five different spaces definitions by function and the needed lux, the amount of m^2 and watts needed was considered to calculate the demand. The total power for lights were calculated at 22.19 kWh/m^2/day.

The plug load demand was calculated on the same principles as the light demand but considered the w/m2 of the equipment needed by the function of the space. The plug loads were calculated at 7.5 kWh/m^2/day.

The total demand for the conservation facility was separated to calculate how much generation capacity was needed for each zone of the facility (fig 183). Using this method of distribution made it easier to calculate the number of PV-panels needed per zone to supply the needed electricity.

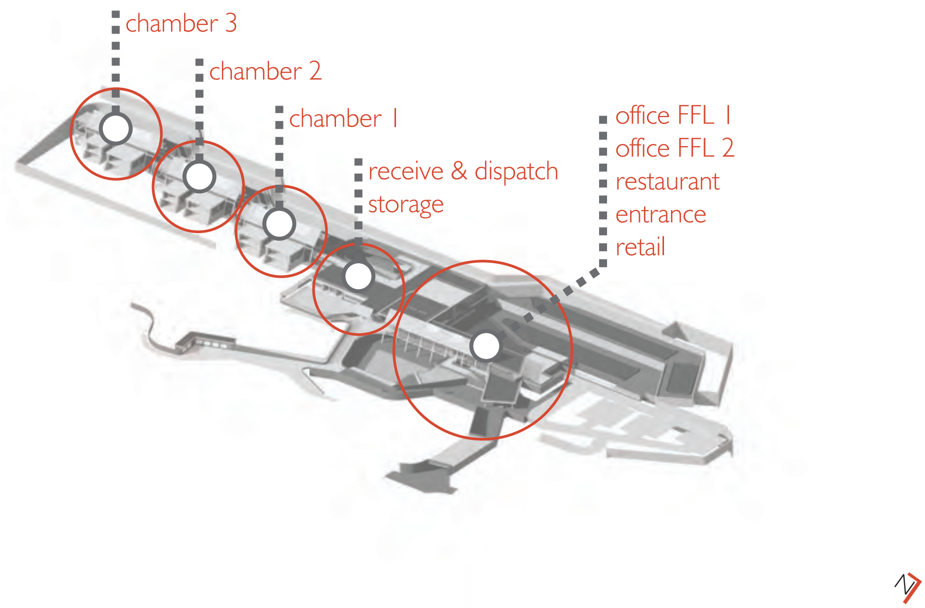


Fig _182 (Above): Zones for electrical demand calculations (Author 2017).

Lights data:

Space definition:	Lighting Lux Level	Lighting (W/m2)
Office	400	30
Restaurants	200	15
Industrial 1	500	20
Industrial 2	750	50
Laboratorium	800	40

Lights demand:

Demand - Lights					
Area Discription	Area (m2 of space)	Total Use (Watts.m2)	Hours used (hours of day)	Total Use per day (W.m2.day)	kWh/m2
1. Chamber 1	1072	53600	10	536000	5.36
2. Chamber 2	1072	21440	10	214400	2.14
3. Chamber 3	1072	42880	10	428800	4.29
4. R&D and Storage	604	12080	24	289920	0.50
5. Office FFL	1818	54540	8	436320	6.82
6. Office FFL	346	10380	8	83040	1.30
7. Restaurant	537	8055	15	120825	0.54
8. Retail	290	8700	15	130500	0.58
9. Entrance	330	9900	15	148500	0.66
	Total	**221575**		**2388305**	**22.19**

Plug load data:

Space definition:	Plug Loads (W/m2)
Office	10
Restaurants	4
Industrial 1	10
Industrial 2	20
Laboratorium	5

Plug load demand:

Demand - Plugs					
Area Discription	Area (m2)	Total Use (Watts)	Hours used (hours)	Total Use per day (W.m2.day)	kWh/m2
1. Chamber 1	1072	21440	10	214400	2.14
2. Chamber 2	1072	10720	10	107200	1.07
3. Chamber 3	1072	5360	10	53600	0.54
4. R&D and Storage	604	6040	24	144960	0.25
5. Office FFL	1818	18180	8	145440	2.27
6. Office FFL	346	3460	8	27680	0.43
7. Restaurant	537	5370	15	80550	0.36
8. Retail	290	2900	15	43500	0.19
9. Entrance	330	3300	15	49500	0.22
	Total	**76770**		**866830**	**7.5**

Demand per area

chamber 1	chamber 2	chamber 3	receive & dispatch storage	office FFL 1, office FFL 2, restaurant, entrance, retail
7.5 kWh	3.21 kWh	4.83 kWh	0.75 kWh	13 kWh

Fig _183 (Page): Electrical demand calculations (Author 2017).

Electrical Generation

To meet the electricity demand, a detailed calculation on the m^2 of roof space available for solar intervention had to be made. With this calculation, the optimal angle and how the panel will be fitted were taken into consideration. With the m^2 of roof space available an estimate on the generation capacity of these areas could be made to compare with the demand . A product specification of a PV-panel was taken to calculate the kilowatt hours available from the assigned areas.

The PV-panel diagram (fig 185) shows the number of panels dedicated to each assigned roof area (fig 184) and the amount of power that will be generated. The generation capacity is evaluated against the demand and where there is a shortfall the amount of power needed from the municipality is indicated. The additional panel option shown (fig 185 - bottom) is the additional panels needed to fill the gap per dedicated area.

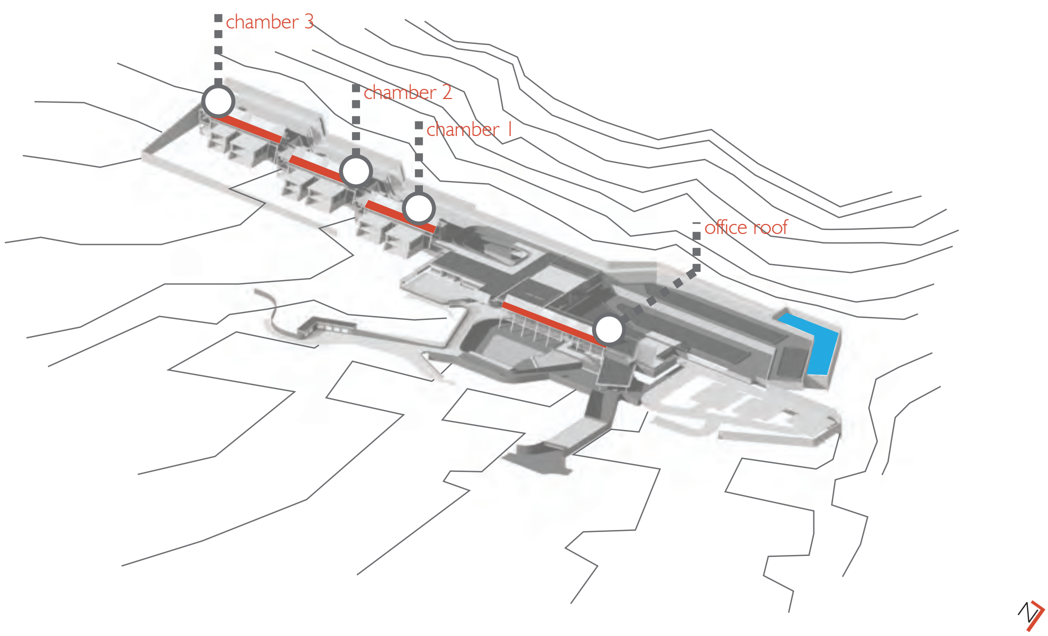


Fig _184 (Above): Dedicated areas for solar power intervetion (Author 2017).
Fig _185 (Right Page): PV-panel diagram showing the generation capacity (Author 2017).

2200 kwh/m2 @ 30 % efficiency 67 kwh/m2

Areas of PV panels

chamber 1	chamber 2	chamber 3	office roof
33m x 1m = 33m2	33m x 1m = 33m2	33m x 1m = 33m2	50m x 1m = 50m2

Product spesification

1940 mm

300 w panel
1.9 m2

980 mm

https://www.bundupower.co.za/solarpanels-single-sd.php?mod=SP-FG-310W

PV panel generation diagram

17 panels | 17 panels | 17 panels | 26 panels

5100 watts 5.1 kWh | 5100 watts 5.1 kWh | 5100 watts 5.1 kWh | 7800 watts 7.8 kWh

7.5 kWh | 3.21 kWh | 4.83 kWh | 0.75 kWh | 13 kWh

15.3 kWh | 7.8 kWh

15.54 kWh | 13.75 kWh

0.24 kWh | municipal connection | 5.95 kWh

Additional panels option

2 panels | 2 panels | 2 panels | 20 panels

7.8 kWh

Building Processes

Harvesting Process

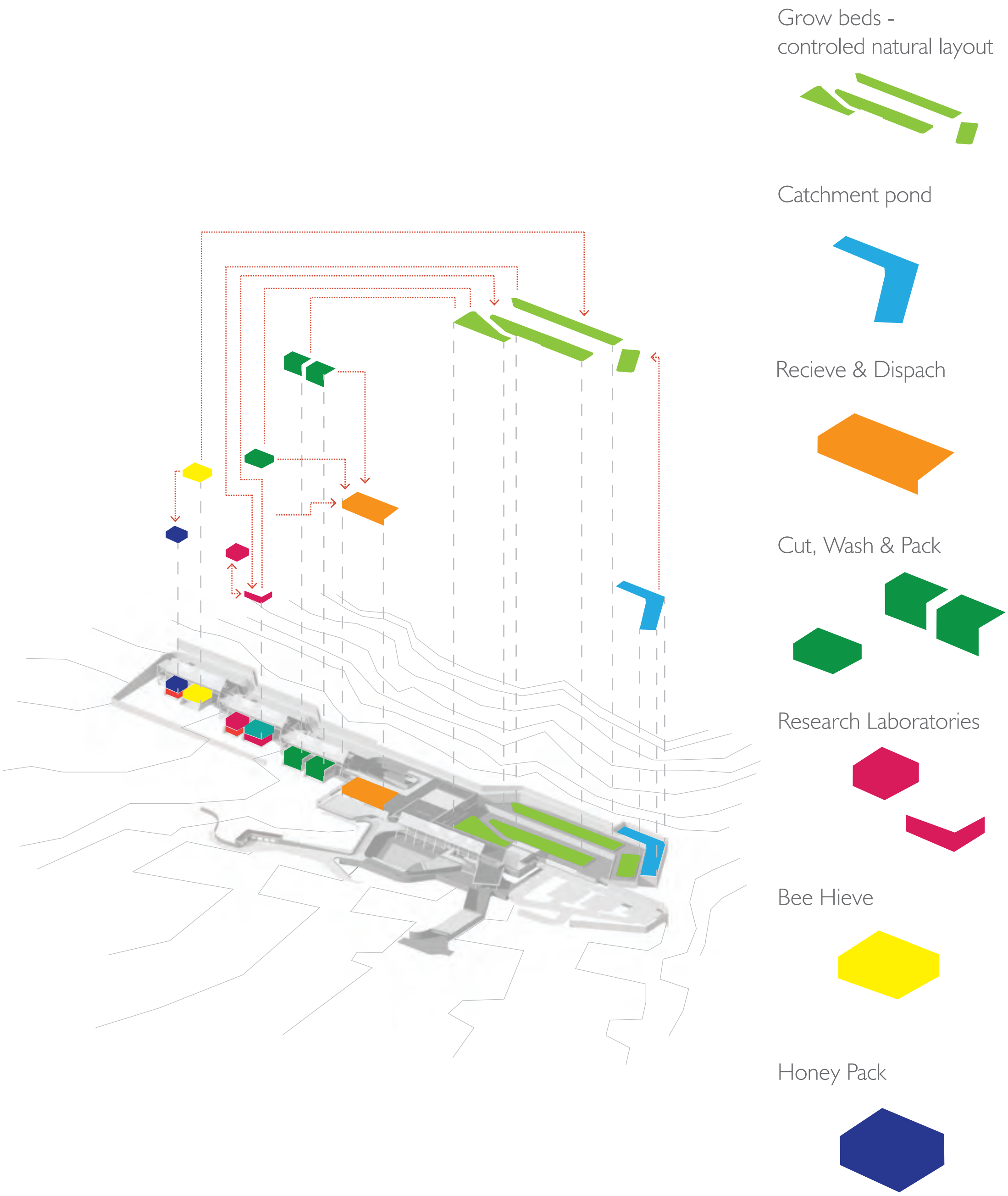


Fig _186 (Spread): Flow and space use of harvesting process (Author 2017).

Plant


http://www.schneidernursery.com/


http://www.midwestgroundcovers.com/page/Our-Growing-Centers

Water


https://www.clearwater.asn.au/resource-library/case-studies/casey-stormwater-harvesting-and-re-use-projects.php


https://www.butek-landline.co.uk/fire-water-storage/

Export to Other Sites


http://www.cavagna.net/en/portfolio/dispatch-warehouse/


https://www.gizmodo.com.au/2015/04/emirates-flight-catering-food-factory-produces-175000-meals-a-day-and-its-all-fresh/

Harvest


https://farm-software.net/fresh-produce-marketing-software/


http://www.asa-agency.com/media/b01c80d1-b010-48ad-925c-0ba5c79fd72c-packaging-plant-of-taylor-farms-the-largest-producer-of-fresh

Ecological Sustainability


https://www.gmi.oeaw.ac.at/


http://www.aprilasia.com/en/about-us/research-development

Pollination


https://www.honeyflow.com/resources/faqs/where-to-locate-your-flow-hive/p/159


http://mahakobees.com/blog/

Organic Food


http://peacebeefarm.blogspot.co.za/2010/09/bottling-honey.html


https://www.aliexpress.com/store/product/semi-automatic-nail-polish-filling-machine-with-10-heads/608153_485043221.html

Visitors Experience

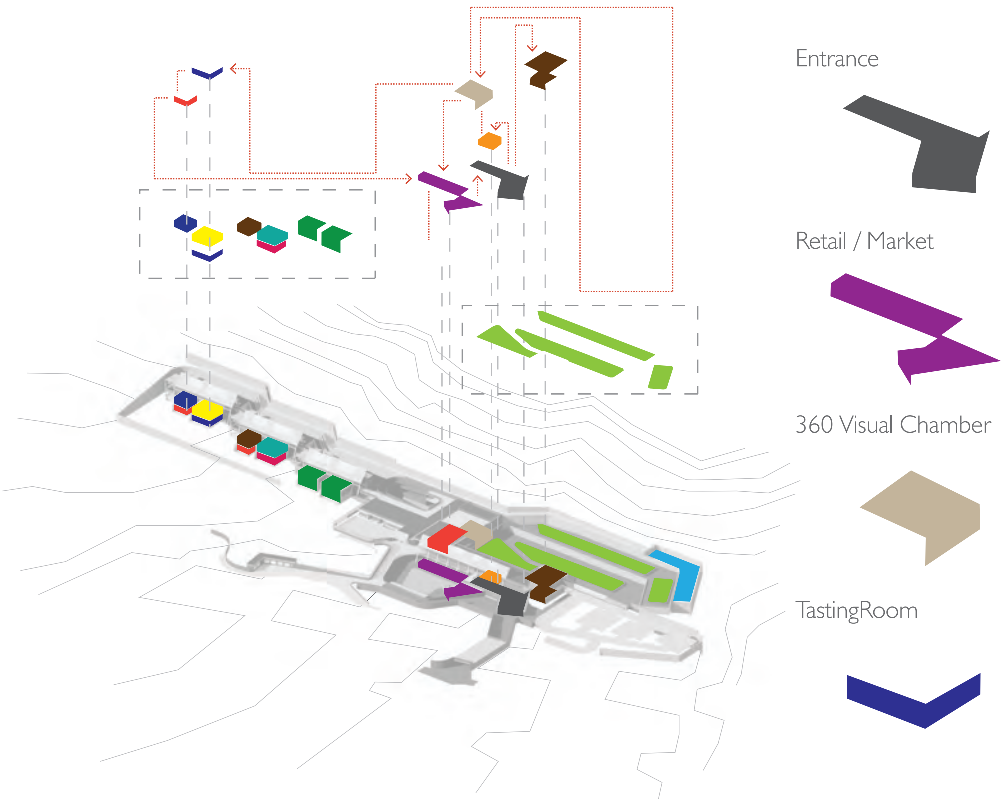


Fig _187 (Spread): Flow and space use of visitor's experience (Author 2017).

