16
environmental considerations

As part of the technical and technological development of the project, Part 03 unpacks some of the main environmental considerations in the design of the transitional housing roof, grey water recycling and thermal performance of the living units.

[a]
The roof: formal, functional & environmental explorations

The roof explorations started off as a formal exploration informed by the shapes and forms of the existing buildings' roofs in order to honour and build on the existing architectural palimpsest (Figure 16.1. and 16.3.). This leads to various explorations of roof shapes that allow for adequate light and ventilation in the transitional housing units. As habitable living spaces, it was necessary to consider northern solar radiation and light for user comfort (Figure 16.4.).

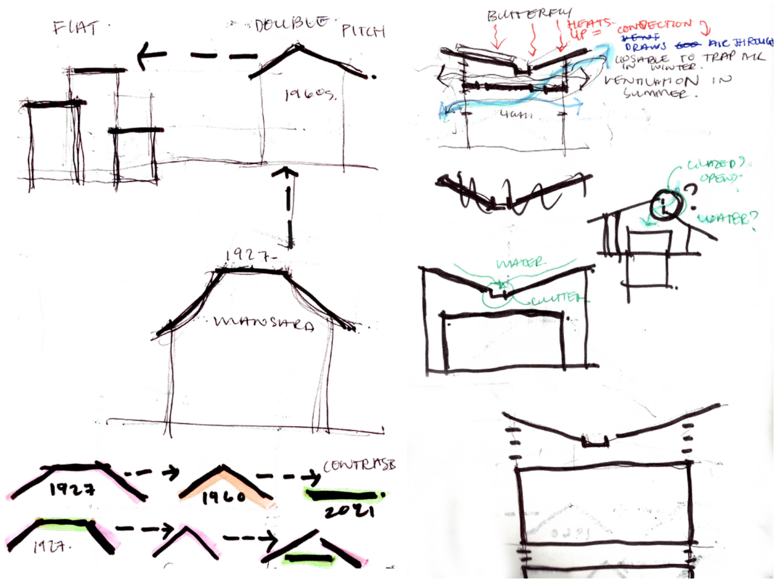
Further exploration of the roof considered admitting light to the top floor units in such a way that a simple double-pitched roof is split into two sections along the middle of the living unit bays to allow light to penetrate both sides of the 6m bay if partitions were to divide the space (Figure 16.6.). A large central channel marks this intersection and allows rainwater to drain towards collection tanks above the circulation and ablution cores. The materiality and construction of this roof was considered on section and plan sketches (Figure 16.5. and 16.6.), using the material language of a load-bearing concrete frame and a timber pole roof structure extending into the tectonic shading device over the circulation.

The roof serves various purposes, including a functional purpose where it rests on the permanent structural elements (concrete structure) in order to free the internal spaces below it, which allows for flexibility. Additionally, it serves a contextual purpose to relate to the existing roof forms and heights, and along with the pergola structures, it indirectly references the tectonic informal structures built with timber pole and branch skeletons. Lastly, it serves as a unifying element, binding all the elements and spaces below that manifest on various levels of the scale of permanence.

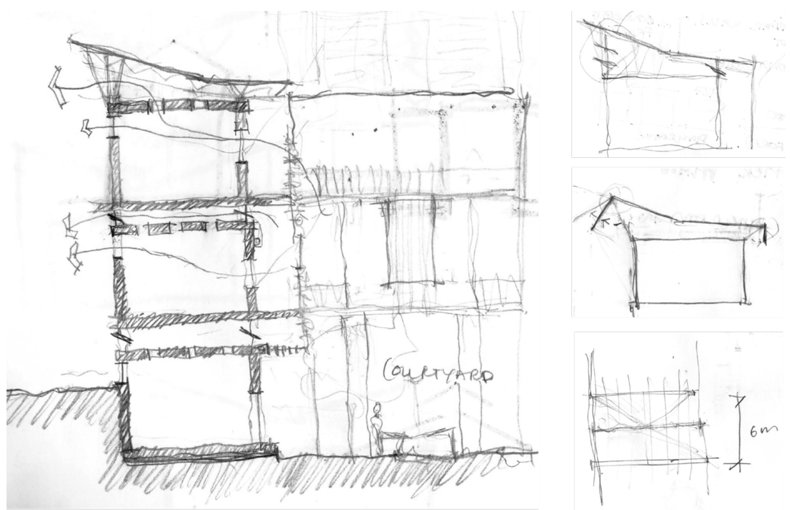
Fig. 16.4. Top left, page 117: Considering solar angles in roof form (Author 2021).

Fig. 16.5. Top right, page 117: Exploring pitched roof with central channel, roof construction/materials (Author 2021).

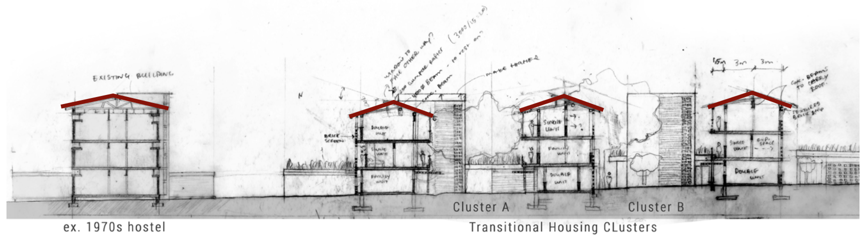
Fig. 16.6. Bottom left, page 117: Latest iteration of roof form with central channel, roof structure and spacing on plan (Author 2021).



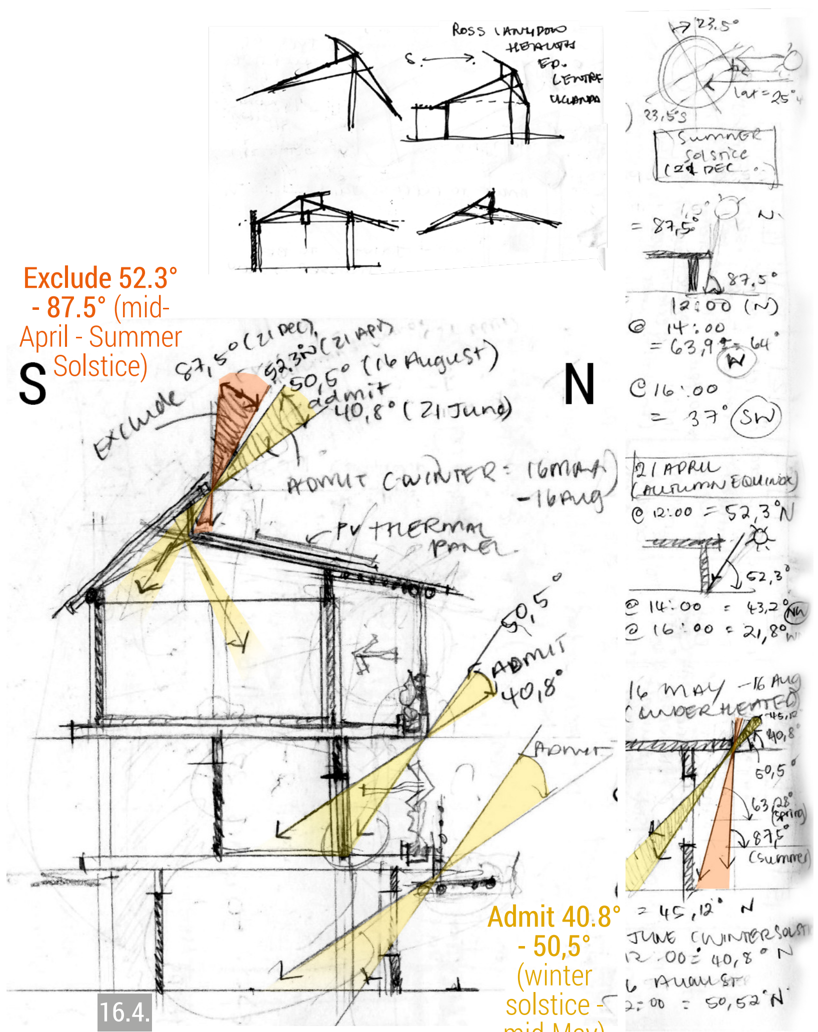
16.1. Explorations of roof shape based on existing forms (Author 2021).



