GROUNDING COMMUNITY

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Designing for social cohesion in Windhoek's informal settlements

EXTREME GRADUATION STUDIO
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i

Table of Content.

Foreword.

After seven years of studying architecture, I have arrived at this final chapter. Throughout those years, I found myself increasingly asking what architecture means to me. Of course, I love well-considered buildings with beautiful materiality. But more importantly, I see architecture as a means to help people. A building can give people a voice.

That is why I chose the Extreme graduation studio. I want my architecture to give meaning to a place and make life a little better for the people who live there. The project in Windhoek pushed me out of my comfort zone: a different context and culture demands a different way of thinking, and that is what drew me to it.

The study trip to Namibia made this process unforgettable. After so much research from behind a desk, it was something else entirely to see the situation with my own eyes. The conversations we had revealed the true complexity of what is happening in Windhoek in ways no paper could. My project is not a solution to the informal settlement crisis as a whole, but it might offer a spark of hope to the people who live there. It can give them a voice.

I would like to thank Joost and Atze for their support throughout this process. Joost taught me to look beyond the immediate brief in order to understand the bigger picture and respond to it meaningfully. Atze challenged me to design for reality, to ground every choice in research and numbers, and to go just one step further in the elaboration.

Finally, I want to thank my dear family and Finn for being there.

Enjoy reading!

Elke

Reading Guide.

This report documents the research and design process behind Grounding Community, a neighbourhood intervention in Brendan Simbwaye, an informal settlement on the outskirts of Windhoek, Namibia.

The report is structured in four chapters that build on one another. The introduction (1) sets out the problem, the relevance of the project, and the research and design questions that guide the work. These questions directly shape the approach taken in chapter two. The approach (2) describes how the research was conducted: through literature review, a field trip to Windhoek, and iterative design research. The insights gathered here form the foundation for the design brief that closes the chapter and sets the agenda for the following design process. The results (3) translate the brief into architecture, moving from the first spatial principles and massing studies through to the final plans, climate strategies, structural choices, and technical elaboration. The conclusion (4) then steps back to reflect on the outcomes and answer the research questions posed at the start.

Technical calculations, system sizing, and case studies referenced throughout the report can be found in the appendix.

01

Introduction.

1.1 PROBLEM STATEMENT

Namibia is undergoing a rapid urban transition (Weber and Mendelsohn, 2017). Driven by the hope of employment and a better life, people are leaving rural areas for the city in growing numbers (Nghiulikwa, 2008). These people are now concentrated largely in the informal settlements on the edges of Windhoek: over 220,000 people live there, almost half of the city's total population (Namibian Sun, 2025).

This rapid transition is driving urban growth at a pace that far exceeds the municipality's capacity to respond. As a result, the informal settlements lack basic services such as water and electricity. The majority of residents do not have household-level access to water or sanitation, with severe consequences for their safety and health (Lewis et al., 2018).

The municipality sometimes places shared sanitation as a temporal solution, but these facilities often suffer from poor maintenance, leading to disuse and neglect (Shiras et al., 2018). Besides that, they are often very unsafe, especially for women and children (WHO, 2022). The deeper problem is not just the absence of sanitation, but the absence of the social and spatial conditions to make these facilities work.

Informal settlements lack not only sanitation, but also the public spaces, community facilities and markets that allow social ties to form and strengthen (von Wietersheim, 2023). This absence of communal anchors reinforces social fragmentation in neighbourhoods already marked by diversity, mistrust, and a history of colonialism and apartheid (Roland et al., 2022).

Yet the potential is real. It lies not in the facilities themselves, but in the people who use them. During a fieldtrip to Windhoek, a shared water point revealed what it could be: women gathered, children were playing, clothes were being washed and conversations were happening. But the space itself offered nothing beyond its single function: there were a few trwees for shade and some improvised chairs, but no reason to stay. These moments of gathering should be built upon. Research shows that when residents are involved in the use of shared spaces, it strengthens community cohesion, which can reduce crime (VPUU, 2021).

This project takes that observation as its starting point: upgrading an informal settlement requires not just better infrastructure, but a spatial intervention that rebuilds the conditions for community life.

> “They weighed my body
> checked my blood
> tested my urine
>
> but they could not measure the
>
> hope
>
> I carried.”

1.2 RELEVANCE

The conditions this project responds to are not unique to a single site. Across the informal settlements, all people face the same lack of adequate housing, sanitation, and public space (Weber and Mendelsohn, 2017). This project does not attempt to address all of that. Instead, it focuses on one neighbourhood intervention, grounded in the belief that small, targeted actions can have an outsized impact. As VPUU (2021) argues, the best approach is to “seek interventions which are small and manageable in scale, which can act as catalysts and which can link easily to similar or parallel projects in scaling up to more extensive programmes.” This project takes that principle as its foundation. By designing a place where people can come together, it explores what architecture can contribute to communities with scarce resources and limited support.

1.3 OBJECTIVE AND MOTIVATION

This project investigates how a neighbourhood intervention that combines housing upgrade with a community centre can strengthen resilience and social cohesion in an informal settlement in Windhoek. The architectural ambition is to design a place that does not work against its environment, but with it.

Windhoek is a hilly city, and the site reflects this: a sloped plot that, rather than being a constraint, becomes a design opportunity. The project explores how the topography can inform the spatial organisation of the building, by directing rainwater, enabling natural ventilation, and responding to solar orientation. In doing so, it aims to demonstrate that the absence of centralised infrastructure need not be a barrier to quality. Decentralised water and energy systems are integrated into the design, not as technical add-ons, but as architectural elements in their own right.

Throughout, the project draws on locally available materials and construction techniques, grounding the design in its context and making it legible, maintainable, and meaningful to the community it serves.

1.4 RESEARCH AND DESIGN QUESTIONS

How can architectural design activate community life in an informal settlement in Windhoek, through a neighbourhood intervention that responds to its social and spatial context?

- How can the programme and spatial layout of the community centre generate ongoing activity and presence for all residents?
- How can decentralised, low-tech systems for water, sewage and energy be integrated as architectural elements of the design?
- How can the design respond to the topography, climate, and locally available materials of the site?

1.5 SCOPE

The project will be taking place in the informal settlements of Windhoek, more specific the settlement Brendan Simbwaye. It is a small settlement that is well established within Windhoek's expanding urban periphery. The location reflects the city's wider trend of spatial inequality due to rapid growth.

The settlement consists of approximately 372 households with an estimated population of 1,172 residents. One household consists of approximately 3.8 persons, most of them have been living in the area for about five to ten years (GIZ, 2026). This indicates a degree of permanence despite the absence of formal tenure and basic services.

The selected plot is situated at one of the highest points in the area, next to the main road leading into the settlement. Centrally located within a 500-metre radius of the majority of households, it meets the Sphere guideline (2018) for maximum walking distance to shared WASH facilities, while also serving as a clearly recognisable landmark within the neighbourhood. The terrain is hilly, with a slope of approximately 14 percent.

The program will consist of housing and a community centre, including a market square, library, internet café, workshop space, an office for the caretaker and sanitation facilities.

The project does not aim to redesign the settlement as a whole. Rather, it focuses on a single plot intervention: the upgrading of a small number of existing dwellings combined with the design of a community centre. This defined scope makes the challenge manageable and allows for architectural depth.

Figure 1 - overview of Brendan Simbwaye. *Source: Guus Teunen*

Figure 2 - Map of Brendan Simbwaye. *Source: own work*

02

Approach.

2.1 METHODS

This project draws on three main methods. First, a literature review and case study analysis were conducted to build a theoretical foundation and explore precedents for decentralised systems, community space design, and informal settlement upgrading. Second, a field trip to Windhoek provided direct insight into the context of Brendan Simbwaye, including observations of daily life and informal conversations with local organisations and residents. Third, design research was carried out through a process of sketch models, variant studies, and drawings, allowing design decisions to be tested and refined throughout the project.

2.2 FIELD TRIP

A field trip to Windhoek in January brought the research to life. Conversations with local organisations revealed insights that would have been impossible to gain from behind a desk. In a country with such complex history, many cultural nuances exist, especially regarding privacy and density. The influences of apartheid are still visible in the mentality of Namibian people today, beautifully captured in the quote “we can share a wall, but not a floor”.

Visiting Brendan Simbwaye made the research tangible. The moment the paved roads changed into sandy paths and self-built structures, the absent of basic services became visible. A school is located nearby, and when the school day ended, many children made their way home through the streets, making the lack of public space and adequate sanitation feel even more urgent.

However, small shops and makeshift churches showed potential, and a conversation with local youth revealed a generation full of ideas for their neighbourhood. They are held back not by ambition, but by a system struggling to keep pace with the city’s growth.

> “We can share a wall
> but not a floor”
>
> ~ Interview on studytrip

Figure 3 - Informal market. *Source: Guus Teunen*

Figure 4 - Brendan Simbwaye. *Source: Guus Teunen*

Figure 5 - Everyday life. *Source: Guus Teunen*

Figure 6 - Outcome of workshop with youth group Brendan Simbwaye . *Source: GIZ (2026)*

2.3 LOCATION ANALYSIS

The following maps show the selected plot within Brendan Simbwaye, examining its position within the neighbourhood, its relationship to existing infrastructure, and the physical conditions of the site.