Admission

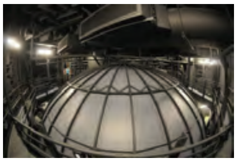
https://www.hassellstudio.com/en/cms-projects/detail/adelaide-zoo-1288/

http://arquitectura.estudioquagliata.com/tag/henning-larsen-architects/page/3

Product

https://en.wikipedia.org/wiki/Agriculture_in_Ghana

Admission



http://www.atlasobscura.com/places/allosphere

http://www.atlasobscura.com/places/allosphere

Recreational

http://www.distillerytrail.com/blog/jack-daniels-cuts-ribbon-refurbished-barrel-house-tasting-room/

http://www.realfoodtraveler.com/2013/06/vodka-the-answer-is-clear/dsc_0025-1183x784/

Office Spaces

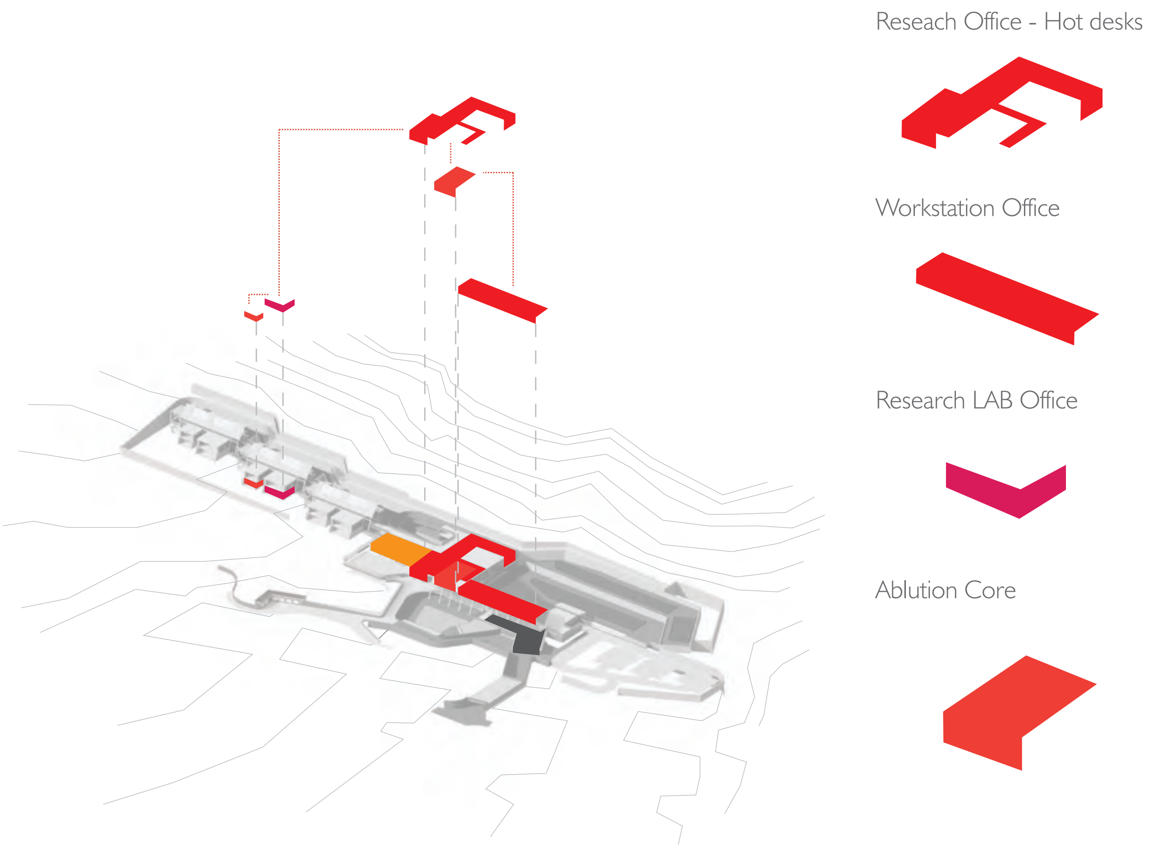


Fig _188 (Spread): Flow and space use of office spaces (Author 2017).

Ecological Sustainability

http://www.architectmagazine.com/technology/wework-takes-on-design-research-and-the-internet-of-things_o

http://www.architectmagazine.com/technology/wework-takes-on-design-research-and-the-internet-of-things_o

Rent Office

Ecological Sustainability

http://newscenter.lbl.gov/2014/10/23/doe-secretary-helps-usher-in-new-era-of-energy-research-at-berkeley-lab/

http://soyouknowbetter.com/2013/11/07/eco-friendly-research-lab-devoted-to-sick-kids/

Ablutions

https://www.pepperfry.com/hardware-electricals-sanitary-ware-water-closets.html

https://www.alibaba.com/product-detail/modern-bathroom-sink-commercial-hand-wash_60483868838.html

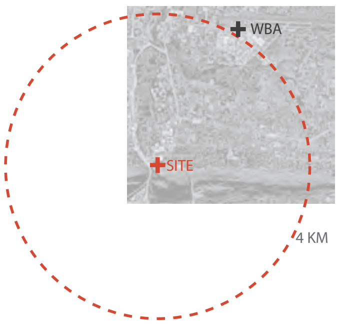
06_5 Building Climate

The building climate sub-category focusses on the internal climate and solar control of the facility. This section investigates the current climatic data of the area and identifies focus points such as key dates and specific times of the year to base investigation on. The approach is based on two distinct periods of climatic change. The summer period considers all the warmer months when temperatures are hot and people as deemed to experience discomfort with heat, the winter period considers the cold months when people will experience a discomfort with a loss in temperature. For the Tshwane climate the summer period is considerably larger than the winter period and due to this more attention was given to keeping the interior spaces cool.

Additional climatic considerations were the wind direction information at three intervals, the humidity of the area in summer and winter and yearly cloud cover. These considerations aided in developing systems to keep the interior spaces as comfortable as possible.

information point : Wonderboom Airport (WBA)

Summer Period : Sept - April (8 months)
Winter Period : May - Aug (4 months)



temperature data

SS Temp Avg.

SEPT	9	28
OCT	13	29
NOV	15	29
DEC	16	30
JAN	17	30
FEB	16	30
MAR	15	28
APR	12	26

WS Temp Avg.

MAY	7	23
JUN	3	20
JUL	2	20
AUG	5	21

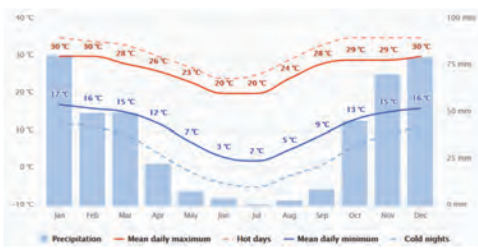
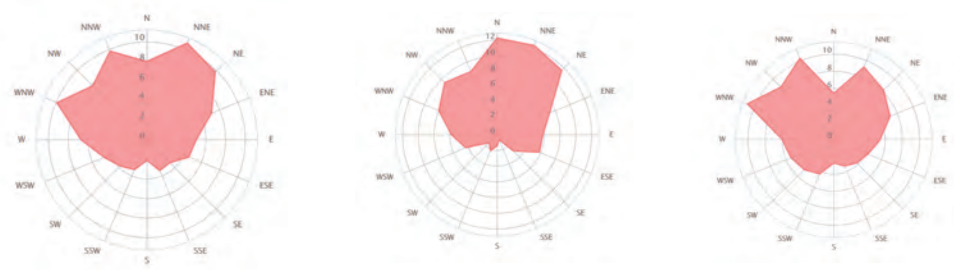


Fig177a. Temprature and Precipatation, Wonderboom Airport. (Meteoblue 2017)

Fig _189 (Top): Climate data gathering point (Author 2017).
Fig _190 (Bottom): Tempature data (Author 2017).

yearly | hotest month | coldest month



Summer Period Info: December

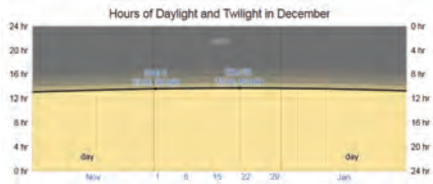


Fig 179a. Hours of Daylight December. (Weatherspark 2017)

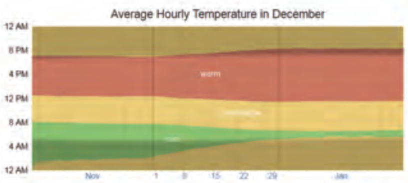


Fig179c. Avg Hourly Tempreture December. (Weatherspark 2017)

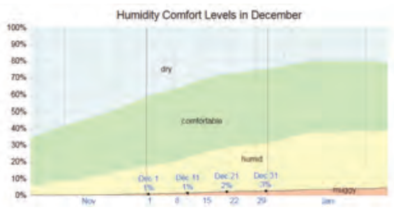


Fig179e. Humidity comfort levels December. (Weatherspark 2017)

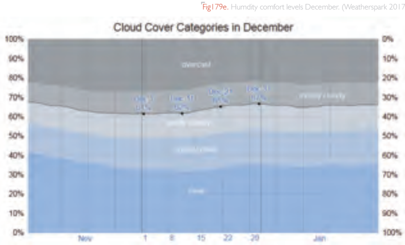


Fig179g. Cloud Cover Categories December. (Weatherspark 2017)

Winter Period Info: June

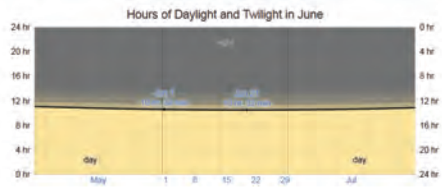


Fig 179b. Hours of Daylight June. (Weatherspark 2017)

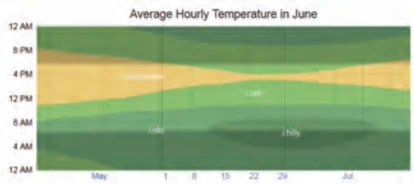


Fig179d. Avg Hourly Tempreture June. (Weatherspark 2017)

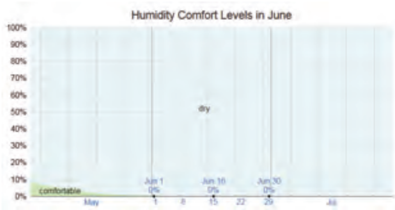


Fig179f. Humidity comfort levels June. (Weatherspark 2017)

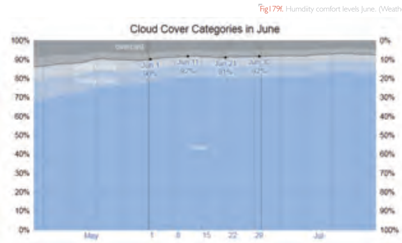


Fig179h. Cloud Cover Categories June. (Weatherspark 2017)

Fig _191 (Top): Wind rose data (Windfinder 2017).
Fig _192 (Bottom): Additional climatic data (Weatherspark 2017).

Ventilation

The data gathered generated the development of systems to keep the interior climate as comfortable as possible. Ventilation was one of the aspects considered to be developed to aid in cooling of the spaces. The first system developed was to aid the spaces by means of passive ventilation where applicable. The aim was to ventilate and cool the spaces with passive systems as far possible. A system was developed to use the anabatic and katabatic mountain winds combined with the solar heat, earth tubes and tree canopy to passively ventilate the chambers and rental office space. The systems utilize the cool ambient air present under the tree canopy to ventilate the spaces.

Passive System

Air is pulled through the spaces by means of an in roof solar chimney system (fig 195), designed as sucking mechanism to draw all the warm air out of the spaces and create an internal closed air flow ventilation system.

The ventilation system starts with the intake of air through earth tubes. This ensures that the air brought into the space is at a constant temperature throughout the year. At the chambers, where the interior spaces need a higher level of cooling, cool air created from the shade of the trees is utilized and the earth tubes are placed deeper to keep this cool air at this temperature. The air from the earth tubes are vented into the spaces through vents. The air changes temperature due to the activities in the space and rises to the celling. The solar chimney extraction system then removes this warm air (see fig 196 - 197).

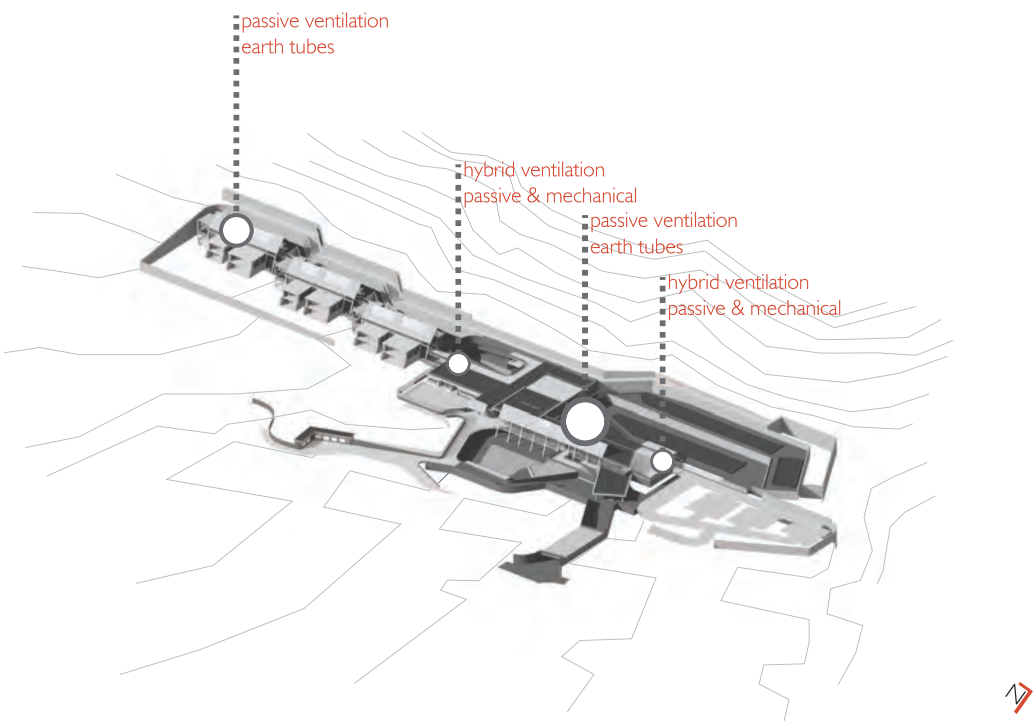


Fig _193 (Above): Ventilation systems (Author 2017).

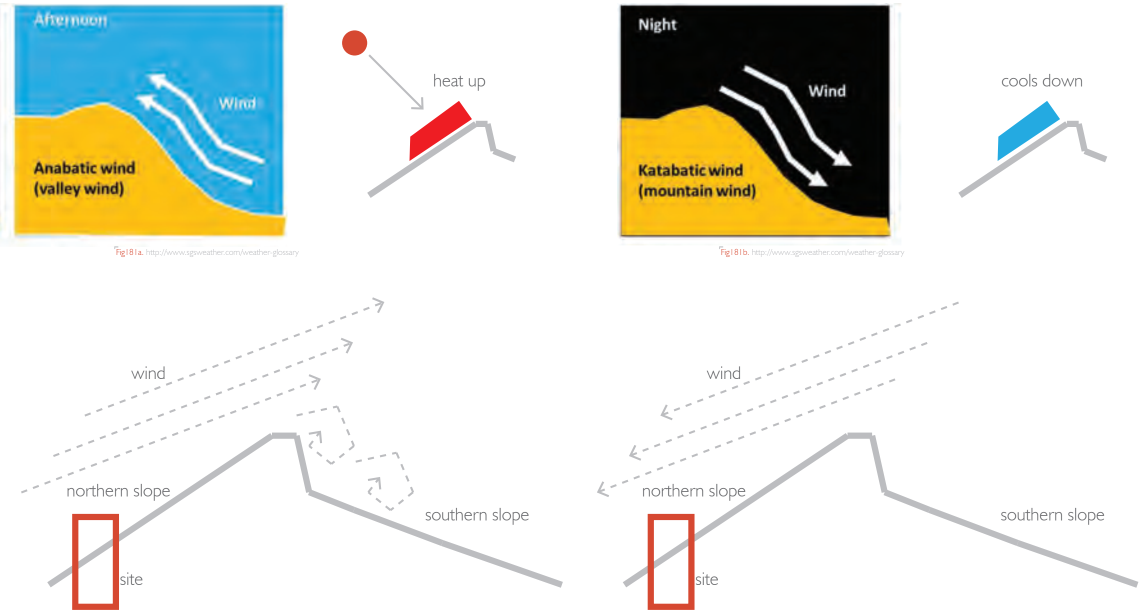


Fig _194 (Above): Anabatic and Katabatic wind systems (Author 2017).