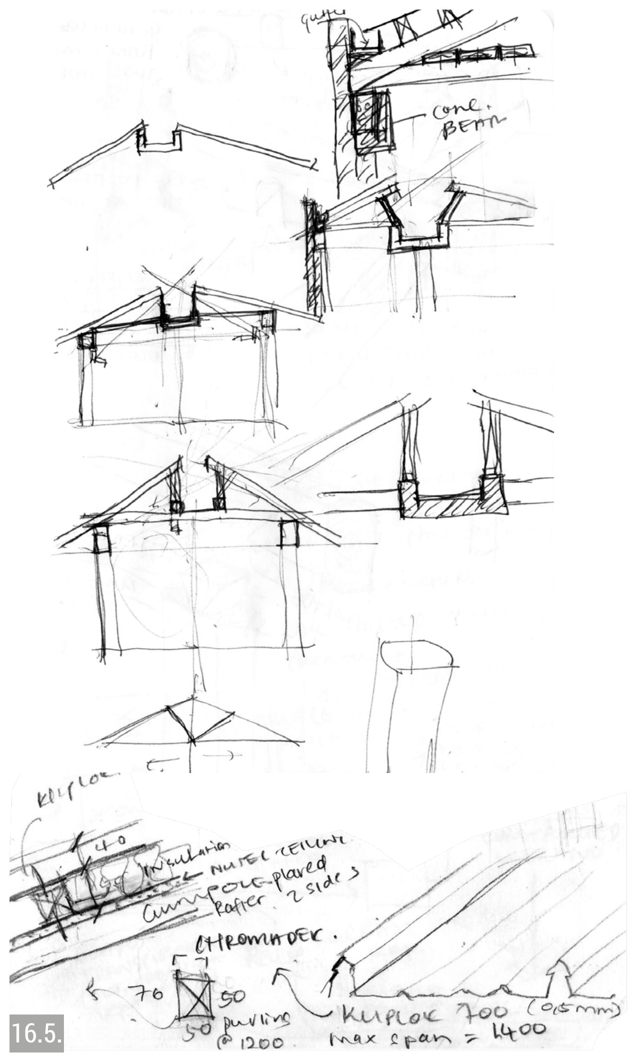
16.2. Exploration of roof in terms of ventilation (Author 2021).



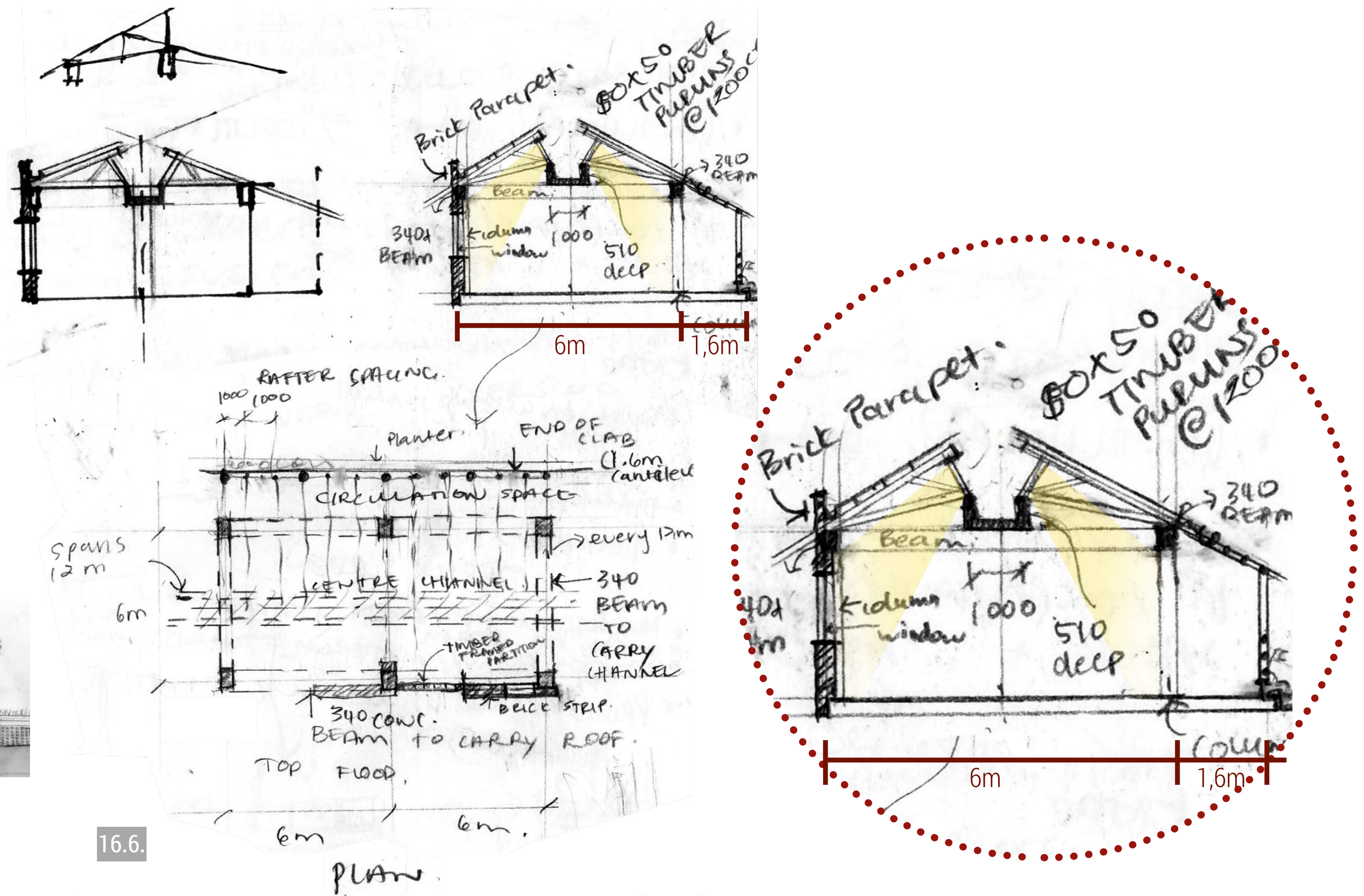
16.3. Iteration 2 section – roof shape relates to existing roofs (Author 2021).



16.4.



16.5.



16.6.