Figure 7 - Selected project area. *Source: own work*

Figure 8 - Mobility. *Source: own work*

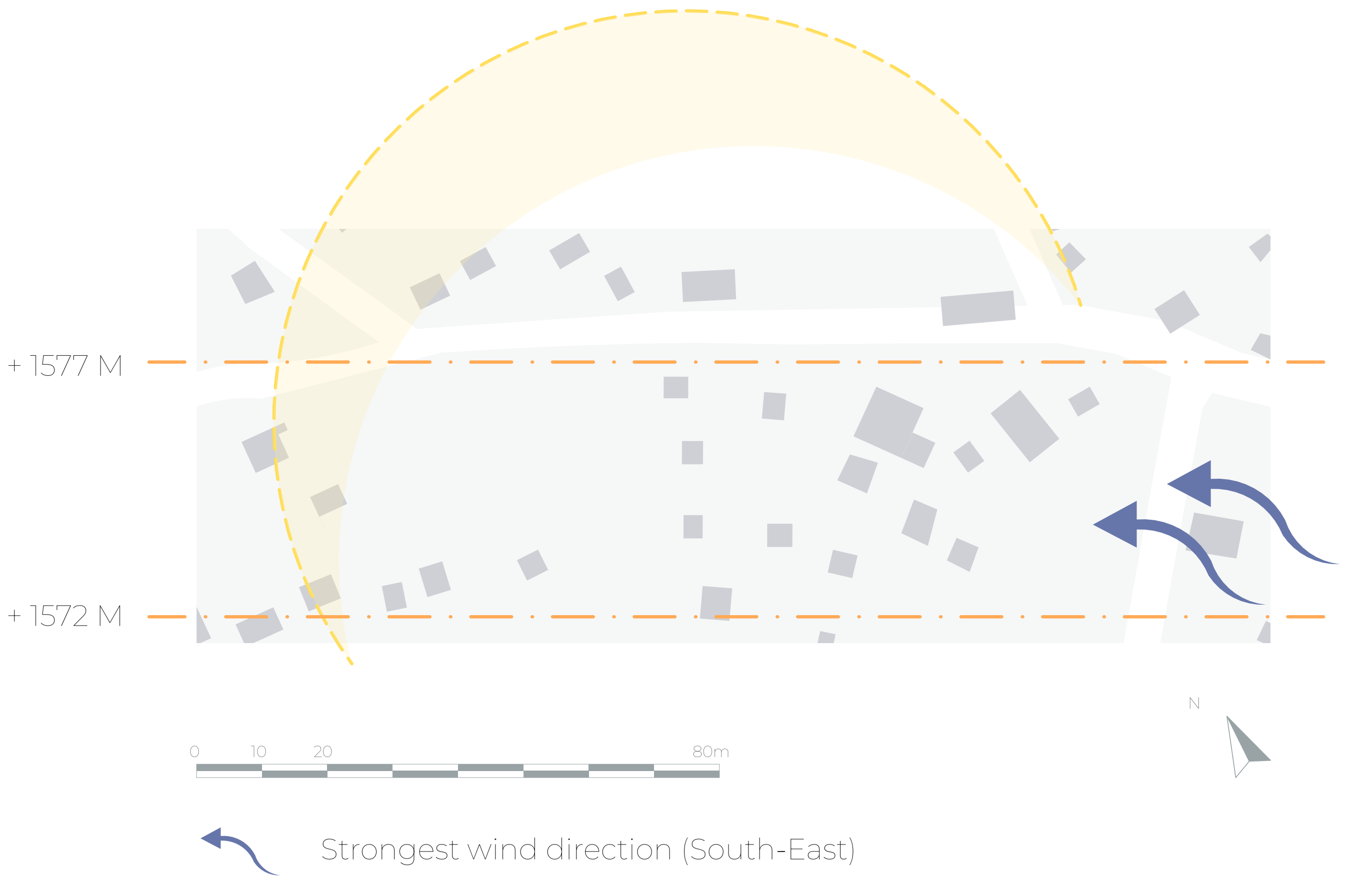


Figure 9 - Environmental conditions. *Source: own work*

2.4 THEORETICAL FRAMEWORK

> "Practice, then, is about making the ordinary special and the special more widely accessible – expanding the boundaries of understanding and possibility with vision and common sense"
>
> ~ Hamdi, 2004, *p. xix*

The shared waterpoint observed during the fieldtrip exemplifies this potential: the ordinary every day practice of collecting water can become a catalyst for community life. However, this remains unrealized because the space currently lacks the conditions that make gathering safe and sustainable. Jacobs (1961) argues that safety in urban spaces depends not on surveillance but on active use: spaces that attract people at different times of day create a natural sense of safety trough presence and activity.

This theory is supported by VPUU (Violence Prevention through Urban Upgrading), an organisation based in Cape Town that has both developed safety guidelines and implemented urban upgrading projects in low-income neighbourhoods. Central to their approach is multifunctionality: when a space supports a range of different activities, it draws a more diverse group of people at different times of day. This ongoing presence contributes to a safer place.

This is further supported by Gehl's (1980) distinction between three types of activity in public space: necessary, optional and social. Necessary activities, for example collecting water, occurs regardless of the spatial quality. Optional activities, such as sitting, lingering or playing only emerge when the space itself invites them. Social activities, including conversation and encounter, are then a consequence of the two: they arise when people are already present for other reasons.

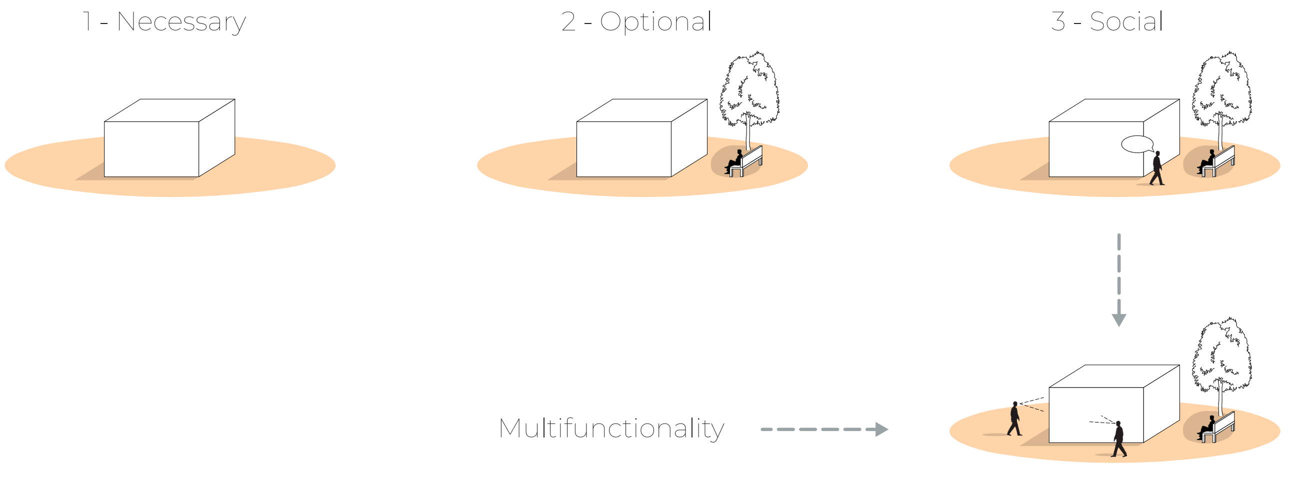


Figure 10 - Types of activity based on theory of Gehl
Source: own work

To translate these principles into a specific design response for Brendan Simbwaye, it is necessary to understand what functions the community actually needs. Community engagement with youth in the settlement identified the following as most urgent: paved roads, access to electricity, improved sanitation and health facilities, public street lighting and additional water taps. When the focus shifted from challenges to aspirations, a richer picture emerged: they dream of their neighbourhood with functions such as a library, community hall, outdoor gym and playground, internet café, open market, supermarket and a bus stop.

While the VPUU guidelines provide a strong framework for public spaces in general, the communal water and sanitation facilities in this project require additional consideration, particularly regarding the safety and dignity of women and children. For this, the guide on female-friendly public and community toilets developed by UNICEF et al. (2018) will inform the design.

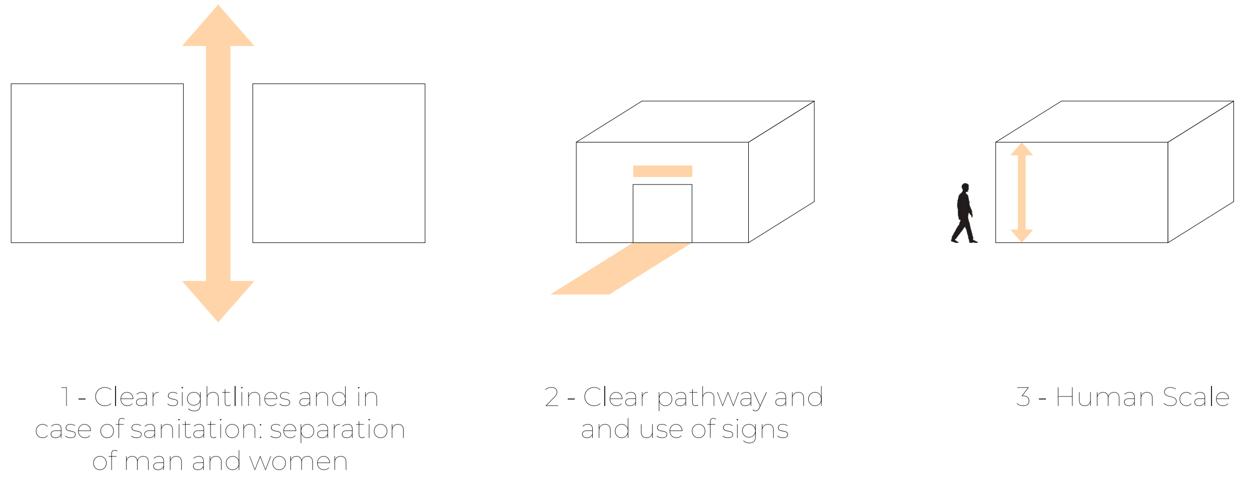


Figure 11 - Building principles based on theory of VPUU. *Source: own work*

Beyond the social and spatial considerations, there are also technical aspects to address. Most informal settlements in Windhoek are not connected to the municipal services (Weber & Mendelsohn, 2017; Mapani et al., 2023). Rather than waiting for these connections, the design integrates decentralised systems for water and energy. Not only as a technical necessity, but as an architectural feature that could inspire future projects to adopt and further develop similar approaches. Maniam et al. (2022) argue that such systems can provide affordable and safe alternatives in exactly these contexts, and case studies in similar conditions further demonstrate their potential. A detailed elaboration of the applied systems is provided in the appendix.