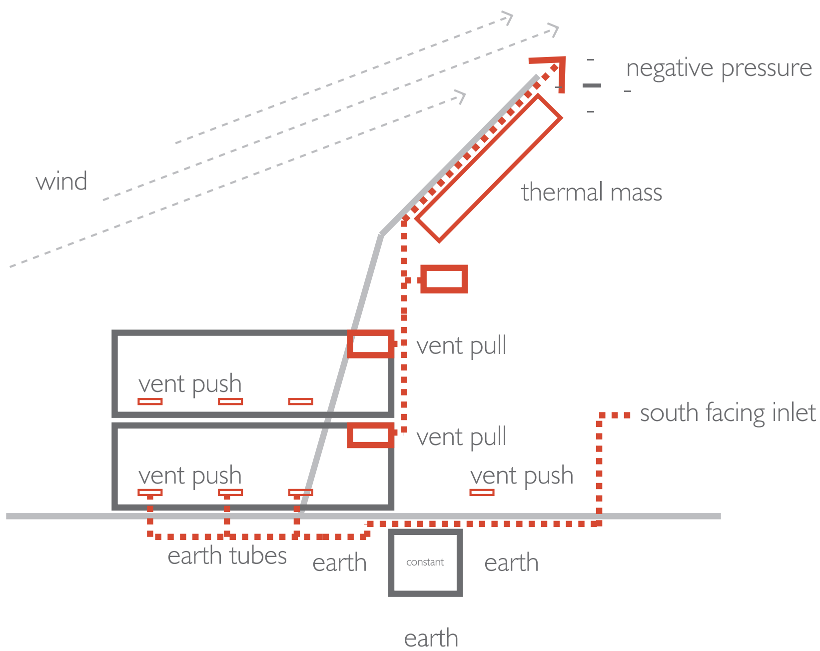


Fig _195 (Above): Passive ventilation systems diagram (Author 2017).

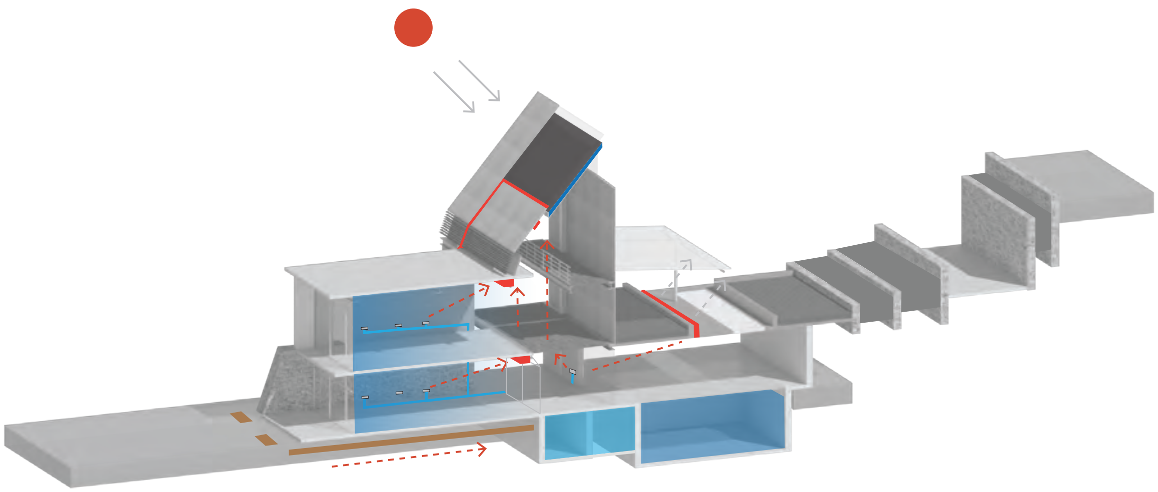


Fig _196 (Above): Passive ventilation systems at chambers (Author 2017).

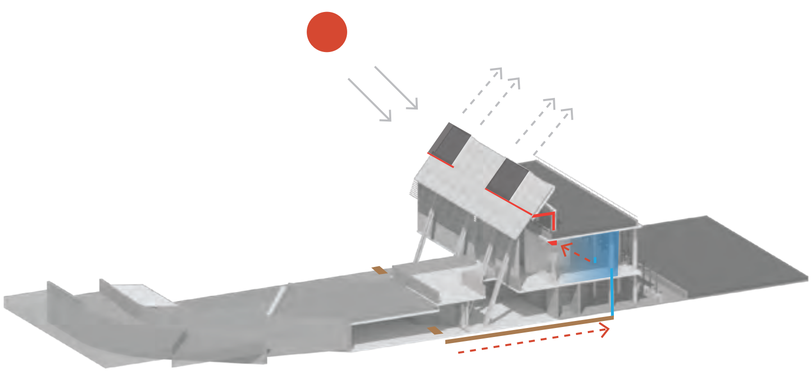
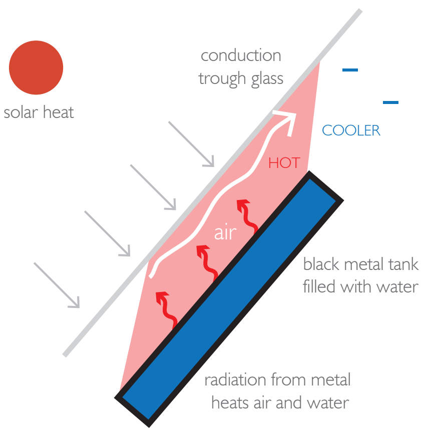


Fig _197 (Above): Passive ventilation systems at offices (Author 2017).

day

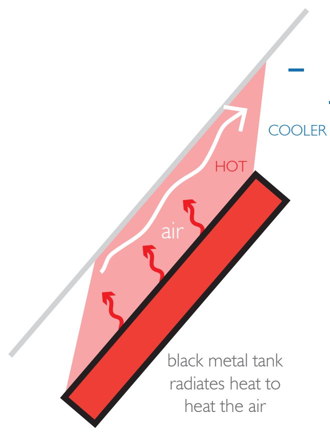


U - Value			
	1	2	3
Type of Material	Glass		
Material tickness (mm)	12	0	0
k - Value	0.96	1	0.12
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)			
R material	**0.01250**	**0.00**	**0.00**
R-inside	0.6		
R-outside	0.12		
R Value	**0.73**		
U Value	**1.37**	W/M2(k)	

Hours of Sunlight ; 8 Hours
Area: 30 m2

U x Ta x A
1.37 x 8 x 30
328.8 Watts (heating power)

night



U - Value			
	1	2	3
Type of Material	Metal	Water	
Material tickness (mm)	20	100	0
k - Value	43	0.85	0.12
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)			
R material	**0.00047**	**0.12**	**0.00**
R-inside	0.6		
R-outside	0.12		
R Value	**0.84**		
U Value	**1.19**	W/M2(k)	

Hours of Sunlight ; 8 Hours
Area: 30 m2

U x Ta x A
1.19 x 8 x 30
285.6 Watts (heating power)

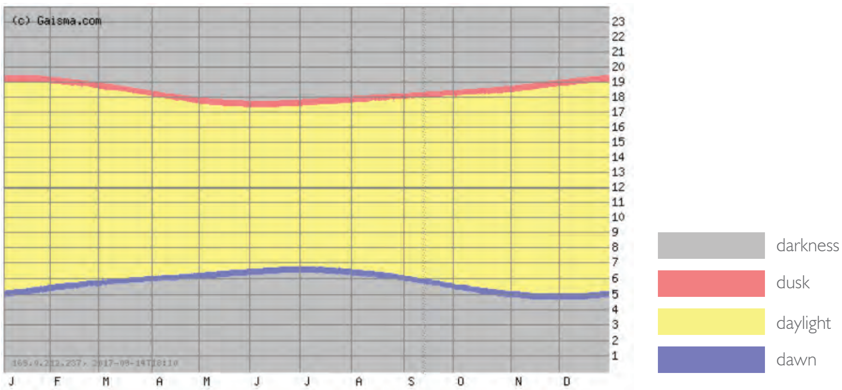
Fig _198 (Above): Passive ventilation systems day and night working and power heating generated (Author 2017).

Solar Control

In keeping the interior climate at the optimal comfort level within the climatic data presented, solar control needed to be investigated and shading devices designed to keep unwanted heat and solar glare out. The investigation considered the yearly sun movement pattern in terms of sunrise, sunset and sun path as a starting point. In terms of the solar control investigation two main dates focused the solar control investigation. 21 September (summer equinox) as the summer datum and 21 April (winter equinox) as the winter datum. These two dates indicate when the sun is at the midpoint between the solar cycles (solstices).

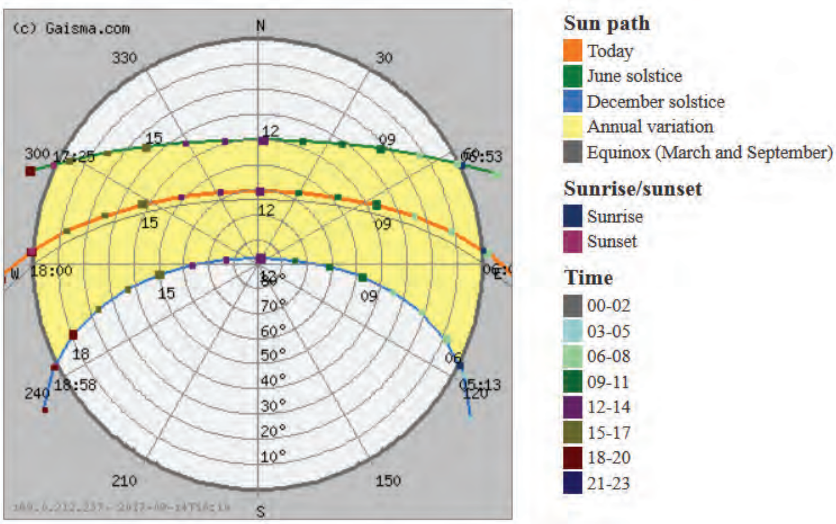
The two dates were divided into bi-hourly intervals to run a solar study on the facility (fig 200). The solar study results showed up areas of concern within the design. These areas concerned time intervals. On 21 September the results showed solar interference between 10:00 and 14:00 and on 21 April between 10:00 and 12:00. Focus was placed on these areas and time intervals to develop solar control shading devices.

Sunrise, sunset dusk and dawn times



https://www.gaisma.com/en/location/pretoria.html

Sunpath diagram



https://www.gaisma.com/en/location/pretoria.html

Fig _199 (Above): Sun data (Gaisma.com 2017).
Fig _200 (Right Page): Solar study (Author 2017).

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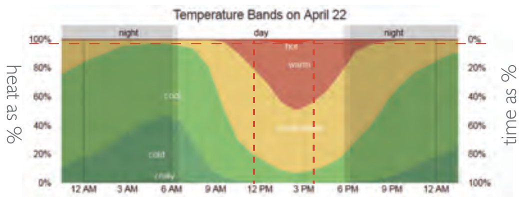
YUNIBESITHI YA PRETORIA

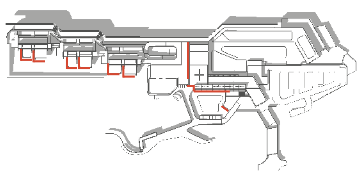
Site

21 April

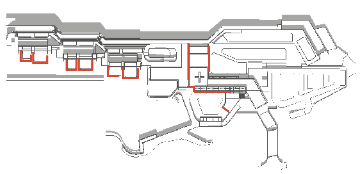
above 29 oC



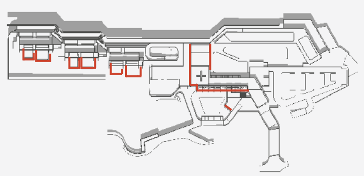
11:30 15:40



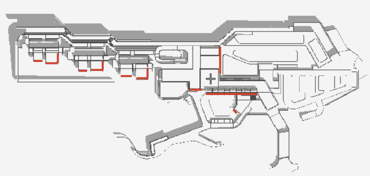
08:00 15oC



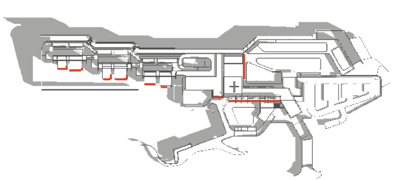
10:00 19oC



12:00 22oC



14:00 24oC

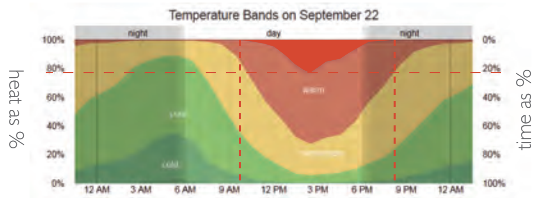


16:00 22oC

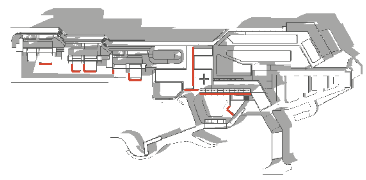
https://weatherspark.com/d/148605/4/22/Average-Weather-on-April-22-at-Pretoria-South-Africa#Sections-Temperature

21 September

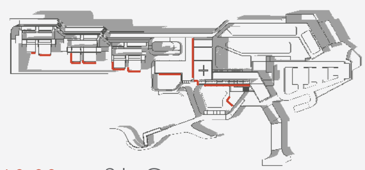
above 29 oC



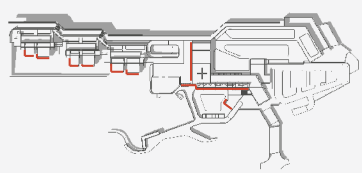
09:40 20:10



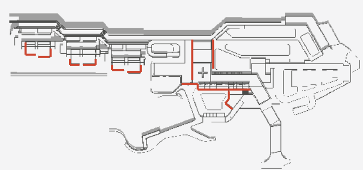
08:00 17oC



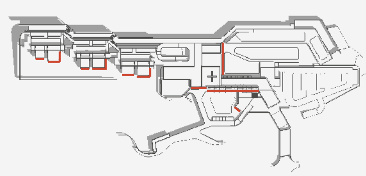
10:00 21oC



12:00 23oC



14:00 26oC



16:00 23oC

https://weatherspark.com/d/148605/9/22/Average-Weather-on-September-22-at-Pretoria-South-Africa#Sections-Temperature

Shading Device Design - Office Workstations

The solar study indicated a problem area at the office workstation space on first floor. The solar heat gain and glare onto the desks were problematic due to the functional nature of the space. To deal with this issue, a shading device design approach was taken to develop solar shutters and louvres.

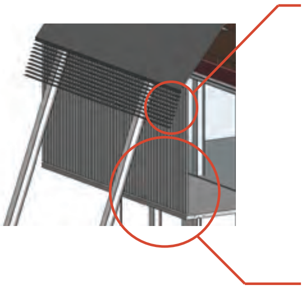
The louvre design was developed to prevent solar infiltration when the sun is at its highest in a daily cycle. The louvres are spaced to keep the sun out of the space between 10:00 and 14:00 during winter and summer periods (fig 201). Using the lowest solar point at midday of 21 June as the angle to determine the louvre spacing. This consideration keeps the work desk computer screens glare free throughout the midday period in summer and winter.

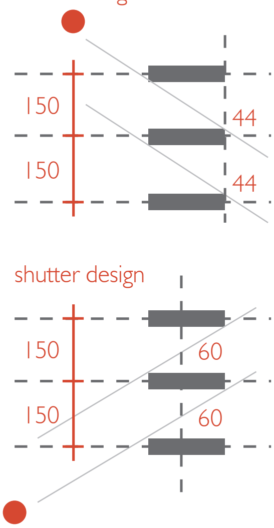
To keep the afternoon sun from penetration the office space, a shutter design was implemented. The shutters were developed to keep the sun out of the space from 14:00 onward when the sun is at a lower angle and the louvres are not required anymore (fig 201). The solar shutters also aid in keeping direct sunlight out of the space in the morning hours to prevent glare. Sunlight protection into the office space is achieved by the southern curtain wall and reflection from the circulation space on the northern edge.

The solar shading devices were tested in the time periods identified in the main solar study as problematic and were found to achieve the desired effect (fig 202).

Fig _201 (Right Top): Louvre and shutter design (Author 2017).
Fig _202 (Right Bottom): Solar study of louvres and shutters (Author 2017).

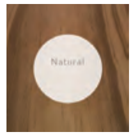
Nothern facade - workstation office





natural, 150mm x 60 mm Rinowood laminated beams @ 150mm cc fixed horizontally, screwed to equal angle support frame.