[b]

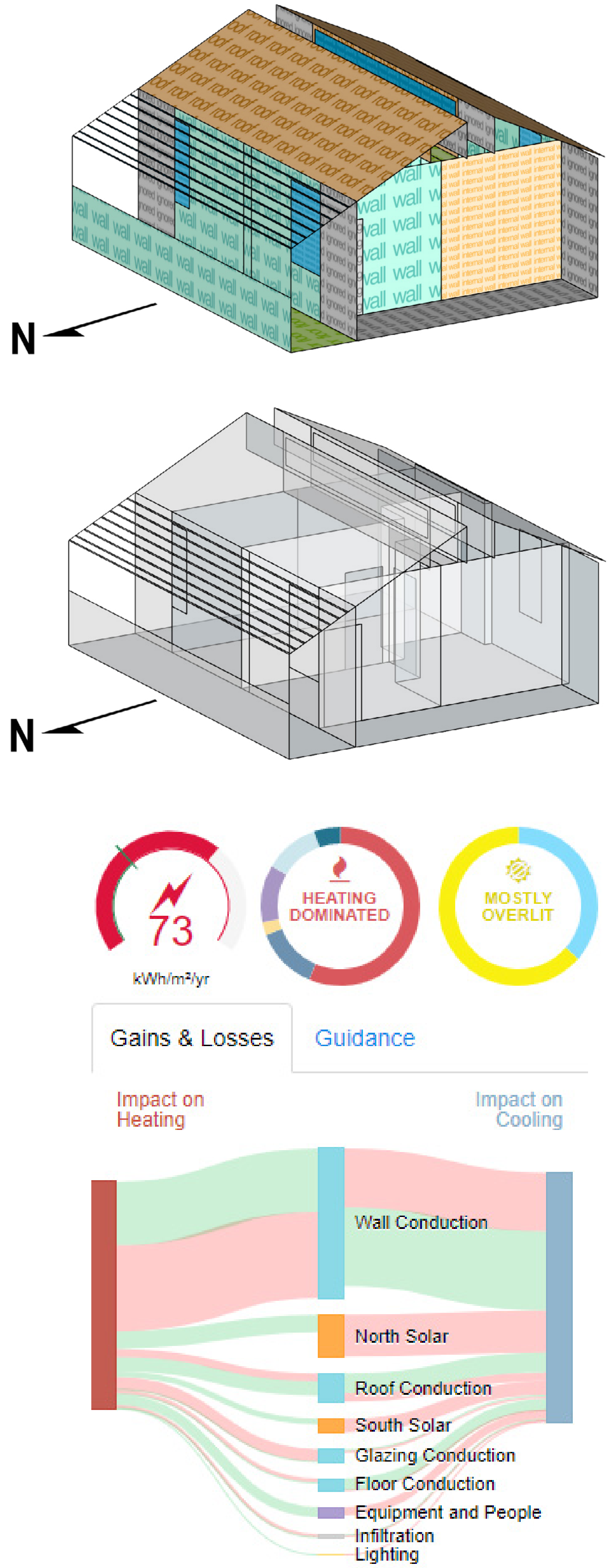
Climatic & environmental informants

Some of the climatic and environmental informants include solar angles, prevailing wind direction and average precipitation (refer to Appendix 5 for additional environmental and climatic data). Using these, the design has been adjusted to perform sustainably in terms of thermal conductance/performance of the building envelope (see Figure 16.8), required shading/overhangs to exclude harsh summer solar radiation and admit winter sun, rainwater harvesting and overall sustainability (using the SBAT tool (Gibberd 2020) – see Figure 20.4. in Appendix 5).

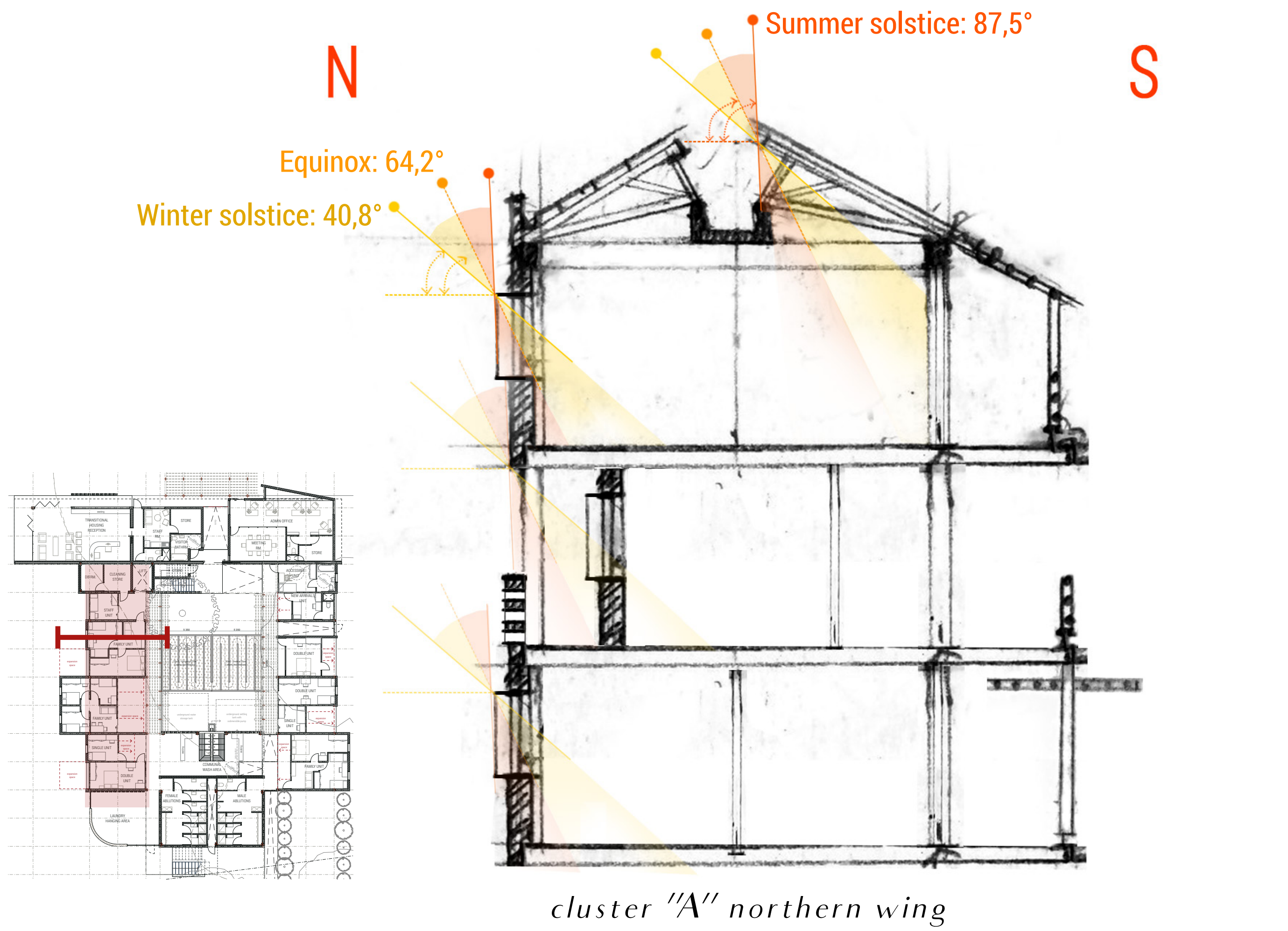
Pretoria receives an average annual rainfall of about 600mm (meteoblue.com n.d.) which has been recorded into monthly data to be used in the yield calculations for rainwater harvesting (see section d] on "Rainwater harvesting" and Appendix 5). Harvesting rainwater in the high-rainfall summer months allows for reserves during winter months to assist in meeting the non-potable water demands.