Together, these principles form the foundation from which the design departs.

2.5 WASH DIMENSIONING

One aspect that requires particular attention before the design brief can be formulated is the WASH infrastructure. Water, Sanitation and Hygiene (WASH) refers to access to safe water, adequate sanitation, and improved hygiene practices, together forming a critical foundation for human health and dignity. Inadequate WASH coverage remains a significant public health challenge, as poor practices are linked to the spread of waterborne diseases (Tseole et al., 2022).

In Windhoek's informal settlements, this challenge is actively being addressed by organisations such as Development Workshop Namibia, which runs a sanitation programme in which community volunteers visit households and organise workshops on hygiene, reaching both adults and children. Since Brendan Simbwaye has no municipal connection, however, water supply and wastewater management also need to be resolved at the level of the building itself.

Based on the estimated number of users and the case studies discussed in the research paper, three system configurations were explored. Considering the scale of the project and the local context, a combination of rainwater harvesting, greywater recycling, and on-site wastewater treatment was selected (see figure 12). Full calculations, system options, and sizing can be found in appendix.

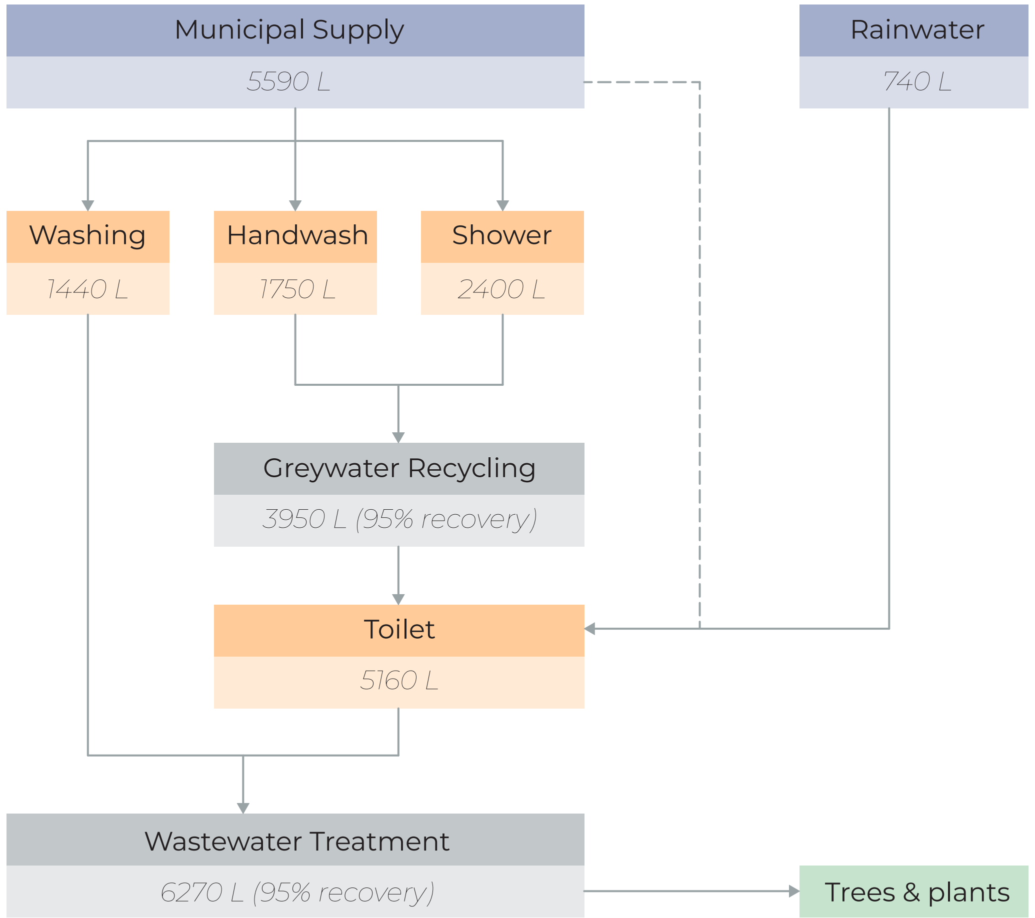


Figure 12 - Scheme of water related systems in the project. *Source: own work*

2.6 DESIGN BRIEF

The research leads to the following programme. The lack of household-level sanitation makes shared facilities essential. These are separated by gender, with sightlines, accessibility and privacy as key design considerations. A workshop space is included to support hygiene education, as elaborated in the WASH chapter. A caretaker's office and storage are added, as research shows that shared sanitation facilities are often poorly maintained without dedicated management (Shiras et al., 2018).

To ensure ongoing activity and safety, additional functions are integrated. A library and internet café respond directly to the needs expressed by local youth, who lack electricity and a quiet place to study at home, particularly relevant given the proximity of a school and the high proportion of young residents in the neighbourhood. A market square provides a better-equipped space for the informal traders who already use the area.

The project also includes housing. To create space for the community centre, 14 existing shacks are removed. The residents are relocated to newly built housing on an adjacent vacant plot. This phased approach ensures no one is displaced without an alternative.

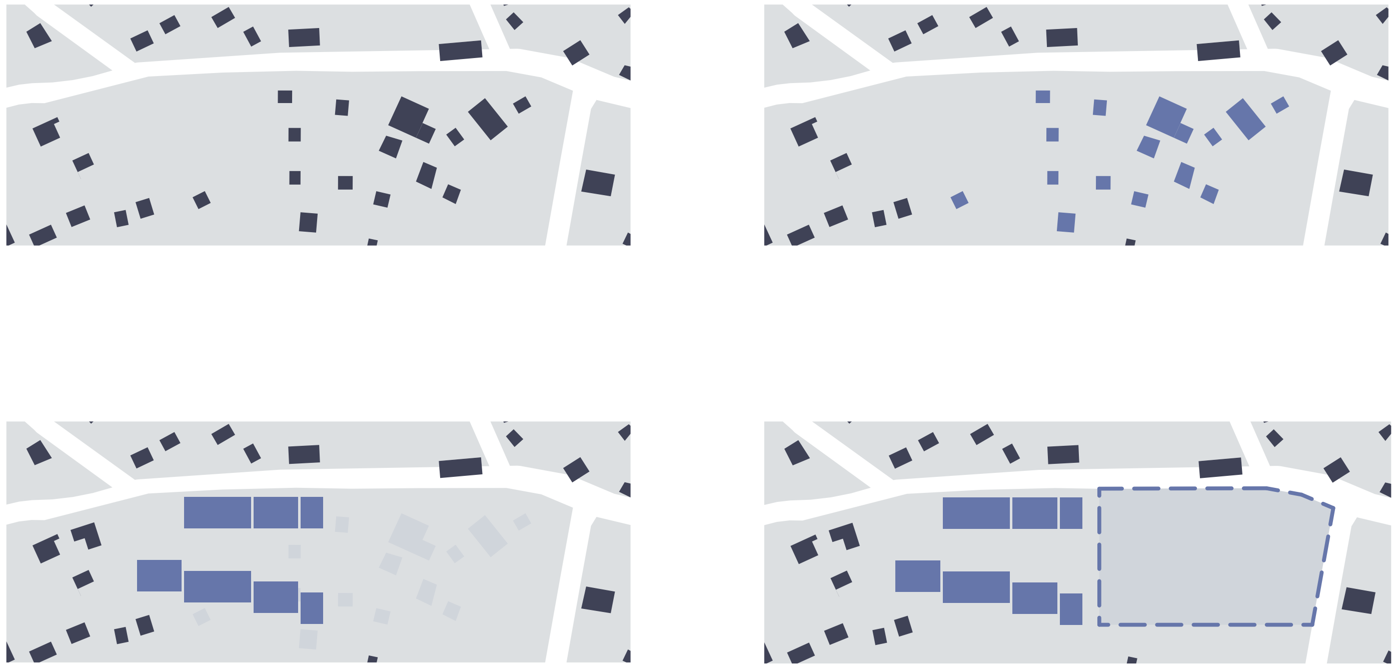


Figure 13 - Phasing of the project. *Source: own work*

The housing is designed around two central themes that emerged from the research: densification and privacy. Based on a comparable affordable housing project in Namibia by Graft Lab (2024), which accommodates four people in approximately 80 m², each unit is sized at around 80 m², corresponding to the average household size of 3.8 persons in Brendan Simbwaye.