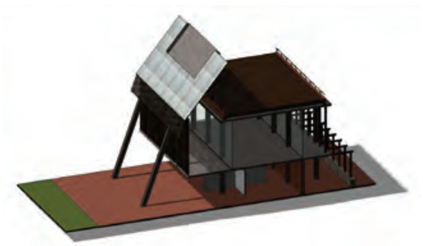
rhino wood



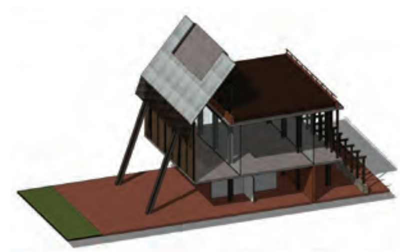
natural, 150mm x 60 mm Rinowood laminated beams @ 150mm cc fixed vertically, screwed to equal angle support frame.

plan view

21 April

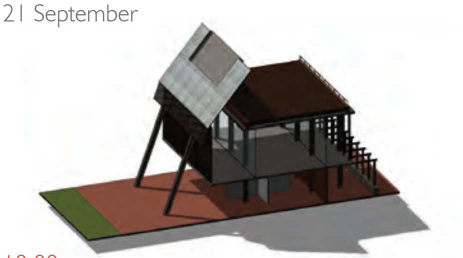


12:00

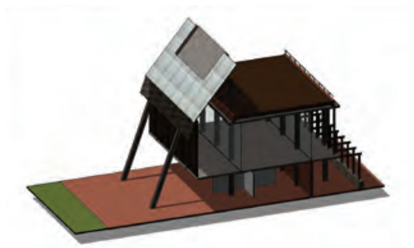


14:00

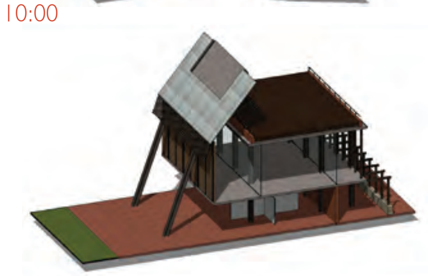
21 September



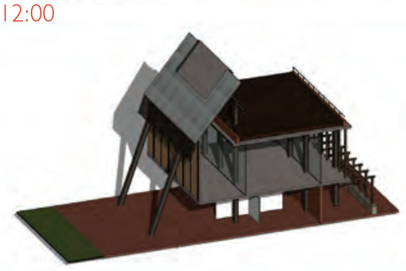
10:00



12:00



14:00



16:00

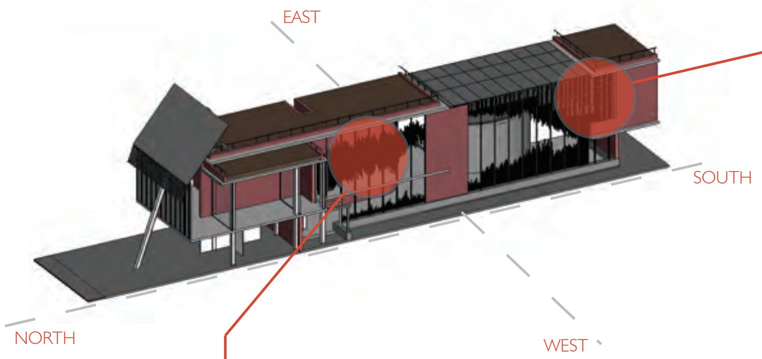
Shading Device Design - Research Offices

Another problematic area with solar gain was presented on the western elevation of the research office and the facility's visitors introduction spaces. To control the solar gain in this area a combination of vertical shutters and perforated shutter screens were implemented. The vertical shutter sections were strategically designed and placed to keep direct sunlight away from any area where a desk might be used or where the interior space surface will absorb the sun's heat.

The ideal intervention on this elevation would have been to completely close it off with shutters but this would have disrupted the views and the architecture's intention to connect with the exterior grow beds. Where the direct sunlight needed to be completely blocked from the space, perforated sun screens were used. These sun screens continue into the roof space to keep direct sunlight out of the double volume without diminishing the light quality of the space.

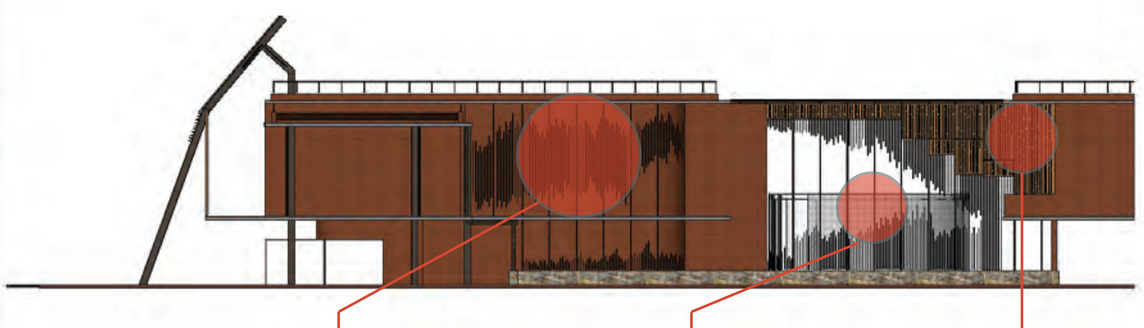
Fig _203 (Right Top): Louvre design for office west fasade (Author 2017).
Fig _204 (Right Bottom): Solar study of louvres for office west facade (Author 2017).

Western facade - reseach group office / interpretation centre



natural pattern cut, 600mm x 30 mm custom made Rinowood laminated sheets fixed to equal angle support frame.

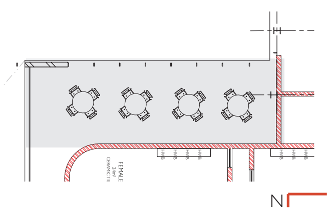
natural, 150mm x 60 mm Rinowood laminated beams @ 150mm cc fixed vertically, screwed to equal angle support frame per detail reference.

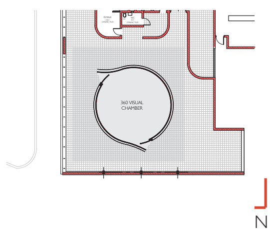


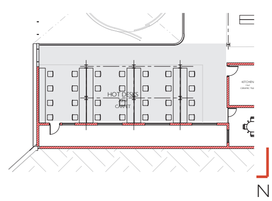
research office discussion space

360 visual chamber

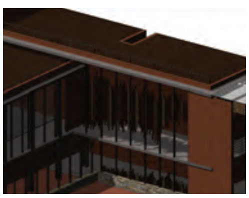
research hot desks







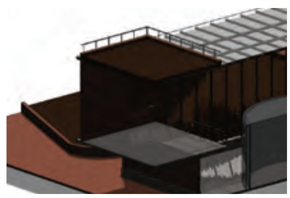
21 September



14:00

16:00

14:00



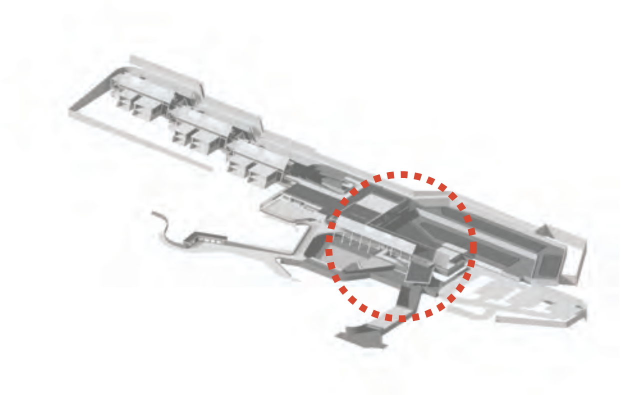
14:00

Climatic Modeling

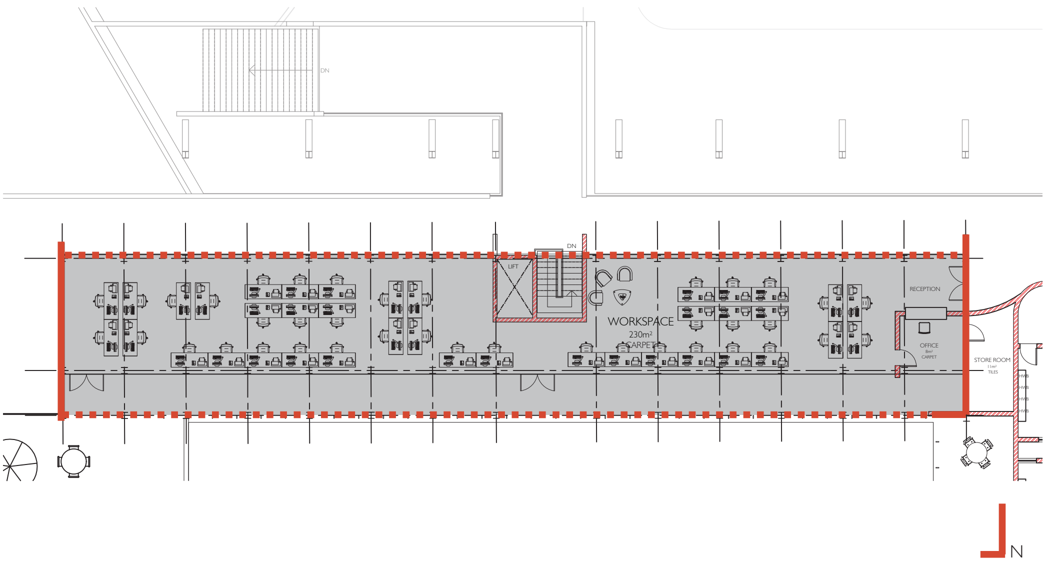
The interior climate of the office workstation space (fig 205 - 206) on the first floor posed a challenge in terms of the large glazing areas to the north and south. The challenge related to interior heat gain and energy needed to keep the climate of this space comfortable. To address this challenge, climatic modelling software (Sefaira 2009) was implemented to test the thermal qualities of the space and the materials used.

The process required of the office space area to be isolated and modelled separately (Revit 2017) to the exact specifications that were intended for the space. A requirement field was set up according to SANS 10400 XA (2011) and SANS 204 (2011) regulations. The intended space model was run in Safaira (2009) to gather results and compare to the requirements as set out. The first attempt (baseline-fig 207) failed the requirements and adjustments were made. These adjustments ranged from adding interior window blinds to adjustments to the structures of the roof and walls. The result (iteration A -fig 208) shows the required construction and range of materials required to meet the requirements as set out. Additional results on the daylight penetration and lux levels of the space are shown in figure 209 and 210.

Fig _205 (Right Top): Area and information of space to be tesed in climatic modelling (Author 2017).
Fig _206 (Right Bottom): Plan view of space to be tested (Author 2017).



SANS classification: G1 Office
floor area: 533sqm
floor to ceiling height: 3.5m
dimensons: 236 m E to W
42 m N to S
discription: office space for rent structure consiting of glazing on nothern and southern elevation with masonary walls on eastern and western elevation. roof consists of green roof and floor of cast in-situ concrete slab with suspended service floor.

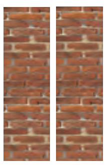


Baseline

Roof
U-Value: 0.74 W/m2.K

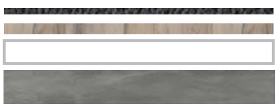
U - Value					
	1	2	3	4	5
Type of Material	Concrete	Stone	Ground		
Material tickness (mm)	150	50	450	0	0
k - Value	1.5	0.6	1	1	1
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)					
R material	**0.10**	**0.08**	**0.45**	**0.00**	**0.00**
R-inside	0.6				
R-outside	0.12				
R Value	**1.35**				
U Value	**0.74**	W/M2(k)			

Walls
U-Value: 1.06 W/m2.K



U - Value					
	1	2	3	4	5
Type of Material	Masonary	Masonary			
Material tickness (mm)	110	110	0	0	0
k - Value	1	1	1	1	1
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)					
R material	**0.11**	**0.11**	**0.00**	**0.00**	**0.00**
R-inside	0.6				
R-outside	0.12				
R Value	**0.94**				
U Value	**1.06**	W/M2(k)			

Floor
U-Value: 0.30 W/m2.K



U - Value					
	1	2	3	4	5
Type of Material	Concrete	Air	Timber	Carpet	
Material tickness (mm)	150	50	50	10	0
k - Value	1.5	0.024	0.12	0.26	1
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)					
R material	**0.10**	**2.08**	**0.42**	**0.04**	**0.00**
R-inside	0.6				
R-outside	0.12				
R Value	**3.36**				
U Value	**0.30**	W/M2(k)			

Glazing
U-Value: 2.84 W/m2.K
SHGC: 0.60

Crealco Facade 60 Thermal Curtain wall
U-Value: 2.84 W/m2.K
SHGC: 0.60

Fig _207 (Above): Baseline results (Author 2017).

Iteration A

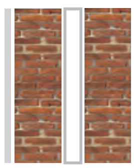
Roof

U-Value: 0.44 W/m2.K

U - Value					
	1	2	3	4	5
Type of Material	Concrete	Stone	Insulation	Ground	
Material tickness (mm)	150	50	100	450	0
k - Value	1.5	0.6	0.11	1	1
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)					
R material	**0.10**	**0.08**	**0.91**	**0.45**	**0.00**
R-inside	0.6				
R-outside	0.12				
R Value	**2.26**				
U Value	**0.44**	W/M2(k)			

Walls

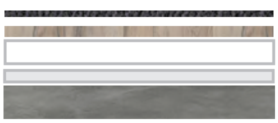
U-Value: 0.33 W/m2.K



U - Value					
	1	2	3	4	5
Type of Material	Masonary	Air	Masonary	Plaster	
Material tickness (mm)	110	50	110	10	0
k - Value	1	0.024	1	0.71	1
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)					
R material	**0.11**	**2.08**	**0.11**	**0.01**	**0.00**
R-inside	0.6				
R-outside	0.12				
R Value	**3.04**				
U Value	**0.33**	W/M2(k)			

Floor

U-Value: 0.29 W/m2.K



U - Value					
	1	2	3	4	5
Type of Material	Concrete	Air	Timber	Carpet	Insulation
Material tickness (mm)	150	50	50	10	10
k - Value	1.5	0.024	0.12	0.26	0.11
(http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html)					
R material	**0.10**	**2.08**	**0.42**	**0.04**	**0.09**
R-inside	0.6				
R-outside	0.12				
R Value	**3.45**				
U Value	**0.29**	W/M2(k)			

Glazing

U-Value: 2.84 W/m2.K

SHGC: 0.20

Metal Technology System 8

U-Value: 1.28 W/m2.K

SHGC: 0.60

internal blinds SHGC: 0.20

Fig _208 (Above): Iteration A results (Author 2017).

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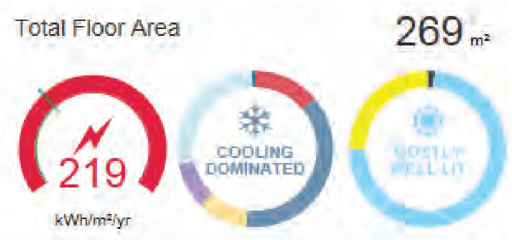
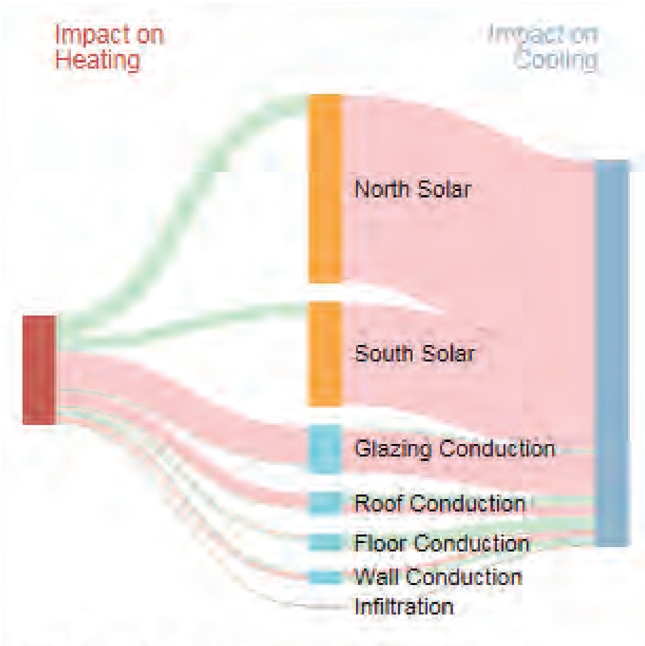


219 kWh/m2 > 190 kWh.m2
Cooling Dominated
Mostly Lit



Gains on north solar is too large to achieve requirements of SANS energy requirements. Decreace needed in heat gains from nother glazing.
South solar impact on cooling can be improved to lower energy demand.