The thermal performance of one family living unit was tested using Sefaira to evaluate the thermal efficiency of the chosen materials and construction as well as the inclusion of shading devices etc. (see Figure 16.7). The R-values of the walls (brick and partition/infill panels) are considerably higher than required for climatic zone 2 in which Pretoria falls, according to SANS 204-2 (2011:12). Similarly with the floor and roof construction, where additional EPS insulation was added in the ceilings to increase the R-values of these constructions. The Sefaira evaluation indicates that Northern solar thermal gain is affecting the need for cooling to a fairly large extent. Therefore additional shading devices should be used to exclude more unwanted Northern sun. The wall conduction can also be improved even further to lower the need for heating and cooling.

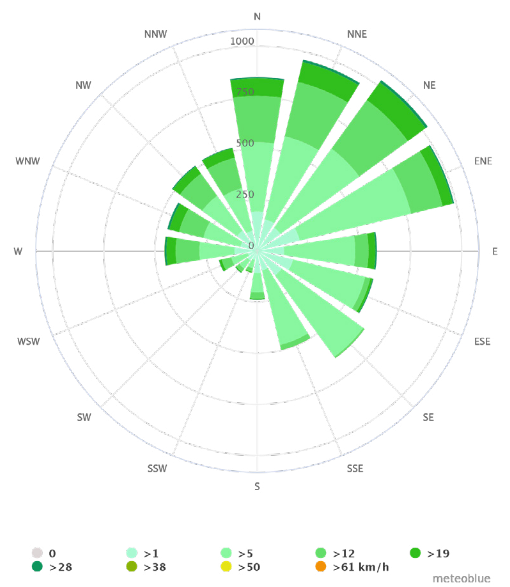
Lastly, the project achieved a score of 4.2. out of 5 on the Sustainable Building Assessment Tool (SBAT) (Gibberd 2020) (see Figure 20.4. in Appendix 5). Although this is considered high, additional improvements can be made in areas such as "energy", "materials" and "waste". As indicated also on the Sefaira evaluation, energy usage could be improved, by implementing renewable energy sources such as photovoltaic panels and solar water heating systems and geothermal heating/cooling systems to improve thermal comfort and energy performance.



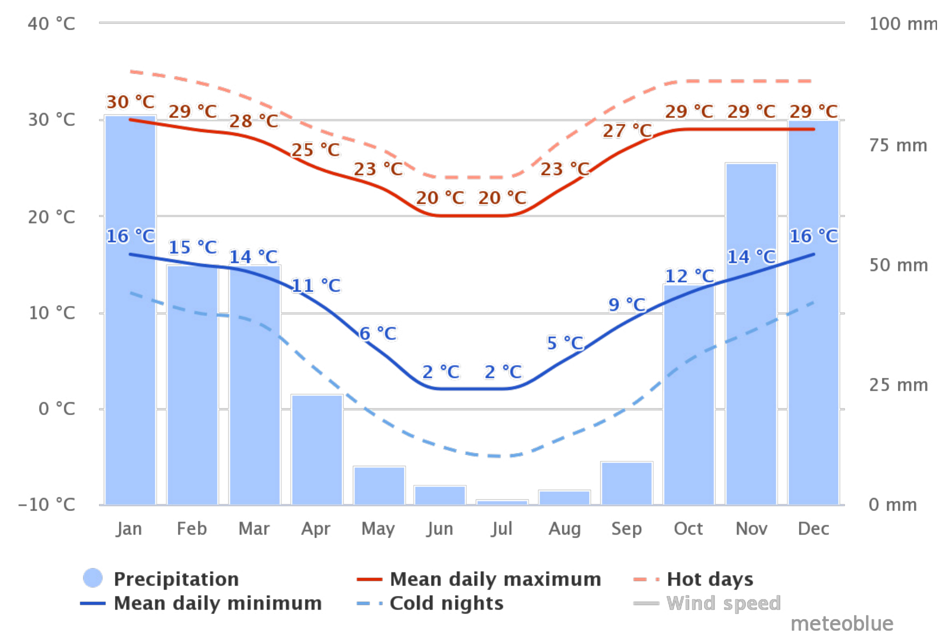
16.7. Sefaira evaluation of thermal performance of a family unit on the southern wing of Cluster A based on envelope u-values, orientation and shading (Author 2021).



16.8. Solar angles, exclusion of summer sun and admission of winter sun through northern facade and roof light of Cluster A's northen housing wing (Author 2021).



16.9. Wind rose for Pretoria, Gauteng (meteoblue.com n.d.)



16.10. Average temperatures and precipitation for Pretoria, Gauteng (meteoblue.com n.d.)

[c]

Constructed wetland system & grey water recycling

The water system for the transitional housing clusters consists of the grey water recycling component coupled with a rainwater collection component. This section will unpack the grey water recycling component in more detail.

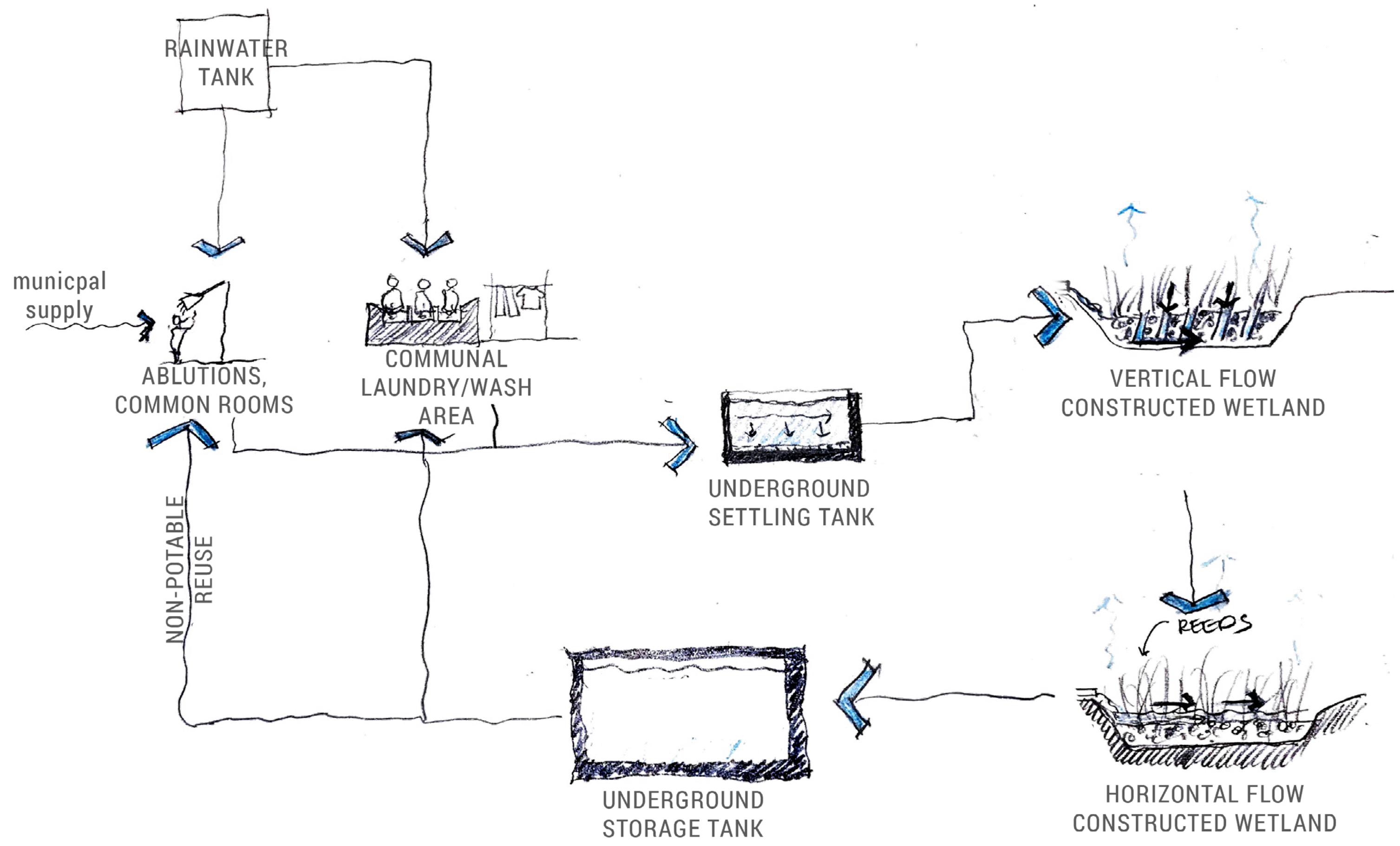
Grey water from domestic activities of transitional housing refers to wastewater from "bathing, cooking, dishwashing and laundry", whereas black water refers to wastewater from toilets (Ramprasad 2018: 155). The grey water from the transitional housing clusters can be recycled, stored and reused for non-potable uses including toilets, clothes washing and irrigation. The grey water would need to be treated to remove organic and inorganic contaminants and chemicals, including those from soaps, detergents, cosmetics, etc. (Ramprasad 2015: 458). Therefore, it is suggested that a baffled hybrid constructed wetland system (HYCW) be used in each of the private courtyards of the housing clusters, modelled after Ramprasad's (2015, 2018) system for a student hostel in India.