Together, these functions form the following programme:

Community Centre	Area (m²)
Marketsquare	390
Library	245
Internet café	50
Workshop space	30
Office caretaker	15
Storage caretaker	15
WASH facilities men	45
WASH facilities women	45
Total	835

Housing	Area (m²)
Housing unit (x 14)	80
Total	1120

Figure 14 - Shop in Brendan Simbwaye. *Source: Guus Teunen*

03

Results.

3.1 FROM BRIEF TO CONCEPT

The design departs from a set of spatial principles that directly respond to the research findings. The massing and positioning of the building are guided by the balance between open and closed spaces, human scale, and the activation of place through encounter, with a clear routing at neighbourhood level as both a precondition and a reinforcement of this activation. Through a series of massing studies, these principles were translated into a first spatial proposal, as elaborated below.

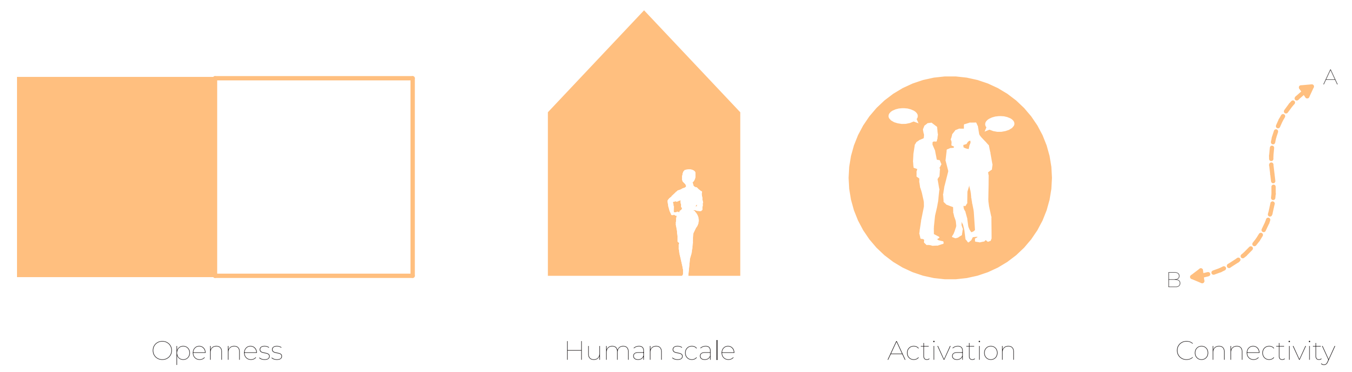


Figure 15 - Design Principles. *Source: own work*

The community centre consists of a market space, library, internet café, sanitation facilities, office and workshop space. Each function has its own degree of openness that should be accounted for in the design.

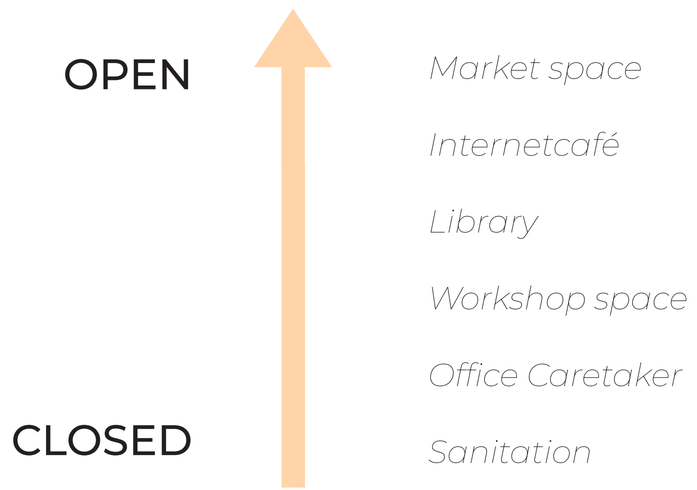


Figure 16 - Level of openness. *Source: own work*

The site also has a more open (public) and closed (private) side. The road located above the site can be seen as the more open side since people walk and drive there all day long. The other side is adjacent to housing plots so more private.

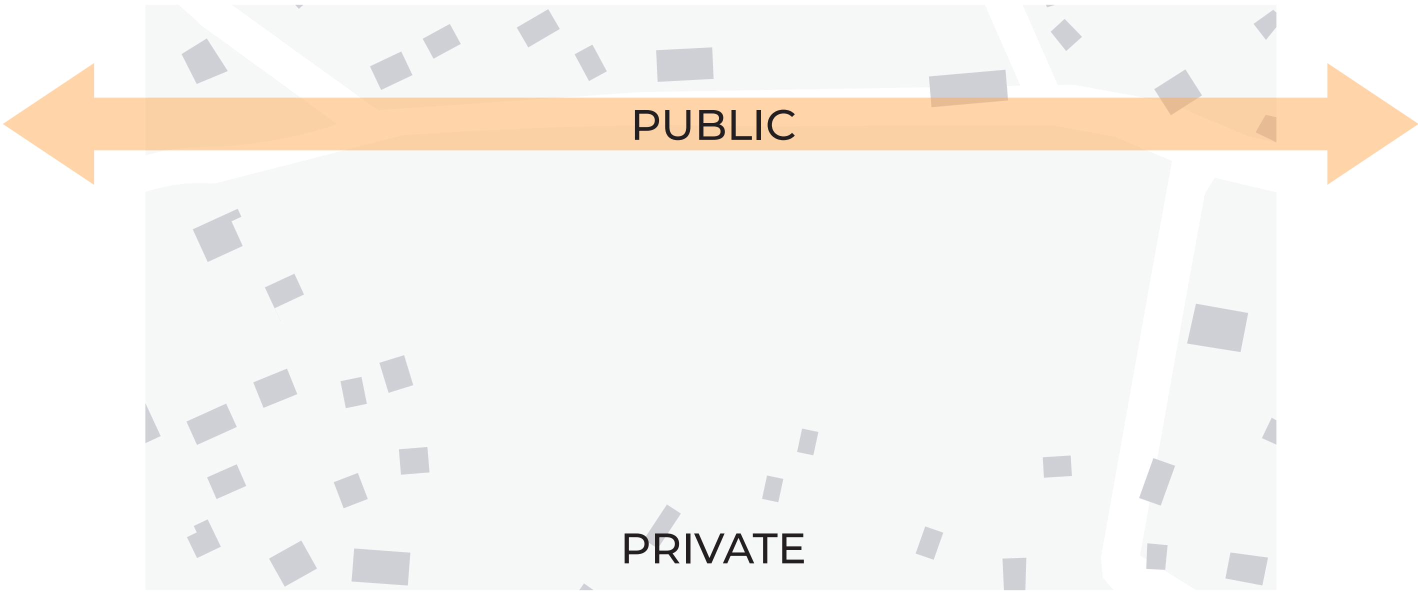


Figure 17 - Level of privacy in site. *Source: own work*

Four compositions were created to explore this relationship between open and closed spaces. These variants highlight different spatial arrangements that naturally create a more open or closed experience.

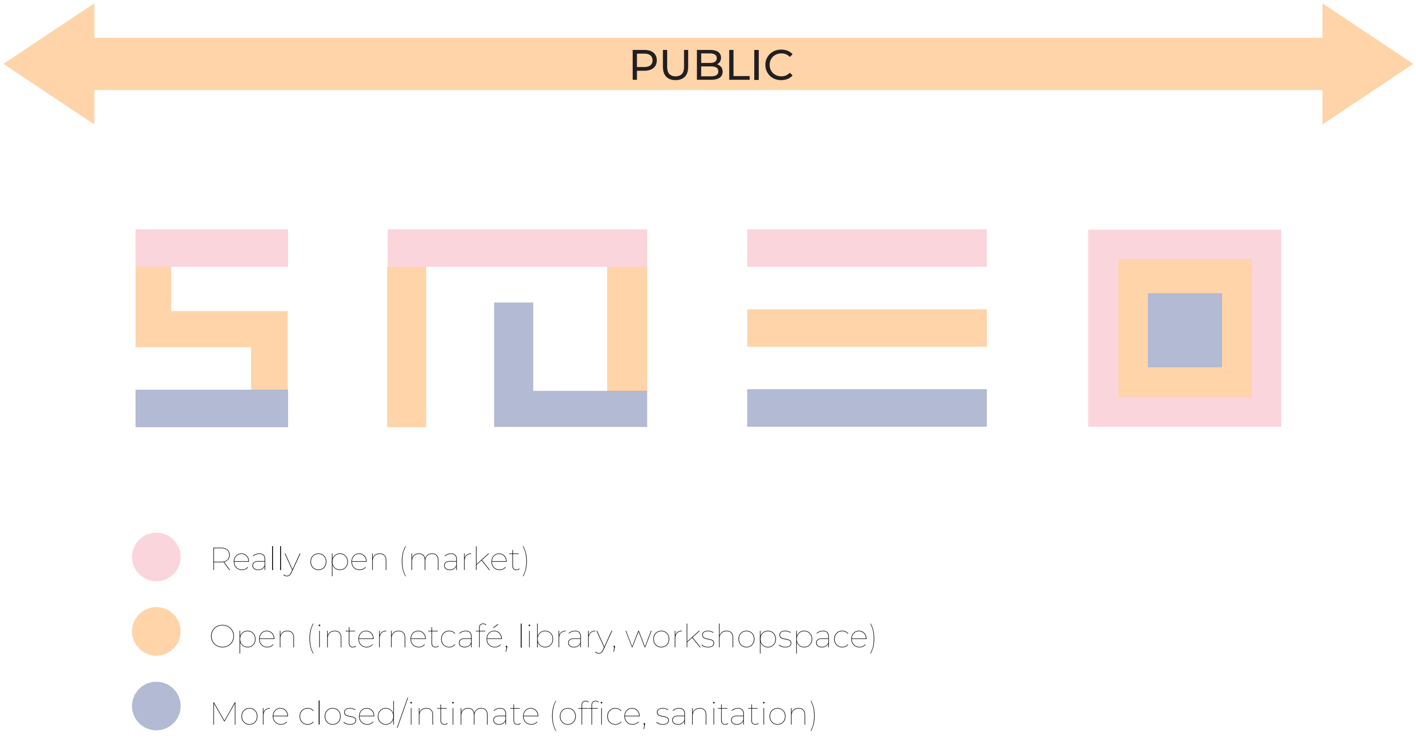


Figure 18 - Level of privacy in design schemes. *Source: own work*

Different variants of these compositions have been tested with abstract study models.