Daylight - Overlit / Underlit

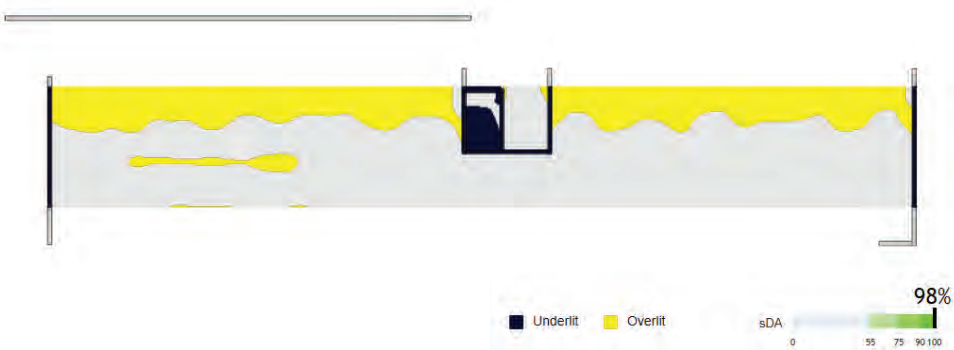
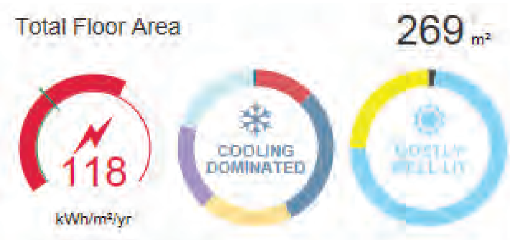
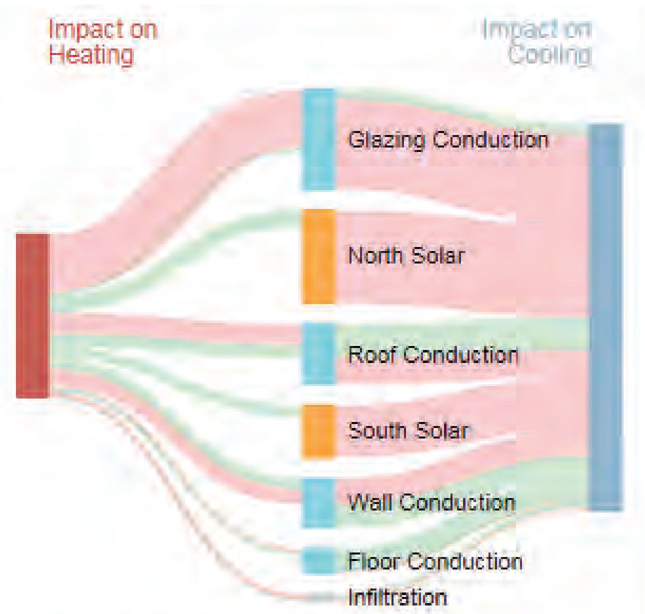


Fig _209 (Above): Aditional Baseline results - Daylight over and under lit areas and Energy use (Author 2017).



118 kWh/m2 < 190 kWh.m2
Cooling Dominated
Mostly Lit



Balance between conductive elements keeping energy demand below requirements.

Daylight - Above 300 lux

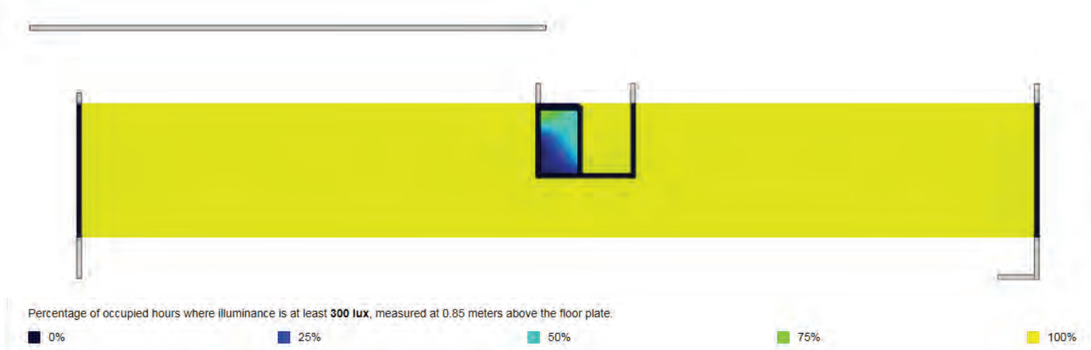


Fig _210 (Above): Aditional Iteration A results - Daylight factor and Energy use (Author 2017).

06_4 Building Structure

The structure of the conservation facility is investigated in this section. A general approach was taken in terms of investigating and in explaining the structure of the facility. As shown in figure 211, this approach considered the structure in terms of primary, secondary and tertiary elements. The primary elements relate to the structural systems used, the secondary to how this structural system is closed off or filled and the tertiary on how the services are placed into the voids of the structure and/or finished off.

Primary Structure

The primary structure for the conservation facility is a steel frame (portal or other) permanent shuttered concrete construction combination system . This approach was based on the aesthetical quality of steel in making the superstructure seem as light as possible. This creates a contradiction with the spaces directly in contact with the ground, which all have a heavy base. With this contradiction, the in-between becomes highlighted as these segments are exposed as the transition and tie into the relationship consideration of the in-between of the project.

Secondary Structure

The secondary structure considers how the space is created, closed-off or filled in. The system used to create the secondary structure is derived as an extension of the form informant as explained in chapter 2. The "*musée of images*" of the blockhouse structure is re-interpreted and a multi-layer material structure is created. The material used for this multi-layer structure is a stone cladded base with an in-situ cast concrete frame that is filled with a masonry infill. Where needed, the fourth material element of sheet metal is added. This system is used as basis and implemented in different aspects throughout the design.

Tertiary Structure

The tertiary structure refers to all the material elements not included in the primary or secondary structure and completes the structure of the conservation facility. These elements are service or function orientated and differ throughout the conservation facility. The tertiary structure of the office work space is for example the suspended service floor where the tertiary structure for the chambers will be the drainage system pipes that drain the spilled water from washing.

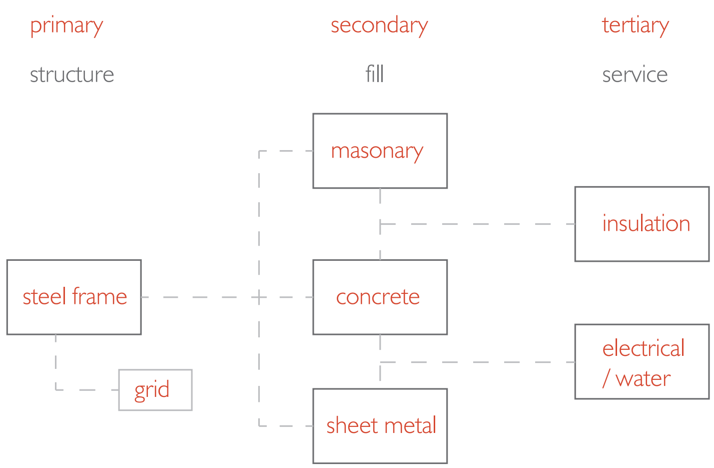
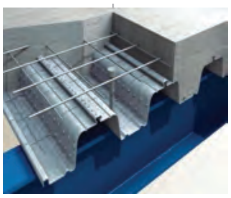


Fig _211 (Above): Structure approach diagram (Author 2017).

primary
steel frame

I - beam
H - column
permanent shuttering



https://4.imimg.com/data4/LK/RP/MY-4774059/cf80-cutaway-500x500.jpg

secondary
floor slab

concrete cast
in-situ

http://buildipedia.com/knowledgebase/division-03-concrete/03-30-00-cast-in-place-concrete/03-37-00-specialty-placed-concrete/03-37-00-specialty-placed-concrete?print=1&tmpl=component

tertiary
finish

ceramic tiles
service floors
timber flooring

http://www.cbi-europe.it/en/catalogo/sistemi+di+condizionamento+integrati/1/1/index.aspx

primary
reinforced
concrete frame

concrete
cast in-situ
into formwork

http://ronie-mooney-encs.us/design-of-reinforced-concrete-walls.html

secondary
masonary / stone
fill

brick laying
stone packing

http://www.bricklaying-courses.co.uk/bricklaying-books/

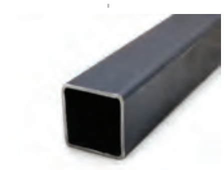
tertiary
finish

plaster
sheet metal
paint

https://www.constructionkit.com/kit-additions/

primary
steel frame

colled rolled
square hollow
sections



http://www.austenknapman.co.uk/mild-steel/mild-steel-box-section/

secondary
roof sheeting

aluminum roof
sheeting

http://lcproofblog.co.za/?p=1664

tertiary
ventilation system

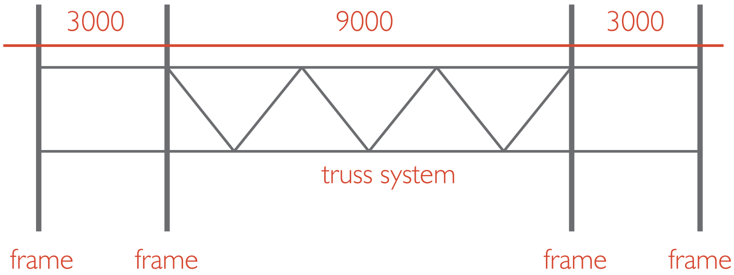
thermal mass
metal tank
piping

https://www.coastandcountrywatertanks.com.au/
https://pxhere.com/en/photo/925035

Fig _212 (Above): Structure explained in terms of materials - Primary, secondary and tertiary (Author 2017).

Chamber Structure

Structure diagram



Portal frame structure

Fig _213 (Top): Diagram of structural grid for chamber portal structure (Author 2017).
Fig _214 (Bottom): Portal frame structure for chambers (Author 2017).

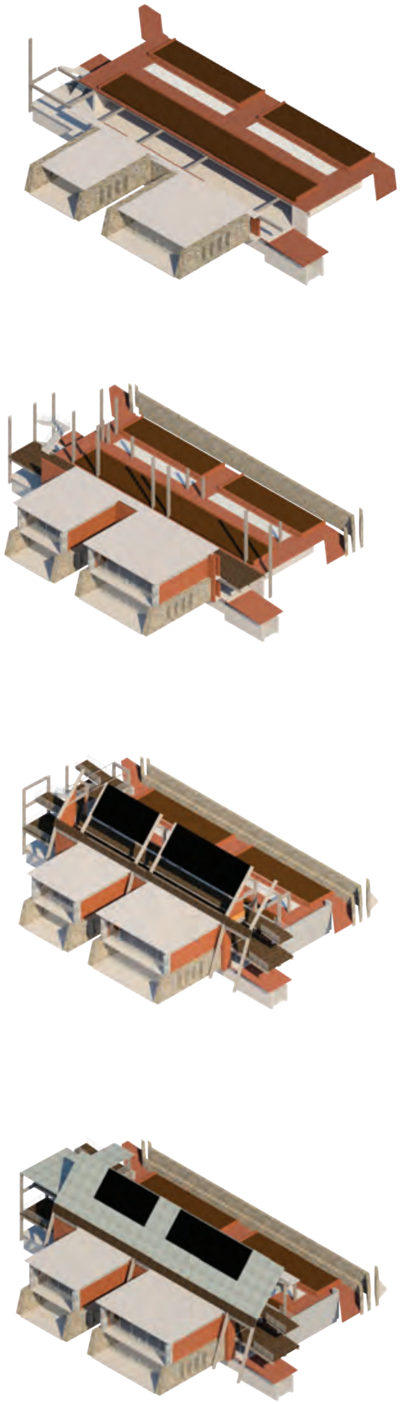
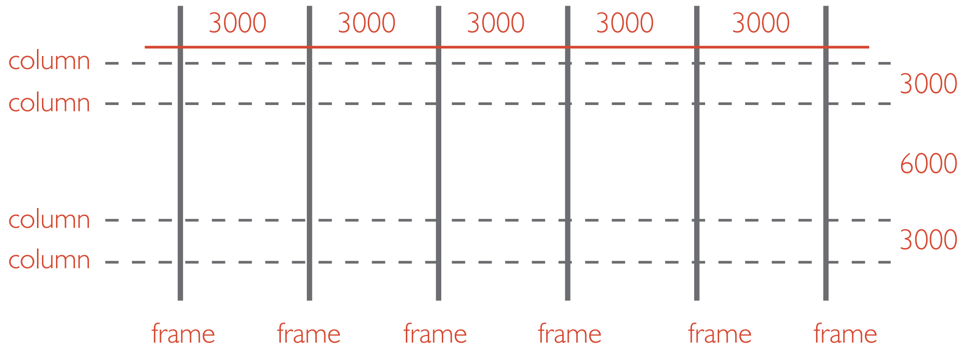


Fig _215 (Above): Typical construction process of chamber (Author 2017).

Office Structure

Structure diagram



Portal frame structure

Fig _216 (Top): Diagram of structural grid for office portal structure (Author 2017).
Fig _217 (Bottom): Portal frame structure for office space (Author 2017).

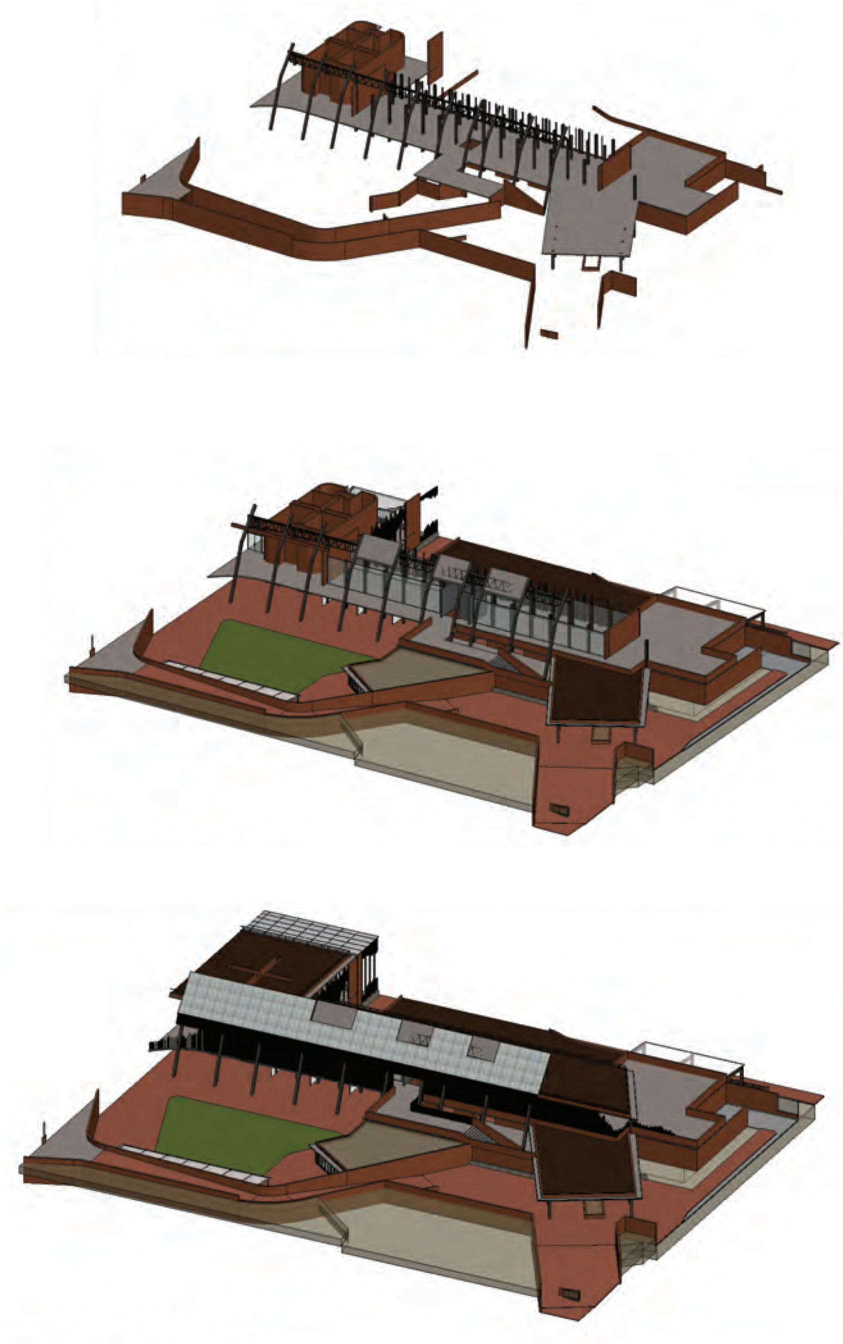


Fig _218 (Above): Typical construction process of office space (Author 2017).