The HYCW consists of an underground settling tank with a submersible pump (pre-treatment), a vertical (subsurface) flow constructed wetland section (VFCW), a horizontal (subsurface) flow constructed wetland section (HFCW) and an underground storage tank (Ramprasad 2015: 458) (Figure 16.11. and 16.12.). The system combines the advantages of both types of constructed wetlands to ensure a sufficient quality of treated water. In the VFCW, water flows vertically through filter media and a top layer of aquatic vegetation (Phragmites Australis), which provides habitats for microorganisms to degrade organics (Ramprasad 2018: 155, Stauffer and Spuhler 2014). The VFCW minimises bad odours and provides greater absorption of toxic and organic contaminants (Vosloo 2017: 15), while the HFCW allows water to flow horizontally through filter media and vegetation to further treat the water.

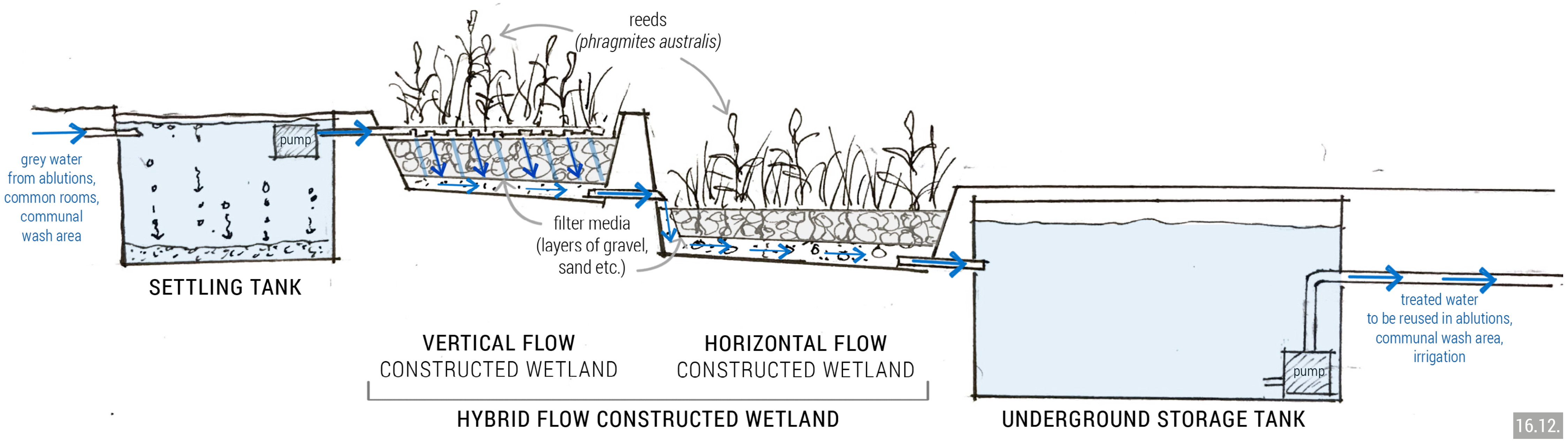
Design considerations include slope, sizing and distance travelled by the water to ensure retention time of no less than 3 days (Vosloo 2017: 13). Sizing of the wetland system depends on the amount of water entering the system daily, considering the surface area of the wetland should be a minimum of two to five times the surface area of the water entering daily, assuming the same depth (Vosloo 2017: 13). A baffled system was chosen to increase the distance that the water travels, therefore allowing a longer retention period (Ramprasad 2018: 156). Some stormwater is expected to enter the system, especially during rainy seasons; therefore, this was also considered when sizing the wetland systems.

Grey water from the ablutions, common rooms and the communal wash area is transferred to the underground settling tank in the courtyard. After solids have settled, the high-level water is pumped intermittently from the settling tank into the inlet at the top of the VFCW (Ramprasad 2015: 458, Stauffer and Spuhler 2014). The water filters vertically through vegetation, gravel and sand layers, and eventually flows into the HFCW (Ramprasad 2015: 459, 460). Here, the horizontal subsurface flow through the sand and gravel filter media further treats the water that eventually flows into an underground storage tank (Figure 16.11. - 16.14.). This water, along with water from the rainwater collection tanks, can be reused for non-potable uses.