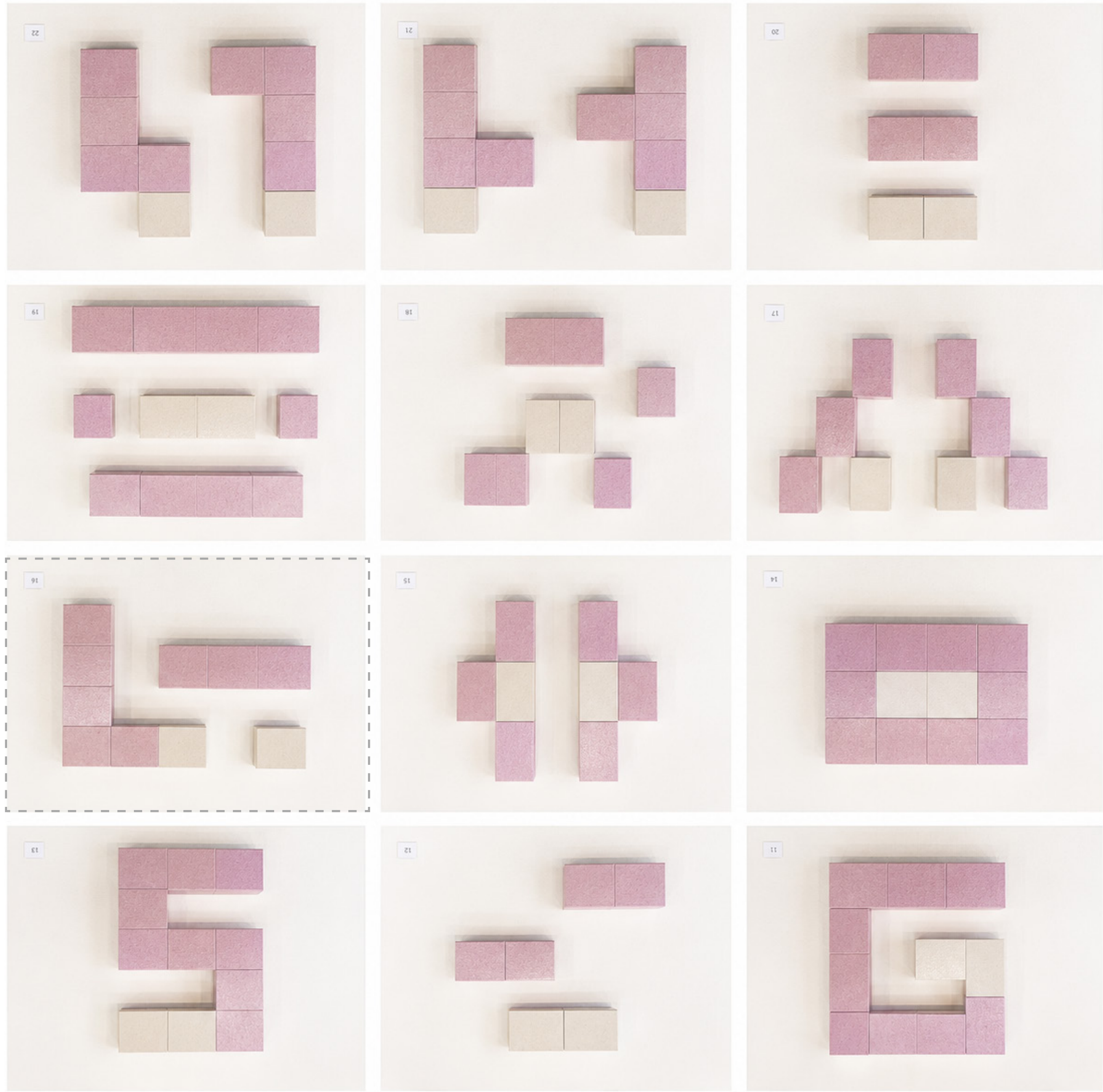


Figure 19 - Abstract models of building configurations. *Source: own work*

The site has a slope of approximately 13%, which is taken into account in the spatial composition of the building. The difference in height is not treated as a constraint but as a design opportunity, which will be further elaborated in the technical chapters.

In the image below the chosen composition is shown. The marketplace (1) is placed next to the road, being an extension of this already public place. It can easily draw people in. Behind that are the workshop space (4), storage (5) and office (6), they are functioning as a barrier between the public market and the more private sanitation space. Between the sanitation space for women (7) and men (8), an outdoor washing area serves as both a practical space and a social buffer between the two. The office (6) maintains a clear sightline over the sanitation spaces, in line with the eyes on the street principle. To the left, the internet café (2) and library (3) complete the composition. Two clear sightlines run throughout the entire complex, ensuring there is always a visible way out from any point in the space.

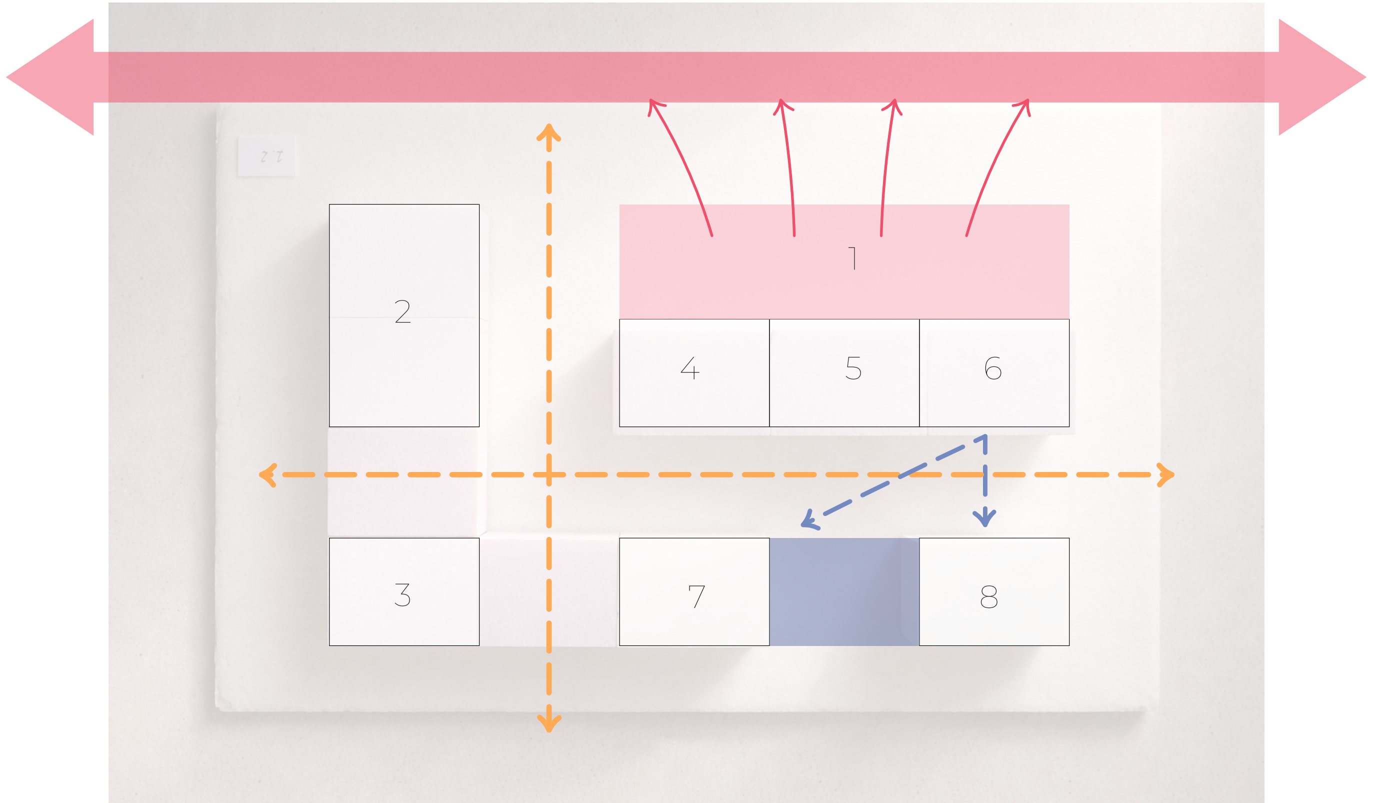


Figure 20 - Programmatic diagram. *Source: own work*

The composition also responds to the climatic conditions of Windhoek. Two volumes are oriented perpendicular to the prevailing wind direction, creating a natural airflow that helps cool the space between them. Roof overhangs provide shade from the intense sun, and the volumes are kept to a single storey to maintain a human scale throughout the design.