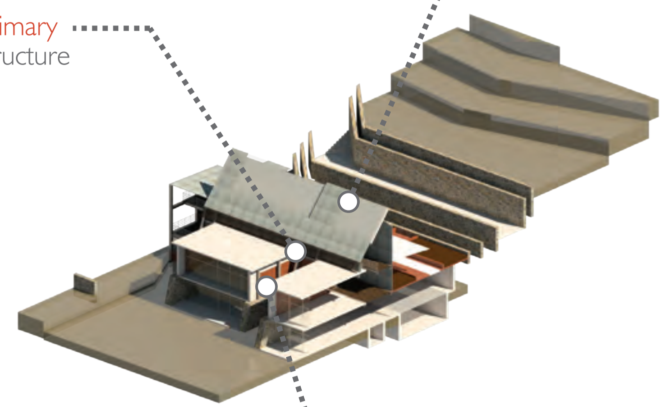
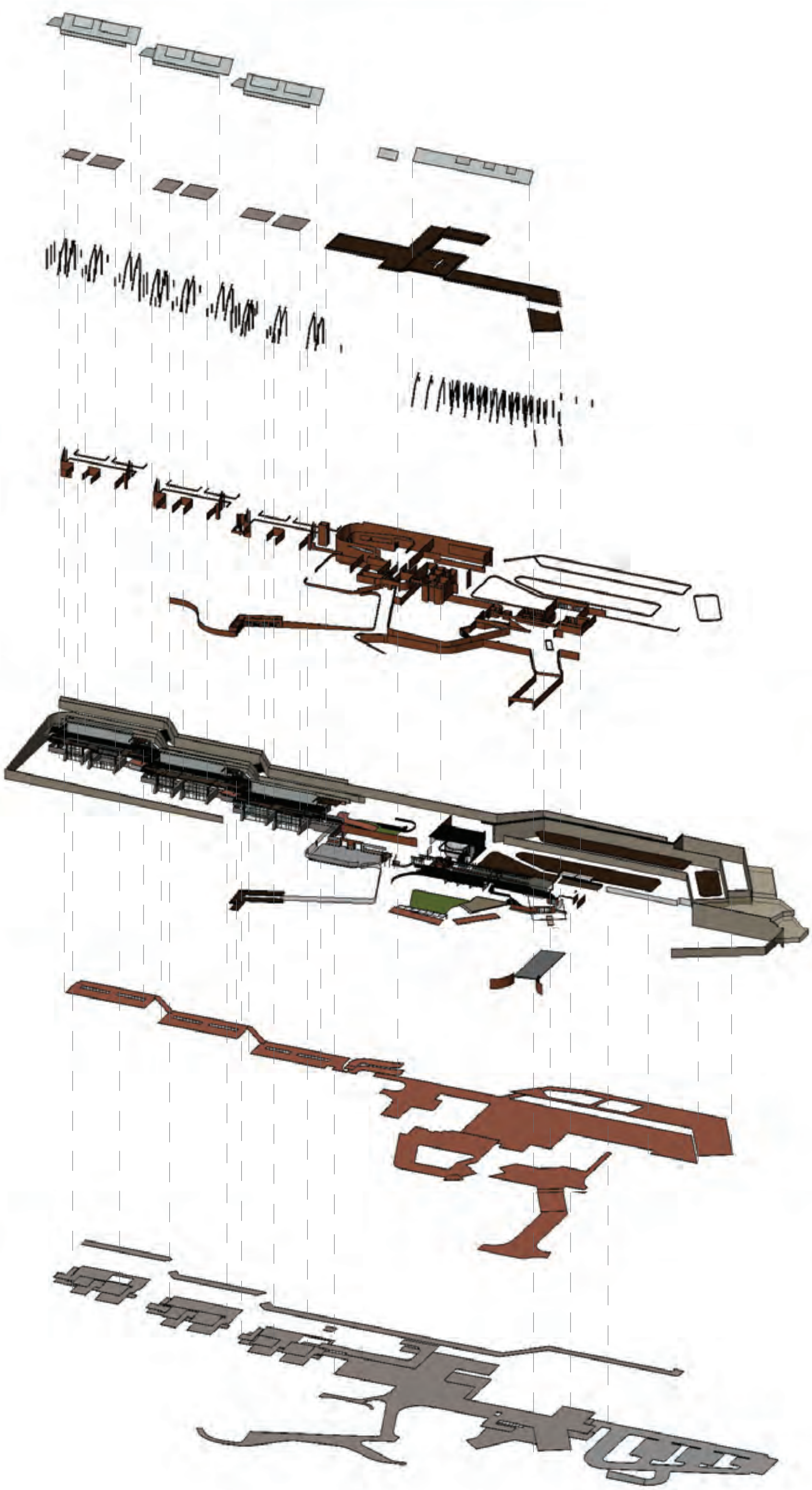


Fig _219 (Top): Section perspective of chamber structure indication the primary, secondary and tertiary structure (Author 2017).
Fig _220 (Right Page): Pull out of design to show the structural elements (Author 2017).



Materiality

The second aspect of the building structure sub-category considers the material pallet for the conservation facility. The investigation of material is built on the explained structure materials and considers the manufacturer, distance from site and quality of the material to determine the sources of all the materials to be used for the conservation facility. A diagram is developed (fig 222 - 230) to show the manufacturer, the distance the material needs to travel to the site and the material finish.

The criteria for manufacturer and product selection were based on the quality of the product, the finish in terms of the aesthetical requirements and the locality of the manufacturer. Although some materials' original source is distant from the site due to the climates required to produce, the distances from manufacturer or distribution centres to the site are kept to within a +/- 50km radius.

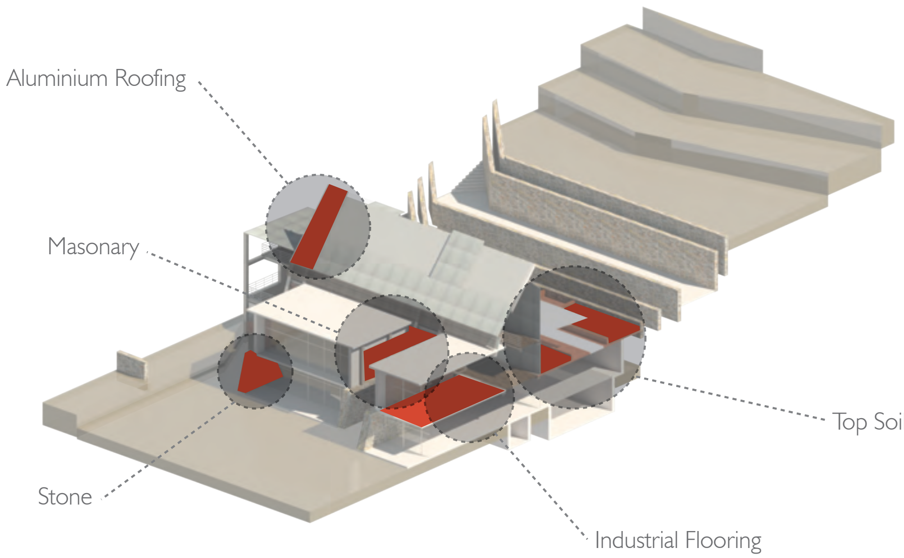


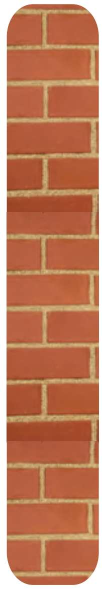
Fig _221 (Above): Section perspective showing the material areas (Author 2017).

Masonary

Walls

230 mm facebrick walls - Roan Satin FBX





Company

Corobrik, 2785 Escallonia Street, Montana Commercial Park, Ext 91, Montana, Pretoria, 1000

CORBRIK

distance to site 12.2 KM
time to site 19 min

Stone

Wall - clad

Quartzite stone clad



Company

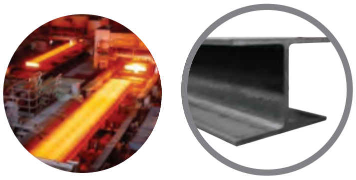
Site - Wonderboom Nature Reserve, M1 Road, Wonderboom, Pretoria, 0182


distance to site 0 KM
time to site 0 min

Fig _222 (Top): Material - Masonary (Author 2017).
Fig _223 (Bottom): Material - Stone (Author 2017).

Steel

Structural system - portal frame
305 mm x 305 mm x 118 mm Hot Rolled H-Section (Parrallel Flange)
305 mm x165 mm x 40 mm Hot Rolled I-Section (Taper Flange)



Company
Arcelor Mittal South Africa, Frikkie Meyer Road, Pretoria West, Pretoria, 0183

ArcelorMittal

distance to site 14.3 KM
time to site 14 min

Concrete

Floor & Roof cast - Permanent suttering
150 mm cast in-situ concrete

Company
PPC Hercules Factory, Es'kia Mphahlele Dr, Eloff Estate 320-Jr, Pretoria, 0084

PPC CEMENT

distance to site 6.3 KM
time to site 8 min

Fig _224 (Top): Material - Steel (Author 2017).
Fig _225 (Bottom): Material - Concrete (Author 2017).

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Ceramic Tiles

Floor finish for circulation / ablution

Company

CTM - Pretoria, 519 Michael Brink St, Gezina, Pretoria, 0183

CTM
Big savings. More style.

distance to site 5.2 KM
time to site 8 min

Industrial Flooring

Floor finish for industrial areas

Company

58 Toermalyn St, Klerksoord AH, Akasia, 0200

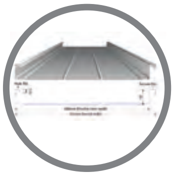
TTMC EPOXY FLOORING
Your Epoxy Flooring Partner.

distance to site 12.6 KM
time to site 11 min

Fig _226 (Top): Material - Ceramic Tiles (Author 2017).
Fig _227 (Bottom): Material - Industrial Flooring (Author 2017).

Roofing - Aluminium

Roof Sheeting - Saflok and Newlok (unseamed)



Company

Kifaru Trading (Pty) Ltd, 4 Fobian St, Hughes, HUGHES EXT 31, 1459

SAFINTRA
world class roofing systems

distance to site 63.5 KM
time to site 50 min

Top Soil

Green Roof top soil
Plant Beds top soil

Company

Topia Gardens, Cnr Zambezi Road & Mountain Drive, Montana Park, Pretoria, 0035

Topia Gardens Nursery/Kwekery

distance to site 18.9 KM
time to site 30 min

Fig _228 (Top): Material - Roofing - Aluminium (Author 2017).
Fig _229 (Bottom): Material - Top soil (Author 2017).

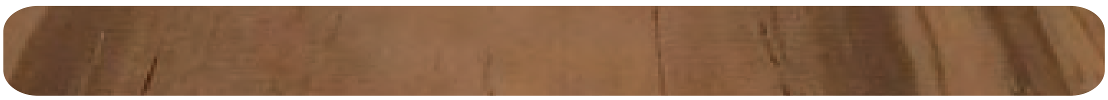
Timber

Shutters and Louvres - all timber applications
Rhino modified wood

Company

Timbermann, Plot 478, Swavelpoort, Pretoria, 0081

distance to site 35.7 KM
time to site 42 min



Carpet

Floor finish for office areas

Company

Top Carpets & Floors Mayville, Cnr Louis Trichardt St & Mortimer ave, Pretoria, 0084

distance to site 2.2 KM
time to site 3 min

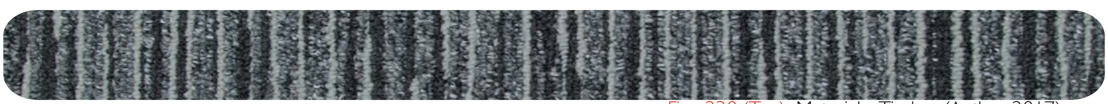


Fig _230 (Top): Material - Timber (Author 2017).
Fig _231 (Bottom): Material - Carpet (Author 2017).

Section Production Chamber

Fig _232 (Spread): Section CC - NTS (Author 2017).

Section Office Space / Retail Market

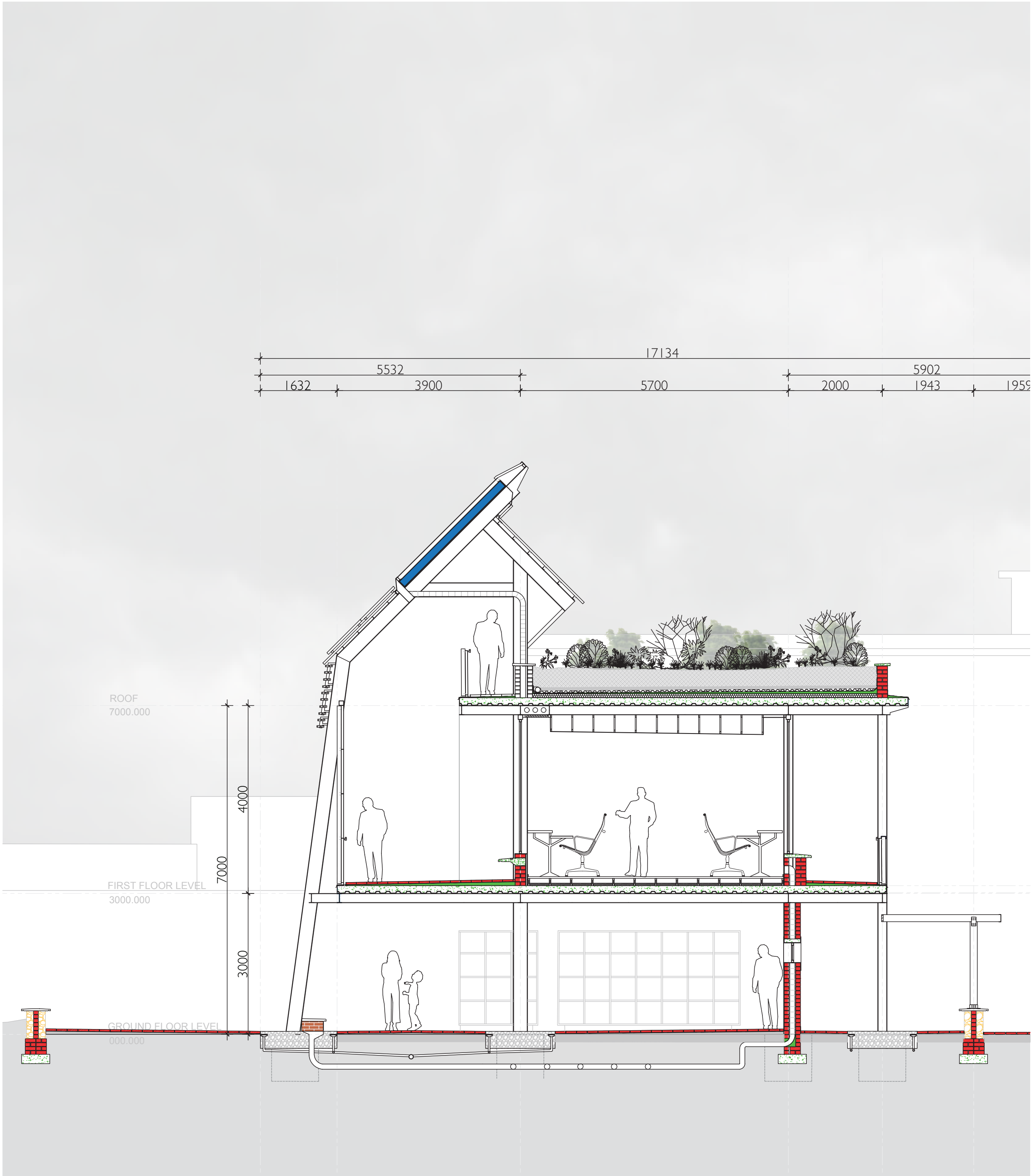


Fig _233 (Spread): Section AA - NTS (Author 2017).