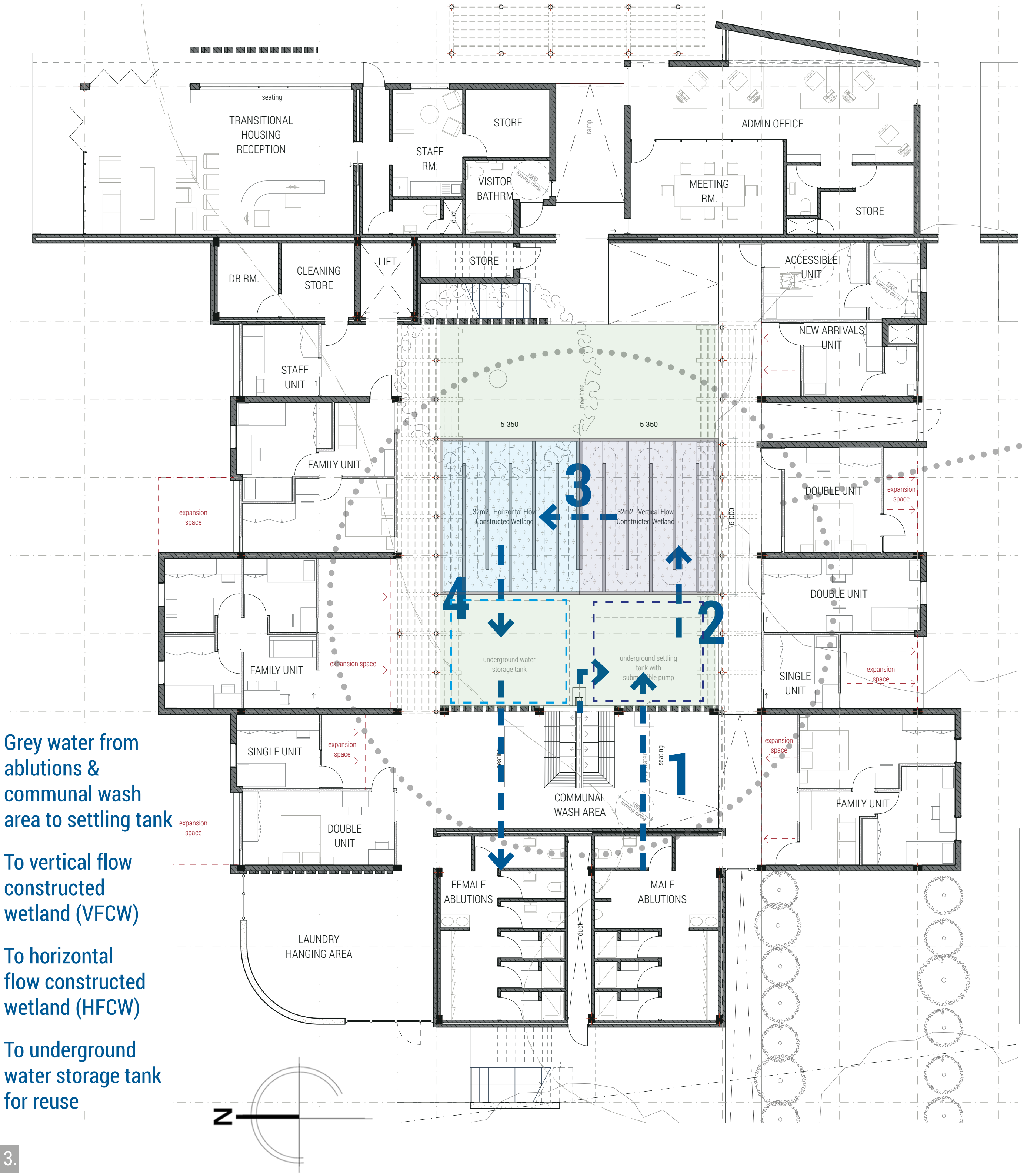
The wetland system softens the courtyard and hard surfaces, provides a living, constantly changing landscape and haven for the users and connects them to nature through the micro-ecosystem that develops here. It also contributes to a cooler micro-climate in the courtyard as water is evaporated and air flows over the wetlands, assisting in the cooling and cross ventilation of the adjacent living units (Figure 16.15.). The recycling of grey water and storage of rainwater also contributes to the resilience of the transitional housing inhabitants and the future of the complex by fostering a culture of environmental- and self-sustainability and independence.



16.11. Diagram of grey water recycling process and components (Author 2021).

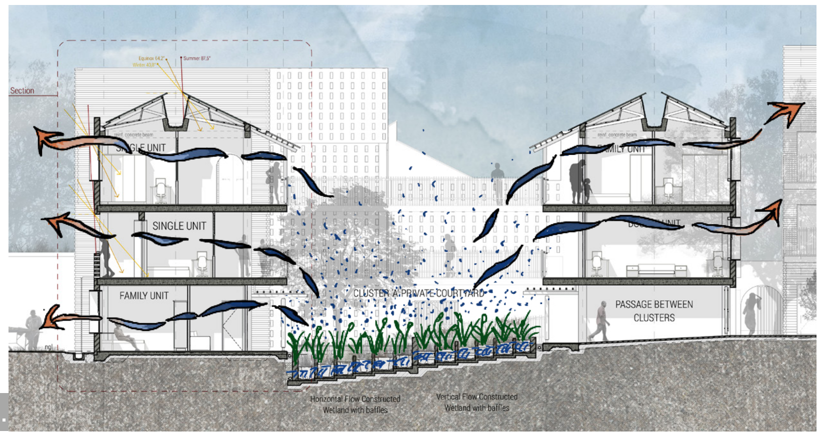


16.12.



1. Grey water from ablutions & communal wash area to settling tank
2. To vertical flow constructed wetland (VFCW)
3. To horizontal flow constructed wetland (HFCW)
4. To underground water storage tank for reuse

16.13.



16.15.

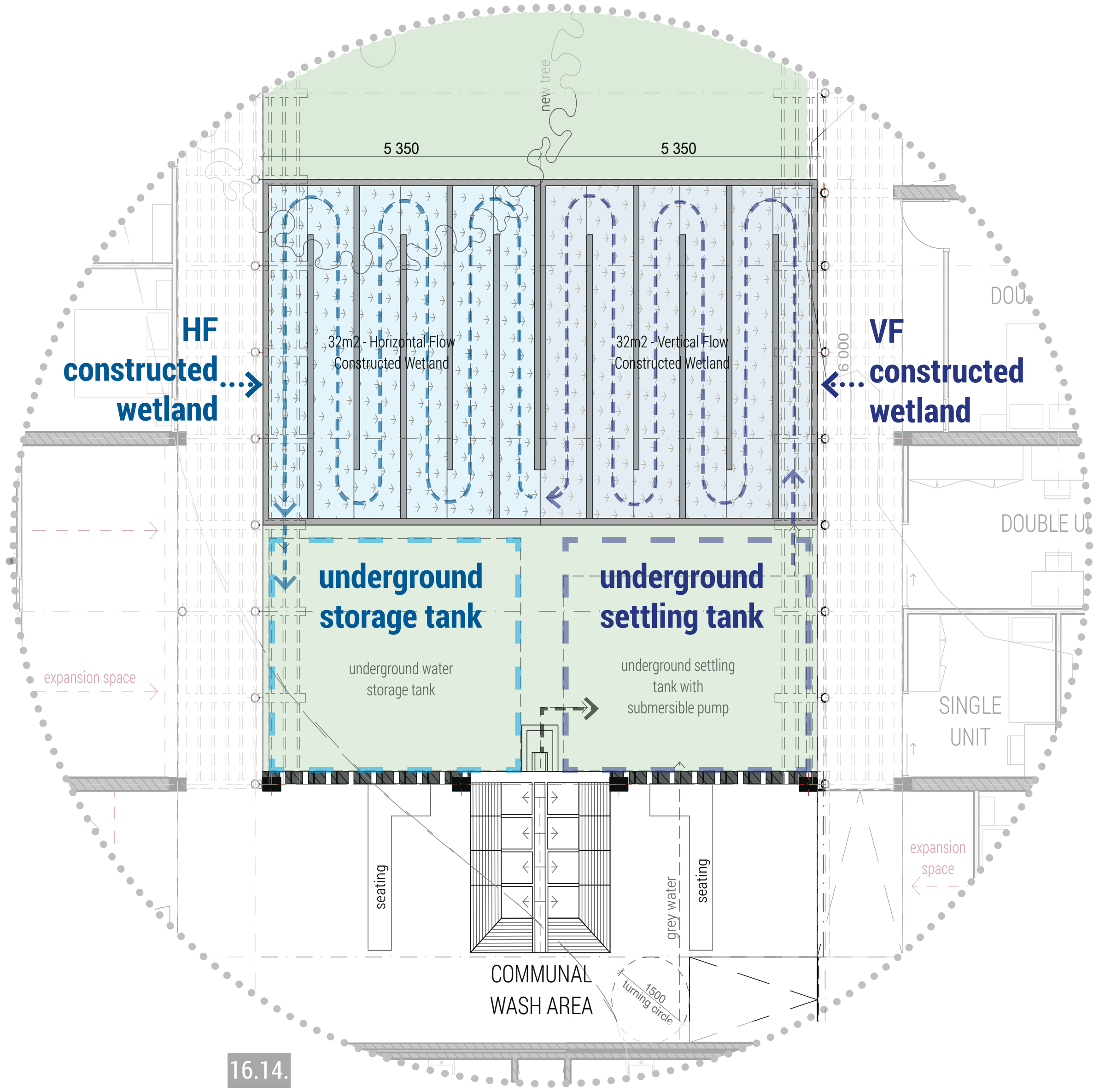
Fig. 6.12. Bottom of previous page: Schematic section diagram through grey water recycling system (Author 2021).