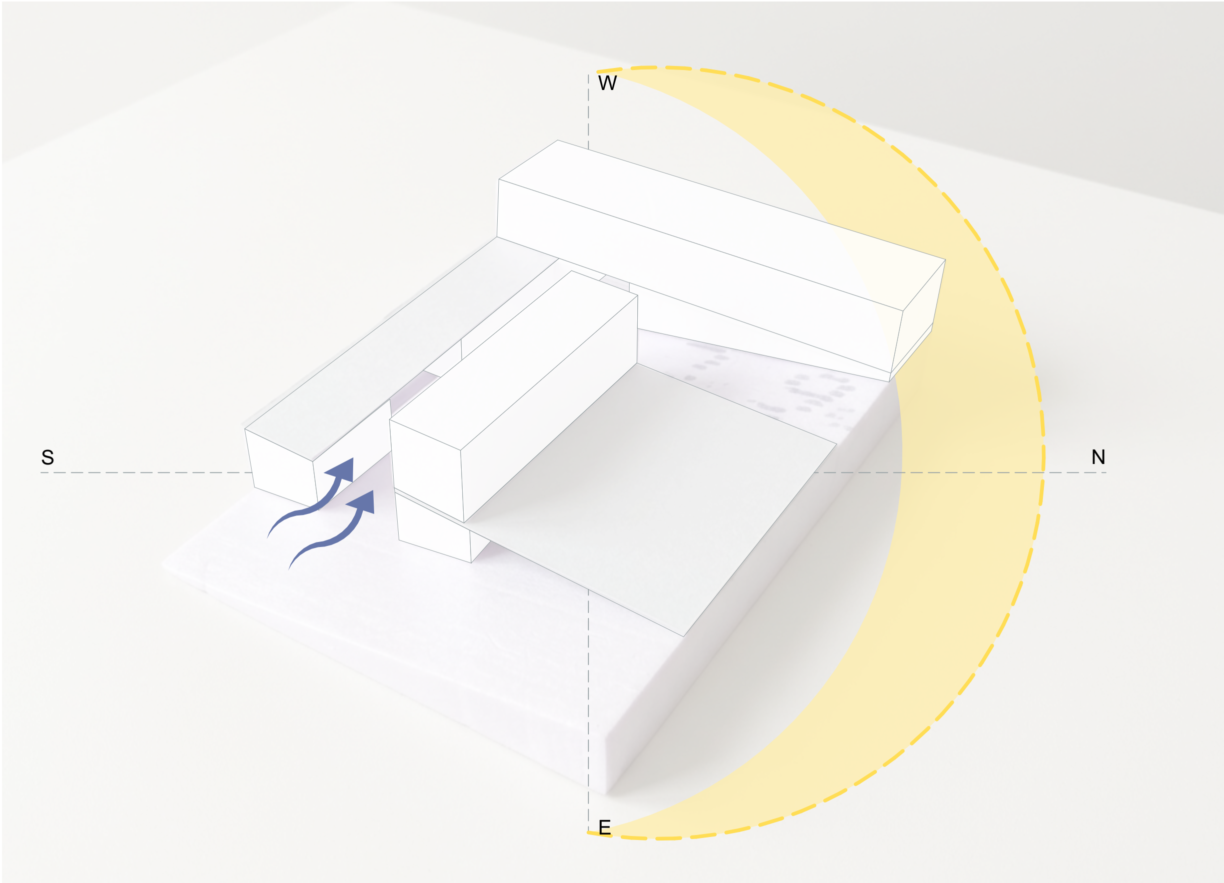


Figure 21 - Environmental conditions. *Source: own work*

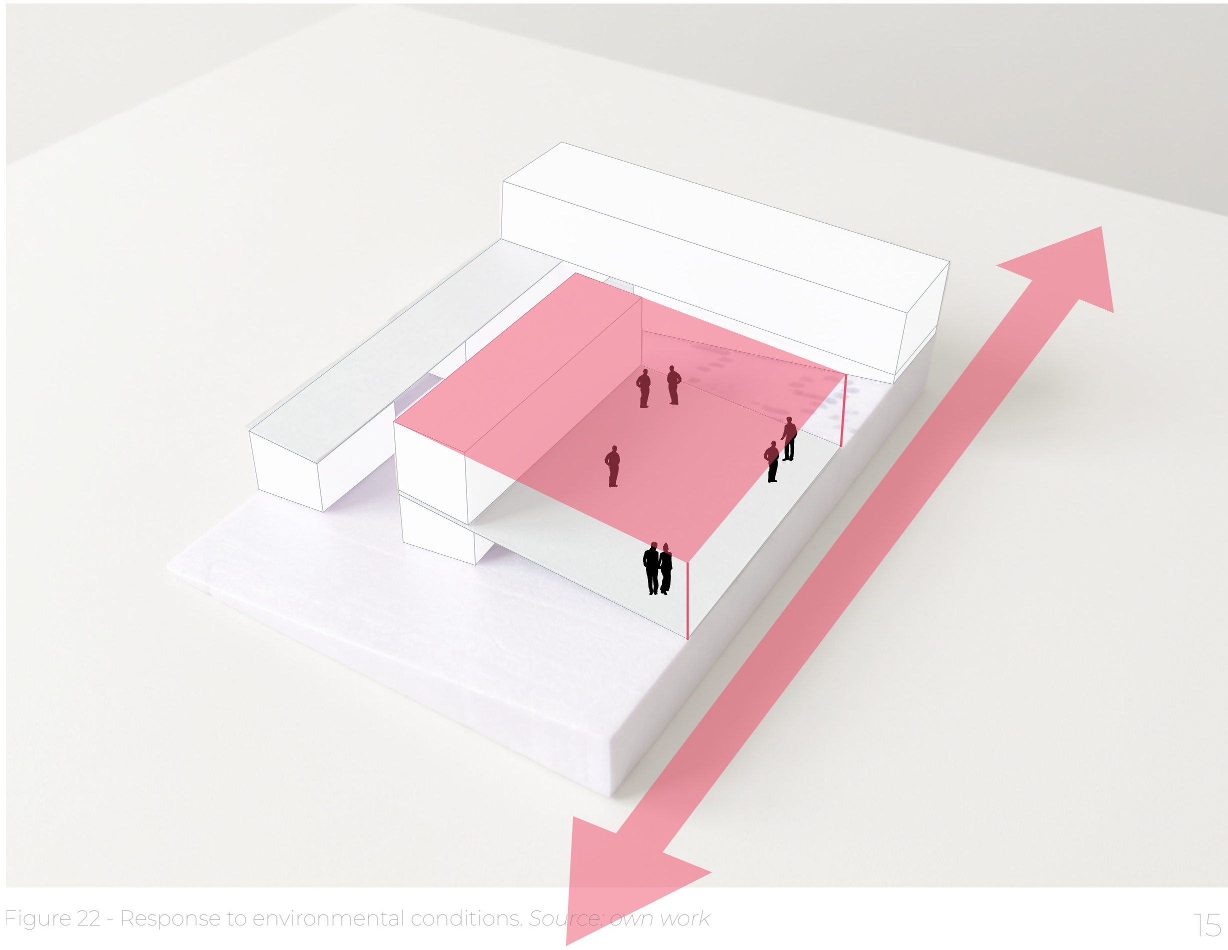


Figure 22 - Response to environmental conditions. *Source: own work*

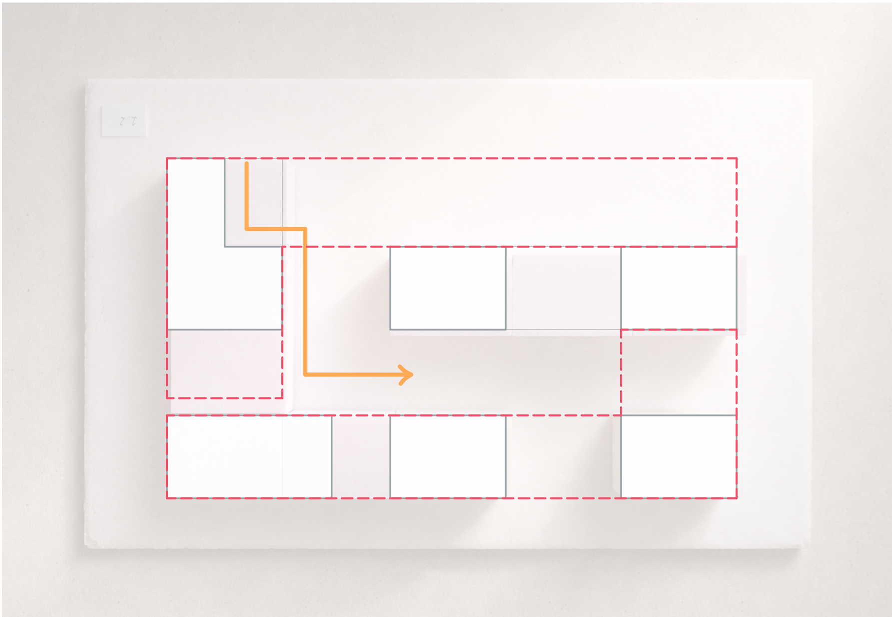


Figure 23 - Refining the volumes. *Source: own work*

The volumes of the sketch model are further refined. The internet café slopes down towards the remaining volumes, creating a more inviting gesture and improving visibility from the road. The volumes are clustered under lifted roofs, providing shade and allowing for natural ventilation. In the centre, the roof is absent, making room for trees as a natural source of shade.