Section Research Office Space / Orientation Chamber

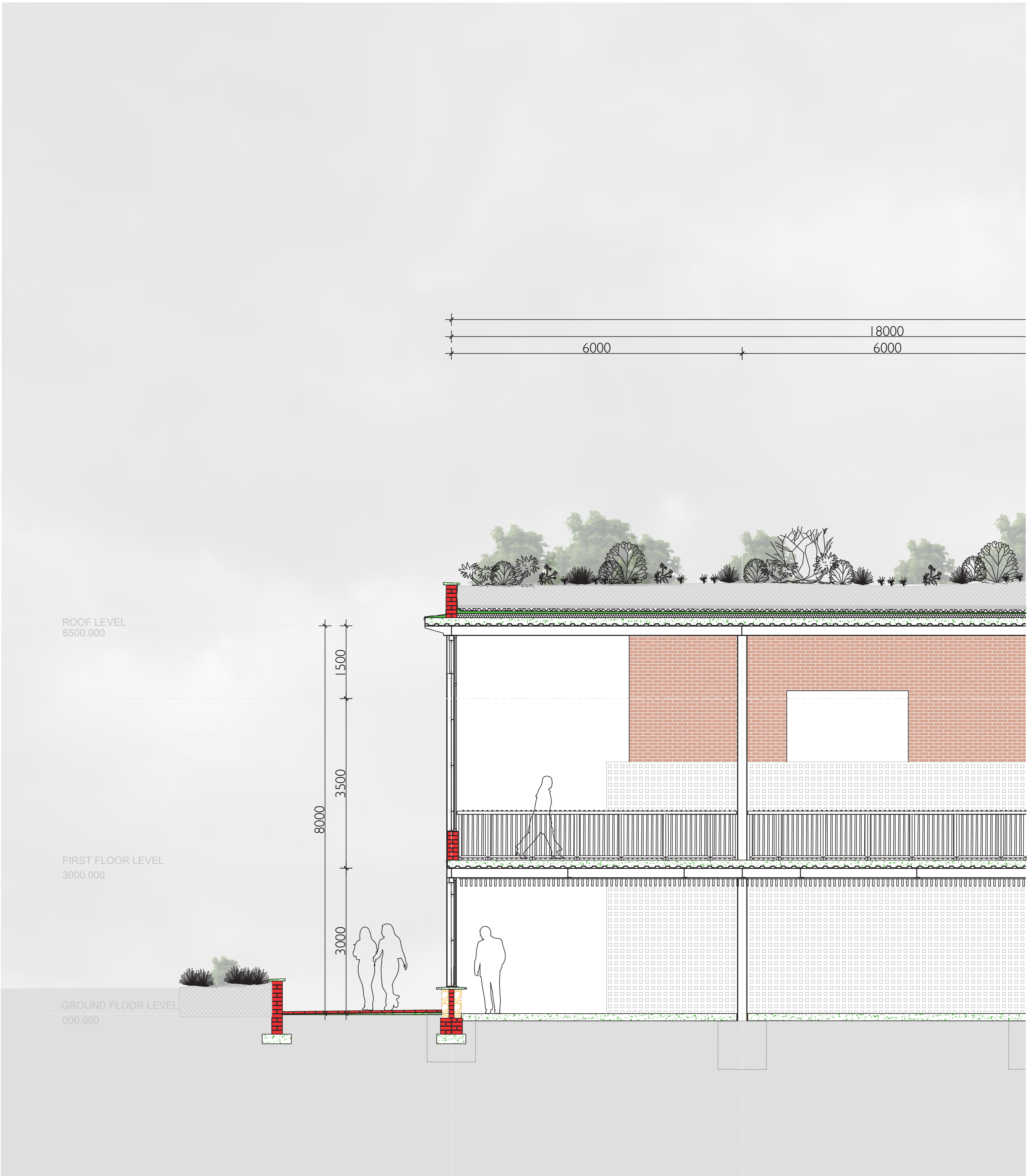
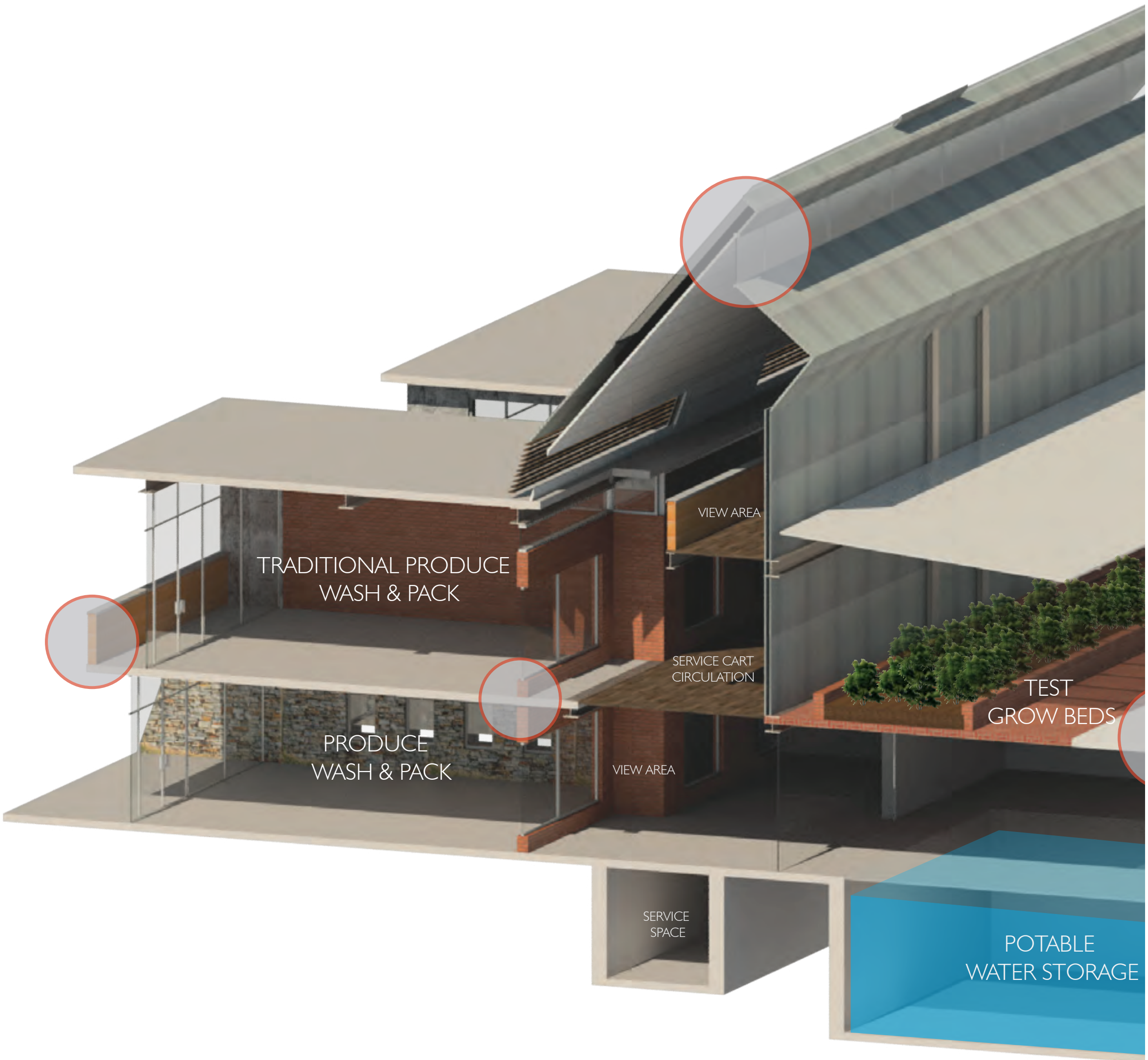


Fig _234 (Spread): Section BB - NTS (Author 2017).


VIEW AREA
TRADITIONAL PRODUCE
WASH & PACK
SERVICE CART
CIRCULATION
TEST
GROW BEDS
PRODUCE
WASH & PACK
VIEW AREA
SERVICE
SPACE
POTABLE
WATER STORAGE

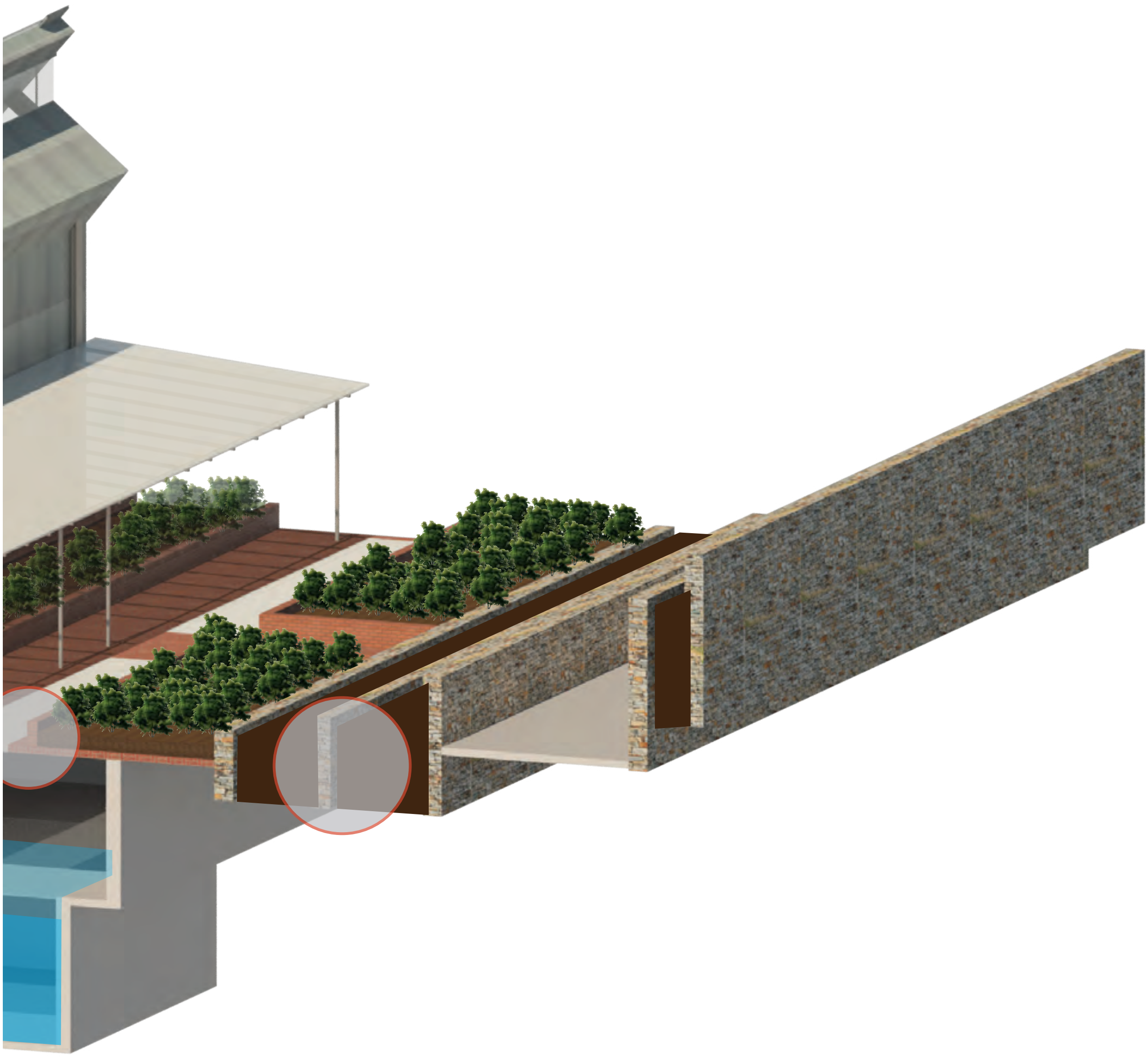


Fig _235 (Spread): 3D Section of Chamber - NTS (Author 2017).

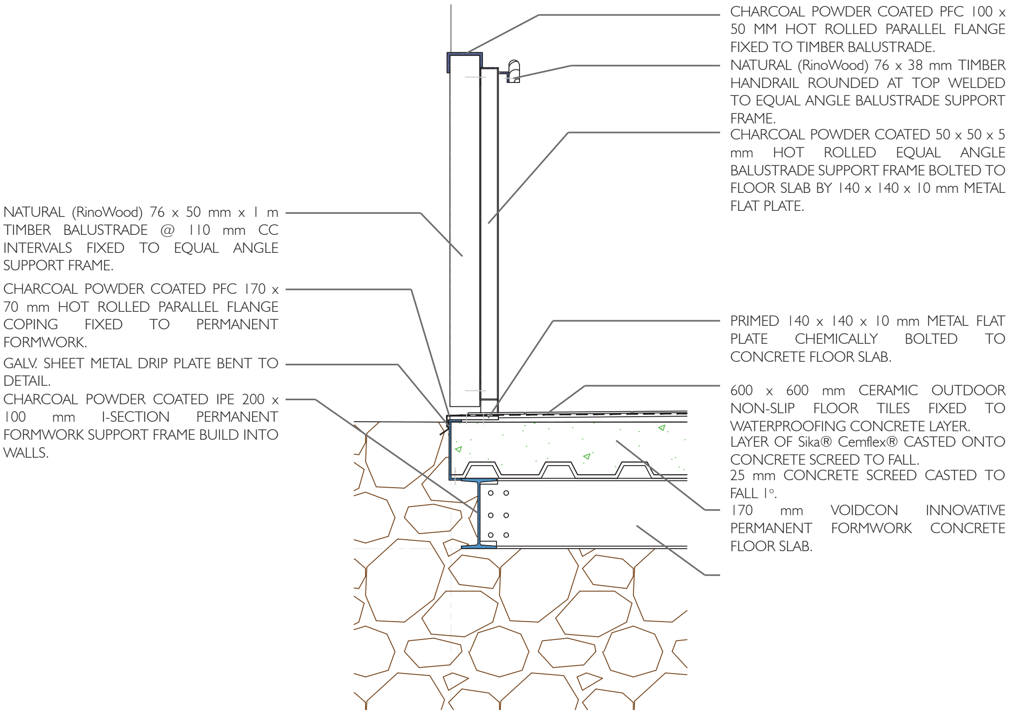


Fig _236 (Above): Detail 1- NTS (Author 2017).

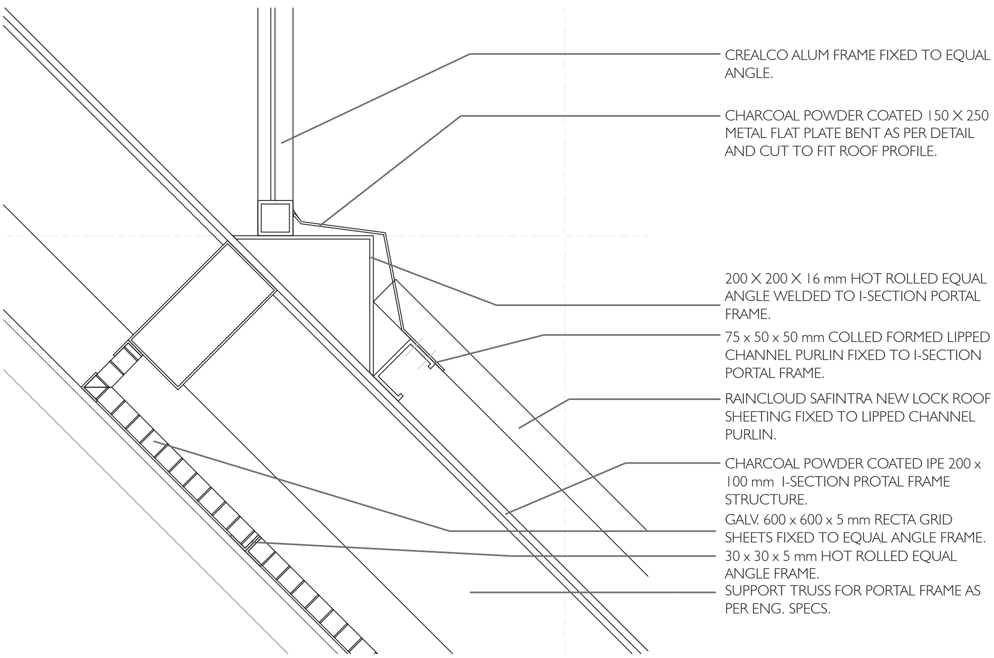


Fig _237 (Above): Detail 2- NTS (Author 2017).

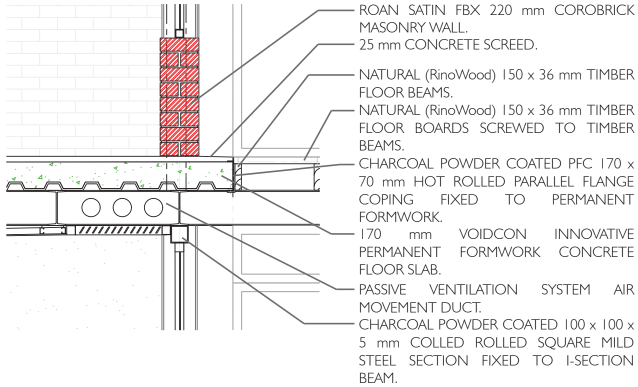


Fig _238 (Above): Detail 3 - NTS (Author 2017).

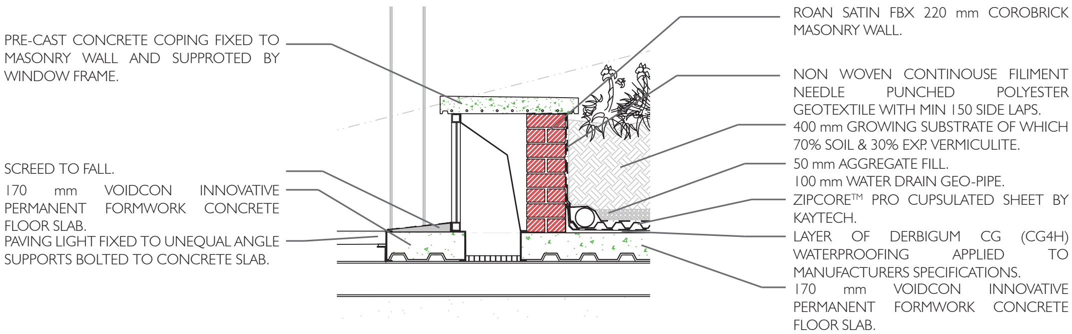


Fig _239 (Above): Detail 4 - NTS (Author 2017).