Fig. 16.13. Above: Plan of transitional Cluster A showing water recycling process (Author 2021).

Fig. 16.14. Adjacent page, top right: Baffled hybrid flow constructed wetland system and components on plan in Cluster A courtyard (Author 2021).

Fig. 16.15. Bottom left: Diagram showing evaporative cooling and presence of water that cools air entering the living units (Author 2021).

Fig. 16.16. Adjacent page, bottom right: Table of non-potable water demands and grey water to be recycled (Author 2021).



16.14.

Sizing of the underground storage tank for treated water:

Daily grey water output x 6 (to account for treating and storage of additional rainwater, runoff etc.)
= 5,33 x 7 = 37,31m^3

Therefore, a 40 000L submerged tank of 5m(l) x 4m(w) x 2m(h) is provided to store the treated water for Cluster A. This is positioned in the private courtyard below landscaping.

Some water is lost to evaporation and some is retained by the wetland, therefore water is released from rainwater tanks into the wetland system as needed to meet the non-potable water demands throughout the month.

*Cleaning is not calculated here and would add a considerable load on the non-potable water demand. This would also be accounted for by topping up the wetland system and treated water from rainwater tanks.

Sizing of the constructed wetland system:

Assuming an average depth of 800mm, the total surface area per constructed wetland component (HFCW and VFCW) is calculated as follows:

Daily grey water output surface area = 5,33m^3 / 0,8m
= 6,66m^2

Minimum surface area per HFCW and VFCW:
2 x 6,66m2 = 13,3m^2

Maximum surface area per HFCW and VFCW:
5 x 6,66m2 = 33,3m^2

Therefore, each of the constructed wetland components (HFCW and VFCW) for Cluster A are sized at 30m^2 with an average depth of 0,8m each.

WATER VALUES (Cluster A)

	Monthly (m^3)	Daily (m^3)
Non-potable water demand - Summer (worst case scenario) (toilets, laundry, irrigation)*	135,81	4,53
Total grey water output to be recycled (wash hand basins, kitchen sinks, wash troughs/laundry, showers)	159,93	5,33

16.16.

[d] RAINWATER HARVESTING

The rainwater harvesting system works in conjunction with the grey water recycling system to provide water suitable for non-potable uses including toilet flushing, laundry washing, cleaning and irrigation. Each cluster has its own dedicated catchment tanks and constructed wetland system for future adaptability and in order to ensure water demands are met across the housing clusters. However, excess water collected and treated in each cluster will be diverted to areas on site where it is most needed, such as irrigation of the communal gardens.

For the purposes of evaluating the rainwater harvesting and grey water recycling potential of a single housing cluster, Cluster A was chosen due to its higher occupancy and number of living units compared to Cluster B. Therefore, the water demand would also be higher than Cluster B. Water calculations for Cluster A would follow a similar strategy for Cluster B, where Cluster B requires a lower water demand due to fewer living units and occupancy numbers. Additionally, not considered in this calculation are the social support services planted roofs to the south which could serve as additional catchment areas, where rainwater could be harvested in underground tanks after passing through the planted roof media, and used for non-potable water uses including irrigation.

Rainwater from the roofs and pavement/hard surfaces is collected via gutters and channels and passes through first flush diverters before being stored in rainwater tanks. From there, the rainwater is gradually fed into the constructed wetland system (as needed) to be treated and eventually reused along with the treated grey water. All treated water from the underground storage tank in the private courtyard is fed back into the cluster for non-potable use. The rainwater is used as reserves whenever the treated grey water is not sufficient to meet the non-potable water demand. Rainwater tanks, distributed on site as underground tanks and on the roofs of the ablution and vertical circulation cores as vertical water storage tanks, are provided to collect as much water as possible based on the available space, and store it until it can be used to supplement non-potable uses in the Cluster. The remainder of the stored water is used for non-potable uses outside of the cluster including irrigation of the landscaping and communal gardens.

CLUSTER 'A' CATCHMENT AREA (A)

	Area (m2)	C (runoff coefficient)	C (weighted)
Roofs			
Reception & admin offices (planted roofs)	225	0,5	0,10
TH living units (pitched metal sheeting)	252	0,9	0,21
Subtotal	**477**		
Paving			
Permeable	**102**	0,75	0,07
Non-permeable	**493**	0,9	0,41
Ground floor	201		
First floor	147		
Second floor	145		
Total	**1072**		0,80

16.17. Table of water catchment area calculations (Author 2021).

AVERAGE MONTHLY PRECIPITATION (P)
(PRETORIA, GAUTENG)