As mentioned before, the community centre is located along a busy road (blue arrow), which many children use on their way to school. While this visibility is an asset for the market, the road also sees regular traffic. With the addition of the housing, a secondary pedestrian path can be introduced, providing a quieter alternative route (orange arrow). This path also passes along the WASH facilities, making them easily accessible

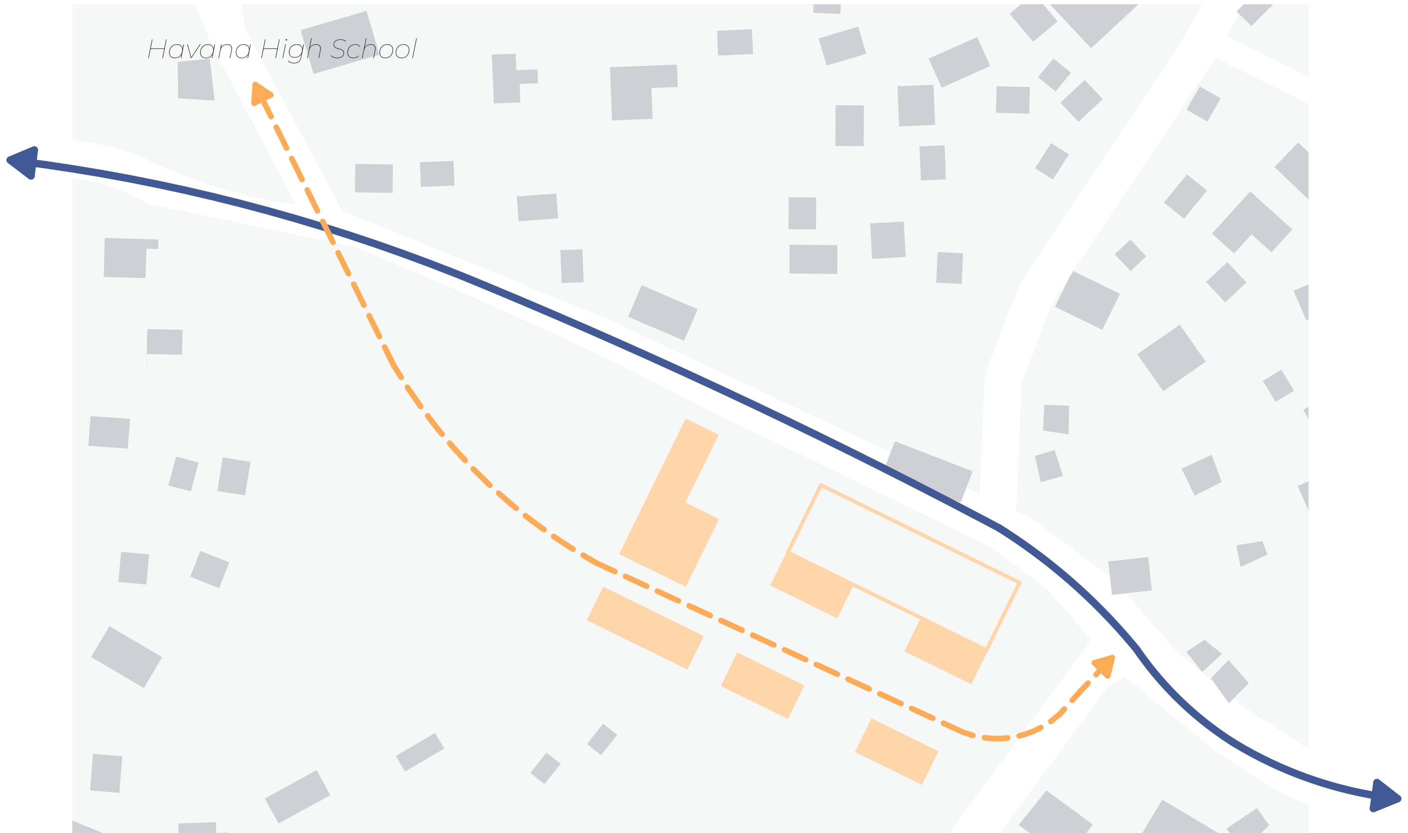


Figure 24 - Creating additional route. *Source: own work*

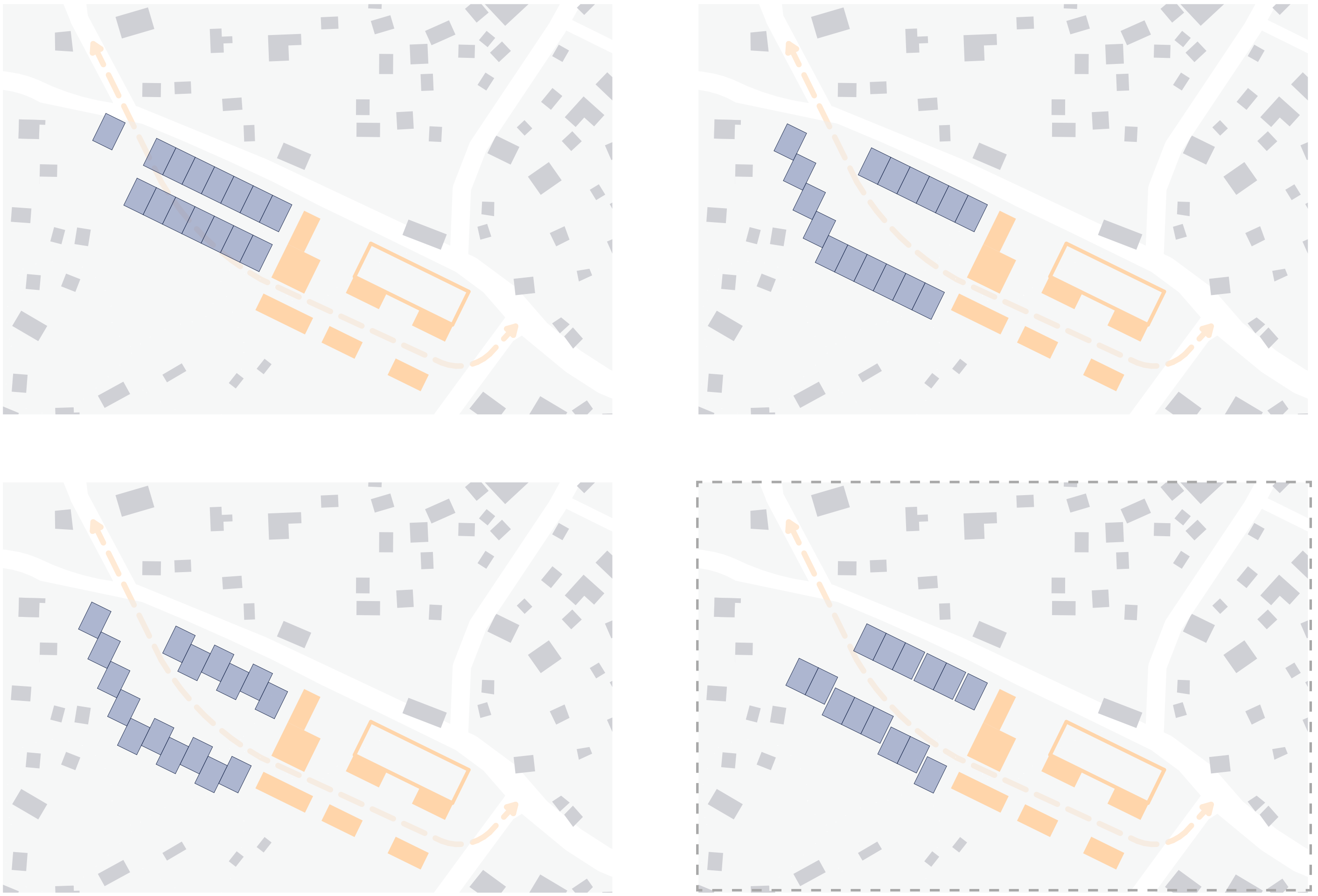


Figure 25 - Exploring different housing configurations. *Source: own work*

After exploring several variations, the final configuration was determined by a set of key considerations. The side facing the busy road is kept more closed, creating a barrier that responds to the Namibian value of privacy within the home. On the opposite side, the housing steps down towards the community centre, creating a guiding and inviting gesture. The space in between serves both as a pedestrian route and as a green courtyard. The houses are clustered in blocks to minimise material use, and the gaps between the blocks allow water to flow through in case of flooding.

3.2 FROM CONCEPT TO PLAN

Building on the conceptual massing, this chapter presents the spatial design of both the community centre and the housing. The layout is shaped by a gradient from public to private, creating spaces that feel open and inviting where activity is encouraged, and sheltered where privacy is needed. The sloped terrain is reflected in the positioning and height of the volumes, as elaborated below.