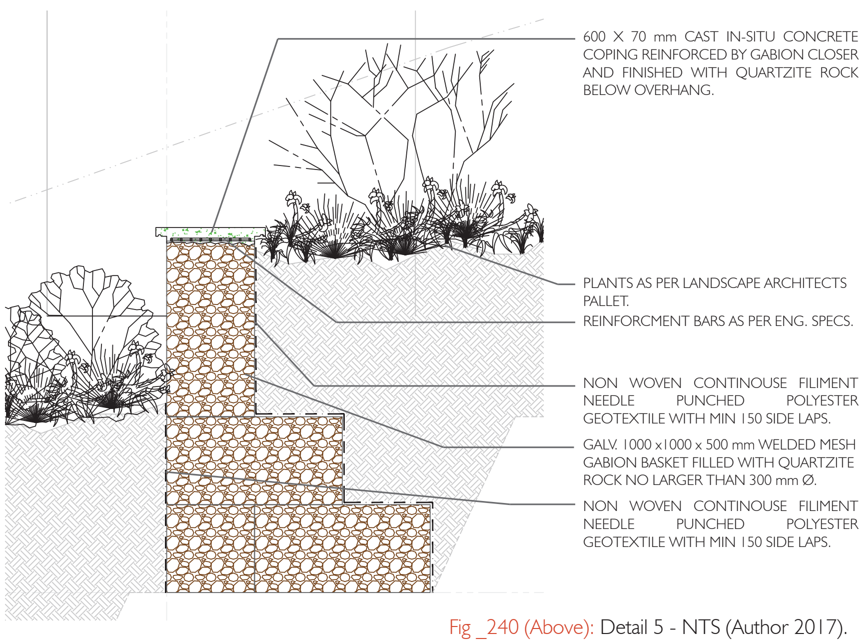


Fig _240 (Above): Detail 5 - NTS (Author 2017).

Common Name: Bracken
Scientific Name: Pteridium aquilinum
Use: Insect repellent.

Common Name: Mountain Medlar
Scientific Name: Vangueria parvifolium
Use: Edible Berries.

Common Name: Parsley Fern
Scientific Name: Cheilanthes hirta
Use: Roots for lice and fleas.

Fig _241 (Above): Plant Information 1 - 3 (Author 2017).

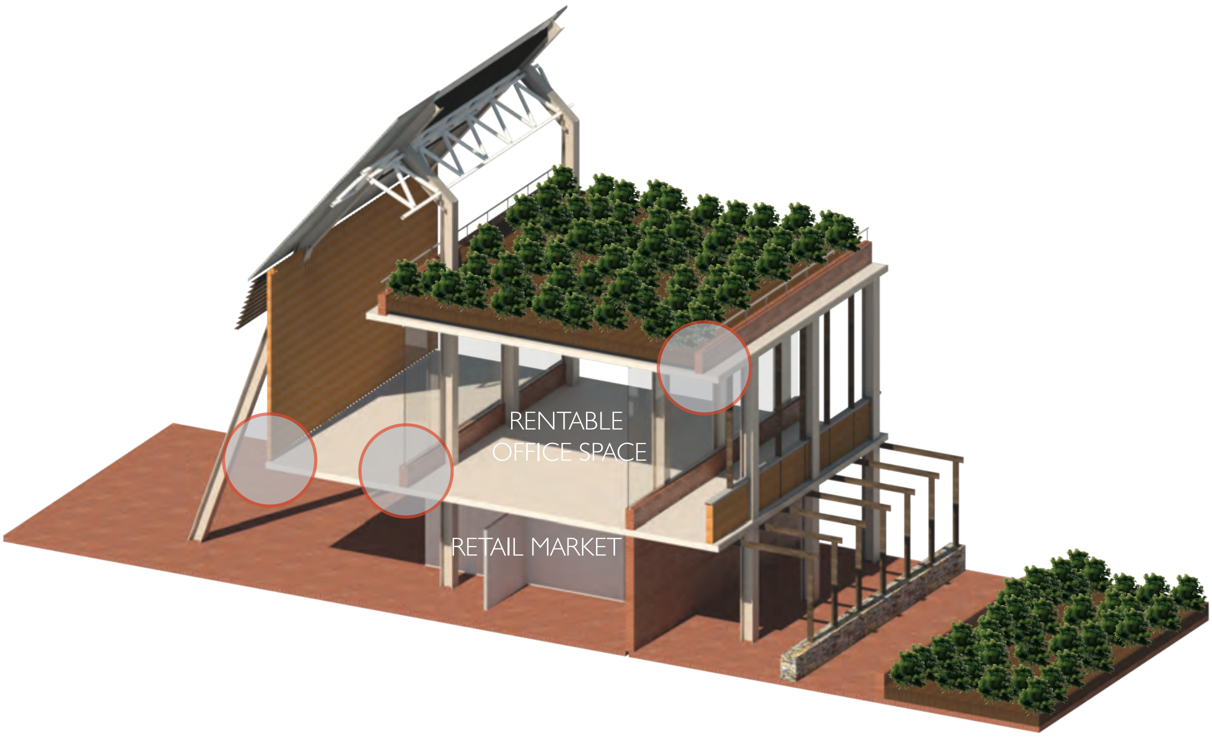


Fig _242 (Above): 3D Section of Rentable Office Space and Retail Market (Author 2017).

Common Name: Wild Wormwood
Scientific Name: Artemisia afra
Use: Various fevers and influenza.
Relief of toothache, earache and nosebleeds.
Insect repellent.

Common Name: Cats Whiskers
Scientific Name: Ocimum obovatum
Use: Herbal remedies and cooking.

Common Name: Poison Bulb
Scientific Name: Boophone disticha
Use: Remedies for muscular disorders.

Fig _243 (Above): Plant Information 4 - 6 (Author 2017).

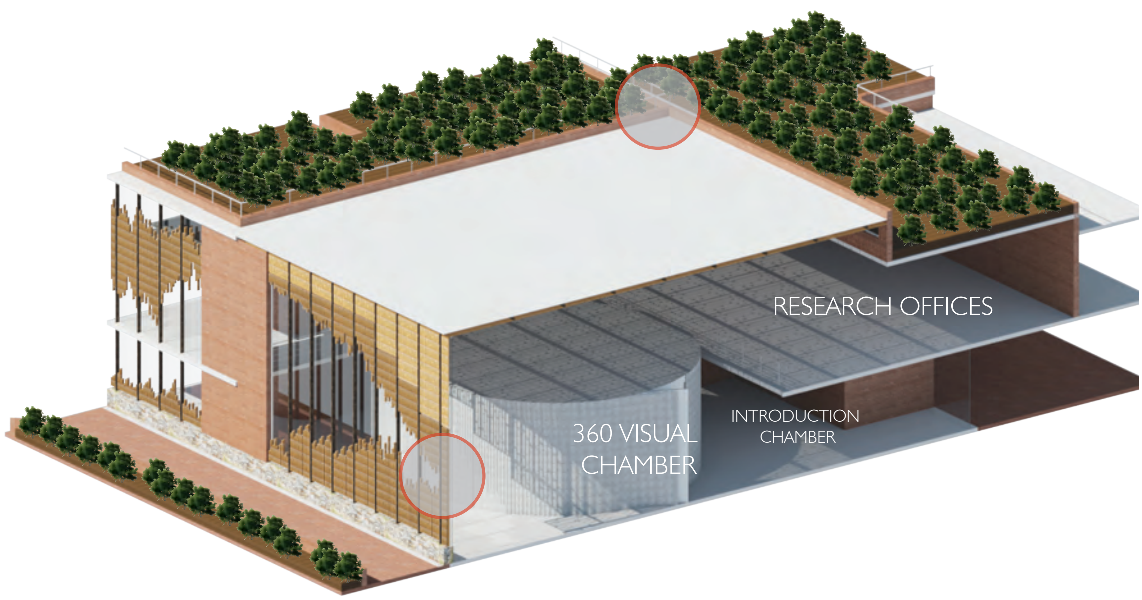


Fig _244 (Above): 3D Section of Research Office Space and Introduction Chamber (Author 2017).

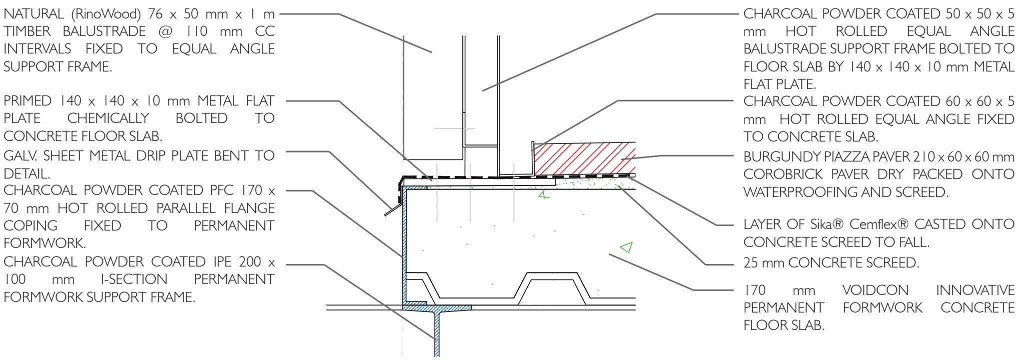


Fig _245 (Above): Detail 6 - NTS (Author 2017).

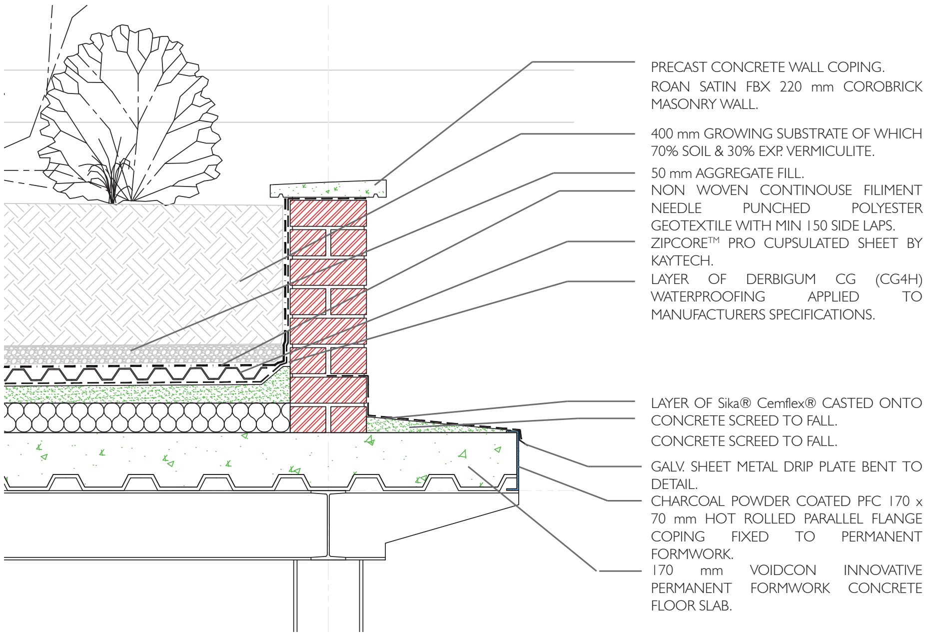


Fig _246 (Above): Detail 7 - NTS (Author 2017).

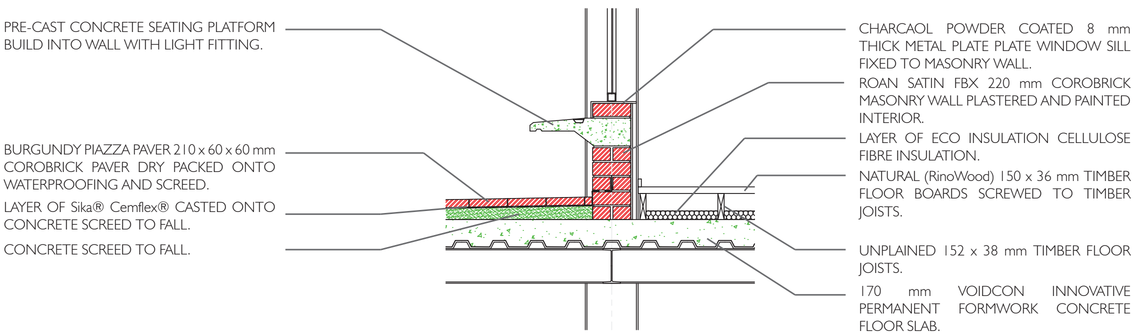


Fig _247 (Above): Detail 8 - NTS (Author 2017).

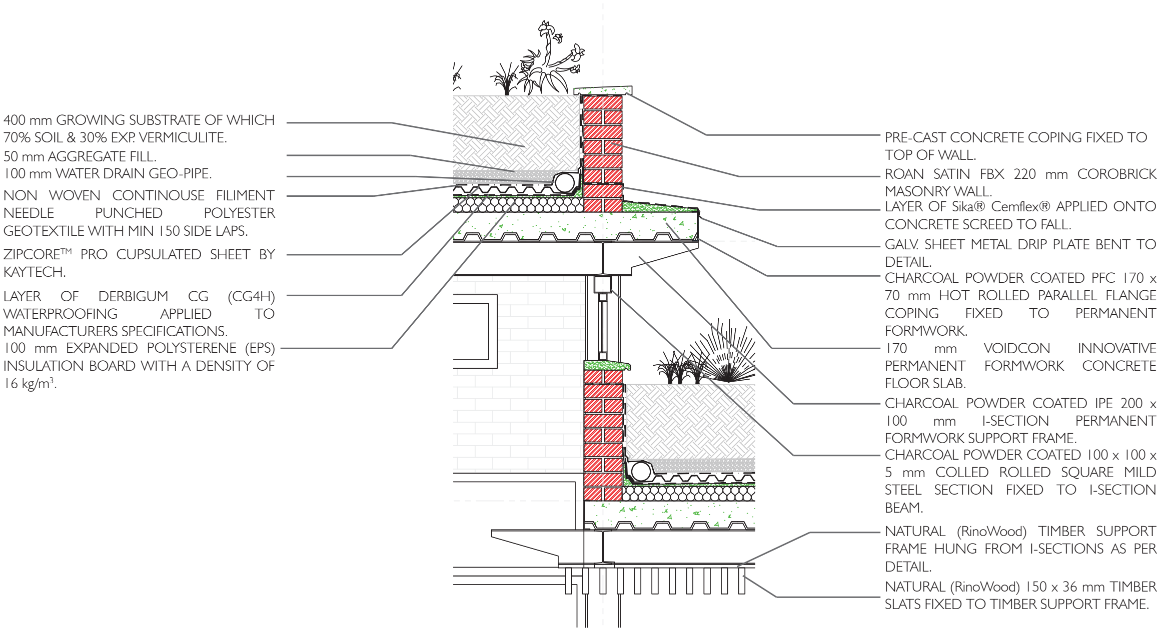


Fig _248 (Above): Detail 9 - NTS (Author 2017).

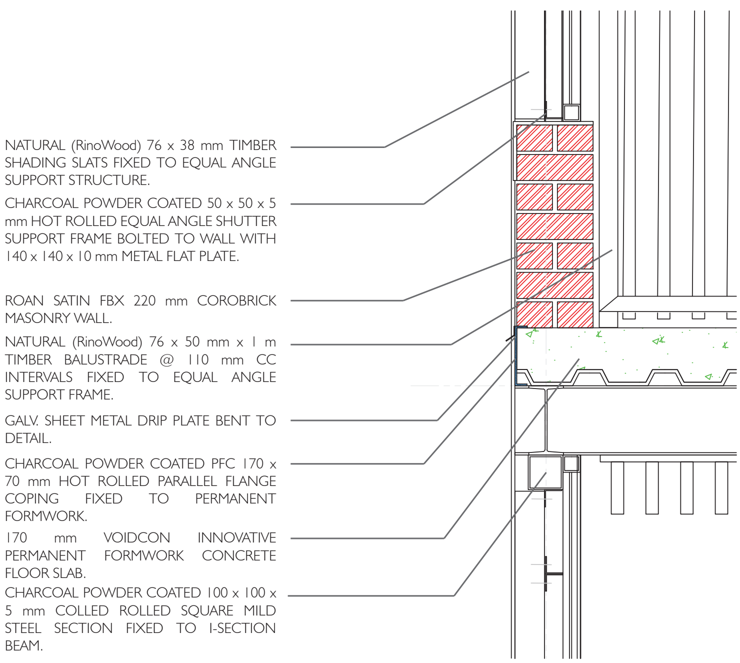


Fig _249 (Above): Detail 10 - NTS (Author 2017).