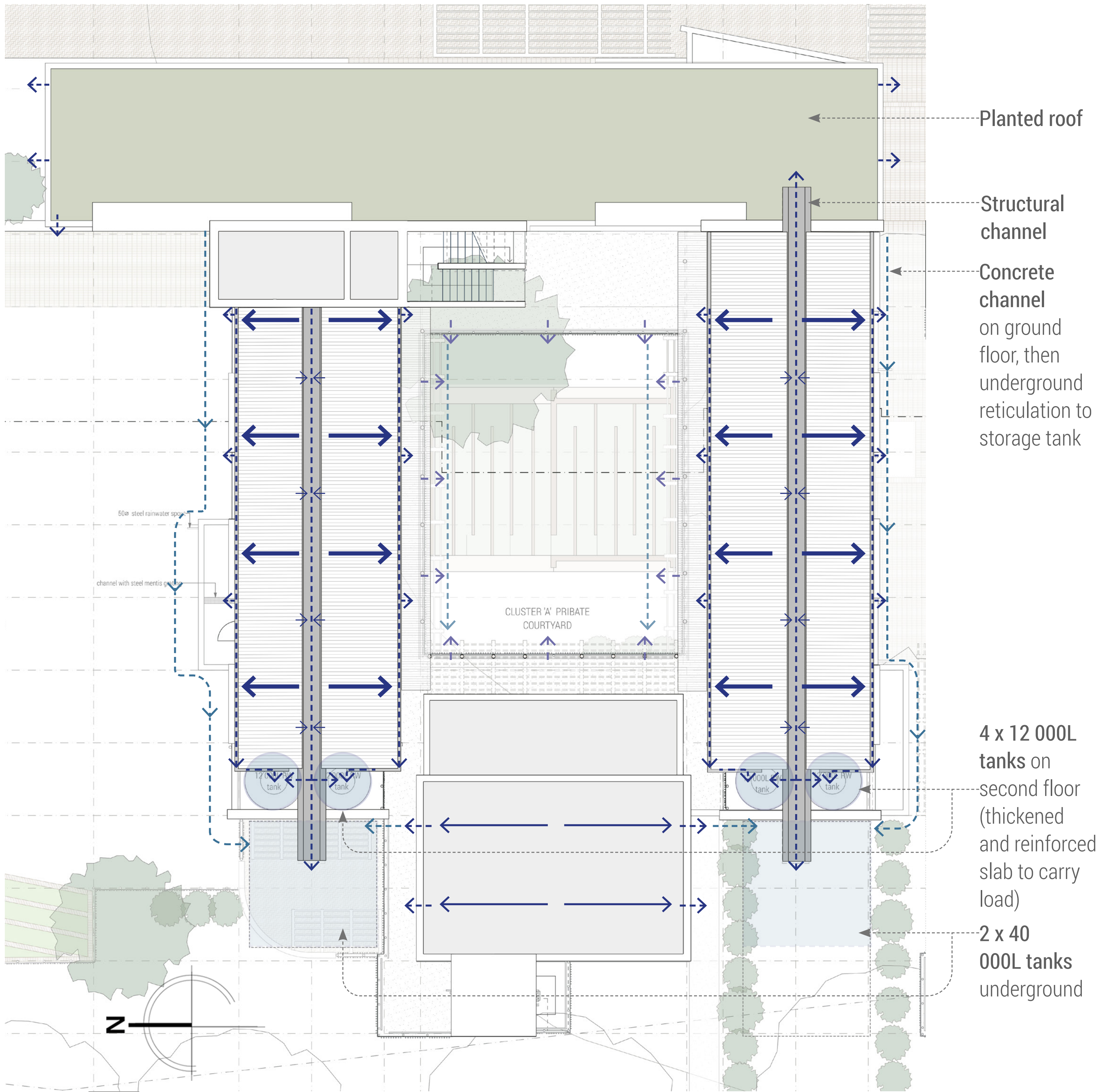
Month	Precipitation (mm)
January 2020	107
February 2020	99
March 2020	82
April 2020	38
May 2020	14
June 2020	5
July 2020	2
August 2020	5
September 2020	18
October 2020	51
November 2020	88
December 2020	98
Annual Total	607

16.18. Table of average monthly precipitation (Author 2021).

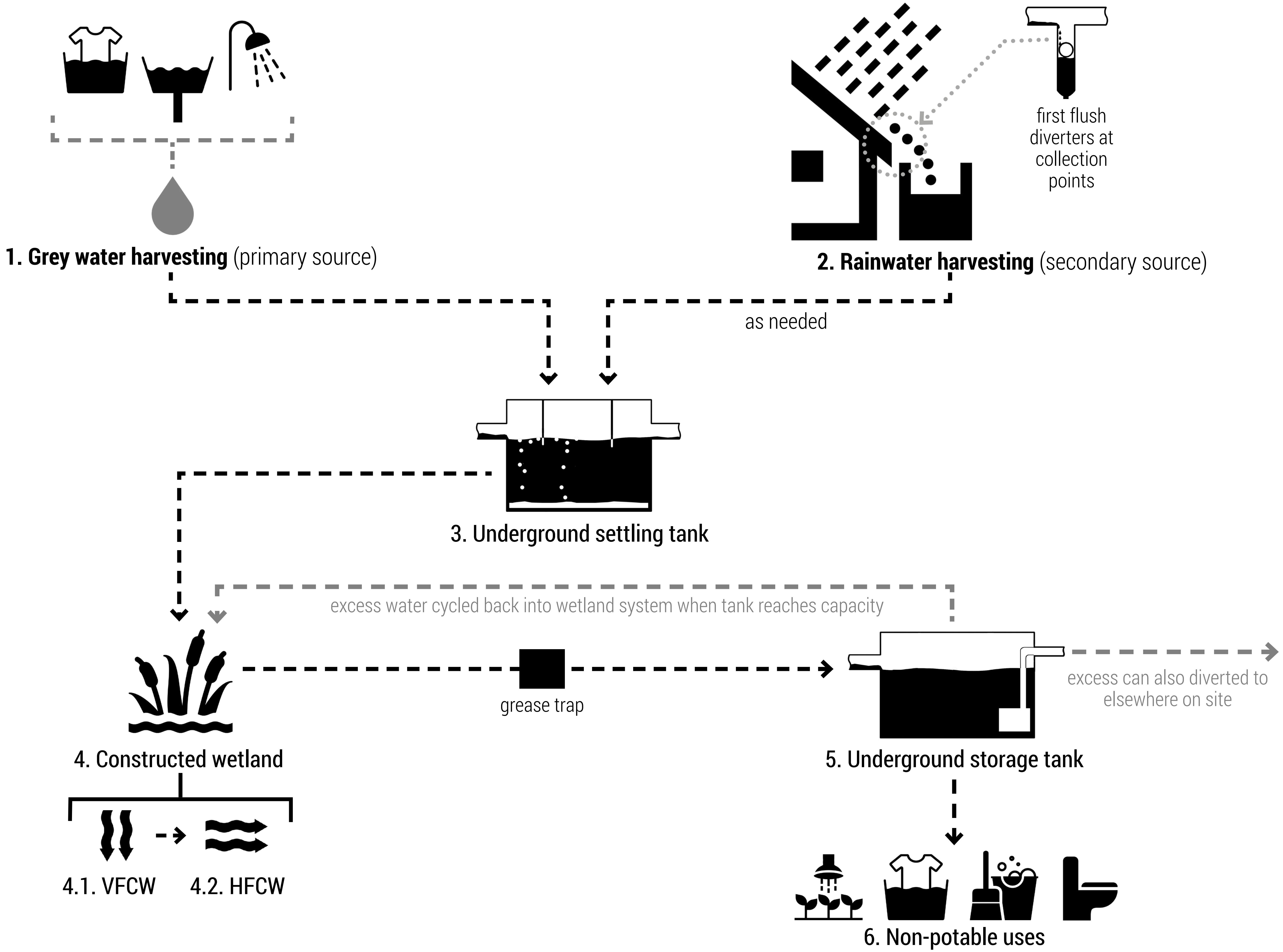
RAINWATER YIELD

Month	Average monthly precipitation (m)	Yield (m^3) Yield = P x A x C
January	0,107	91,97
February	0,099	85,09
March	0,082	70,48
April	0,038	32,66
May	0,014	12,03
June	0,005	4,30
July	0,002	1,72
August	0,005	4,30
September	0,018	15,47
October	0,051	43,83
November	0,088	75,64
December	0,098	84,23
Annual Total	0,607	521,72

16.19. Monthly rainwater yield calculations (Author 2021).



16.20. Rainwater catchment diagram for Cluster A (Author 2021).



Infographic showing water harvesting and recycling system combined (Author 2021). Some icons from nounproject.com (n.d.). 16.21.