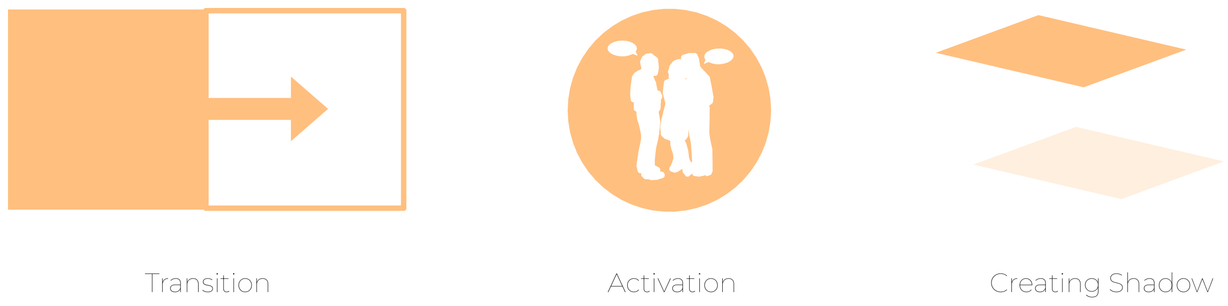


Figure 26 - Design principles. *Source: own work*

The roof has been refined throughout the design process and is an important element of the project. It provides shade, making the spaces more comfortable, while also directing rainwater towards the collection system. At the same time, openings in the roof create space for trees and greenery to provide natural shade, ensuring the design does not feel enclosed.

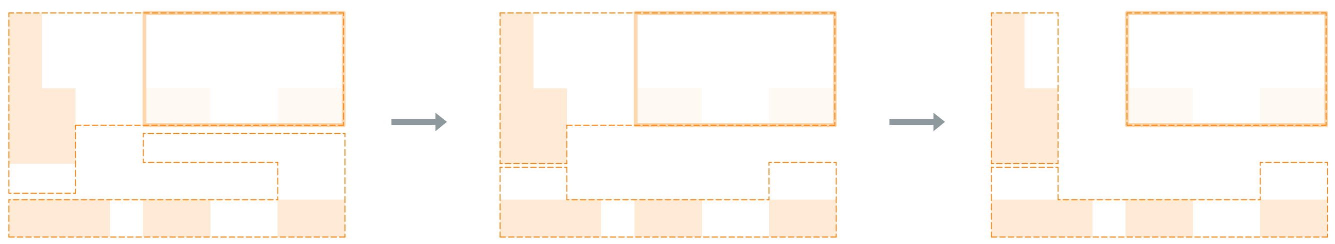


Figure 27 - Process of roof refinement. *Source: own work*

The facades furthermore reflect the gradient from public to private through varying degrees of openness. The open facade type (1) is applied to the more public functions such as the library and internet café. Type (2) is more closed but allows for cross ventilation through semi-open brickwork bonds, and is used for the more private sanitation facilities. Finally, a combination of a semi-open and open facade is applied to the housing, balancing privacy with the eyes on the street principle.

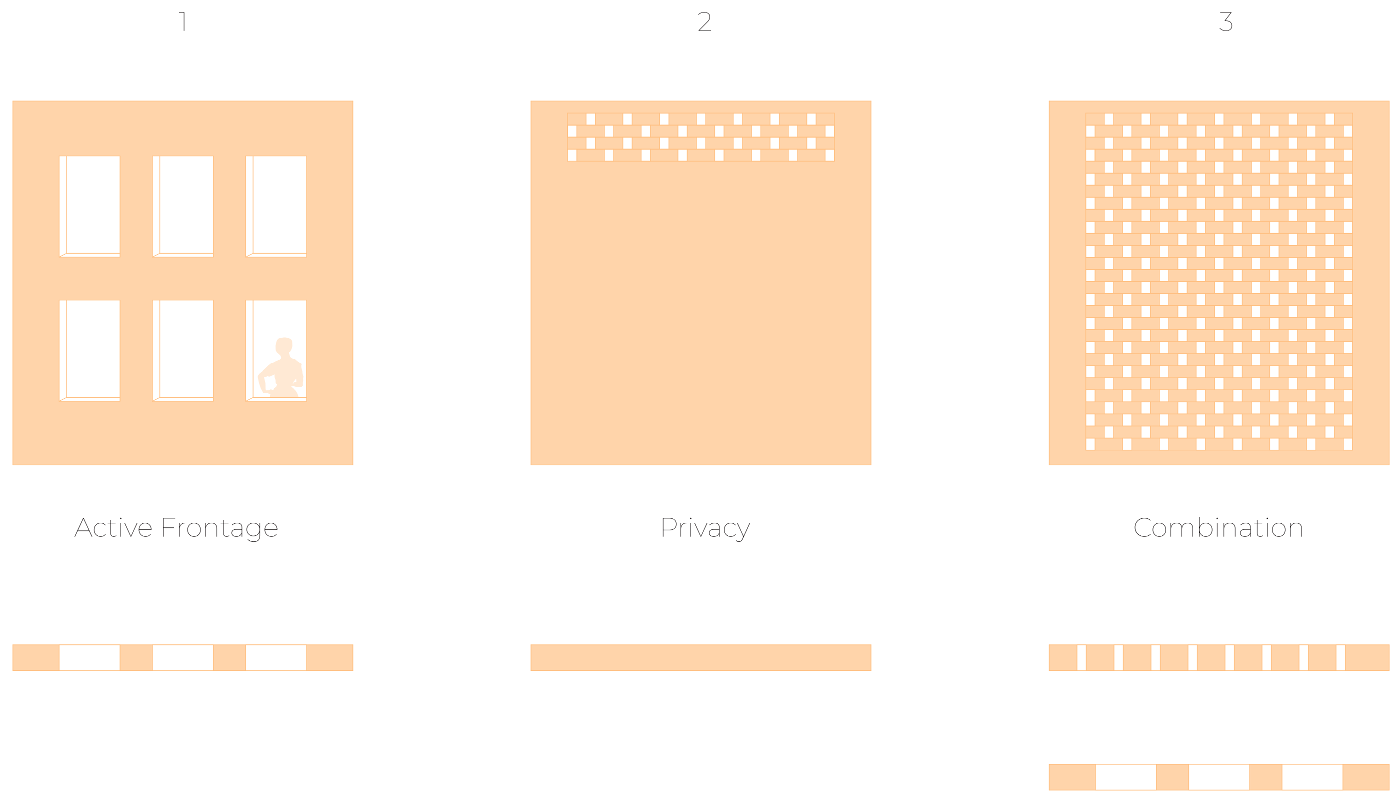
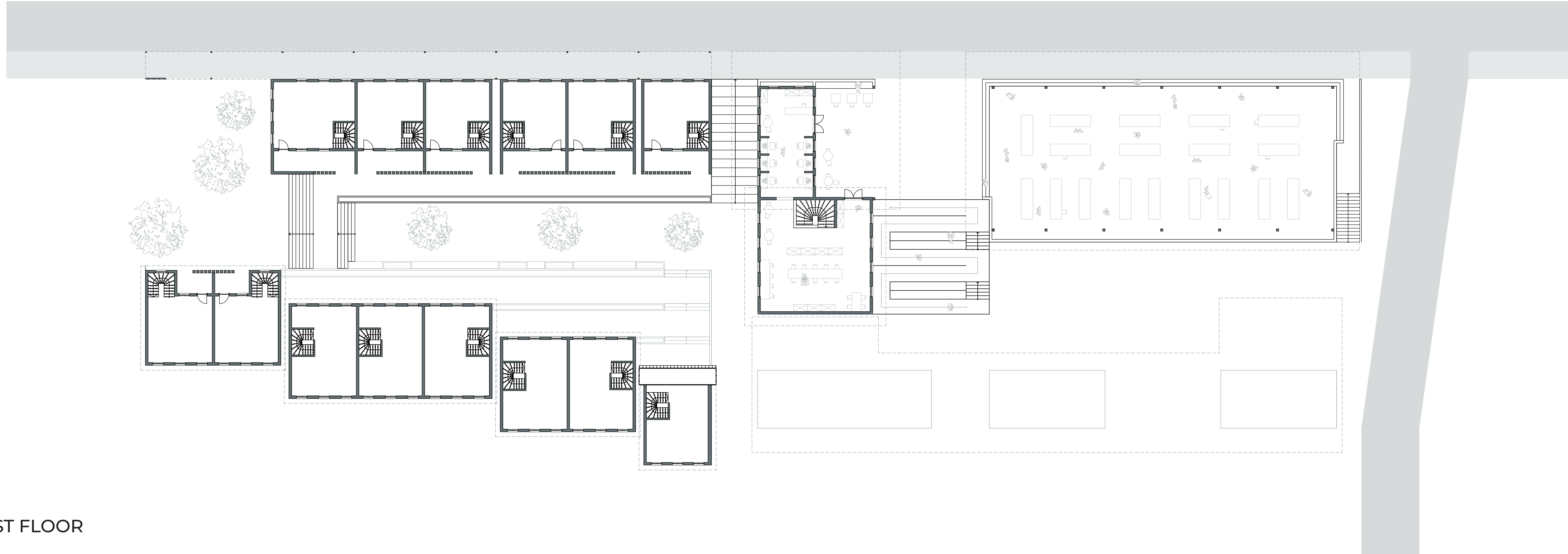


Figure 28 - Abstract version of used facade types. *Source: own work*

The following pages present the drawings of the final design.

GROUND FLOOR



FIRST FLOOR

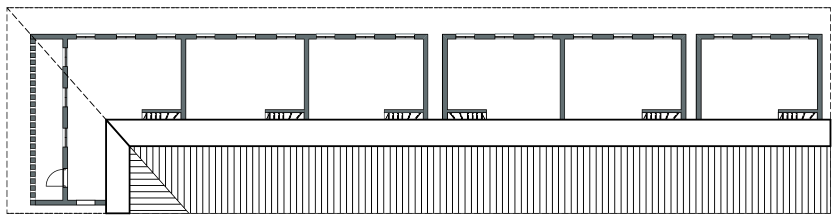


Figure 29 - Floorplans of the final plan. *Source: own work*

LOWER GROUND FLOOR

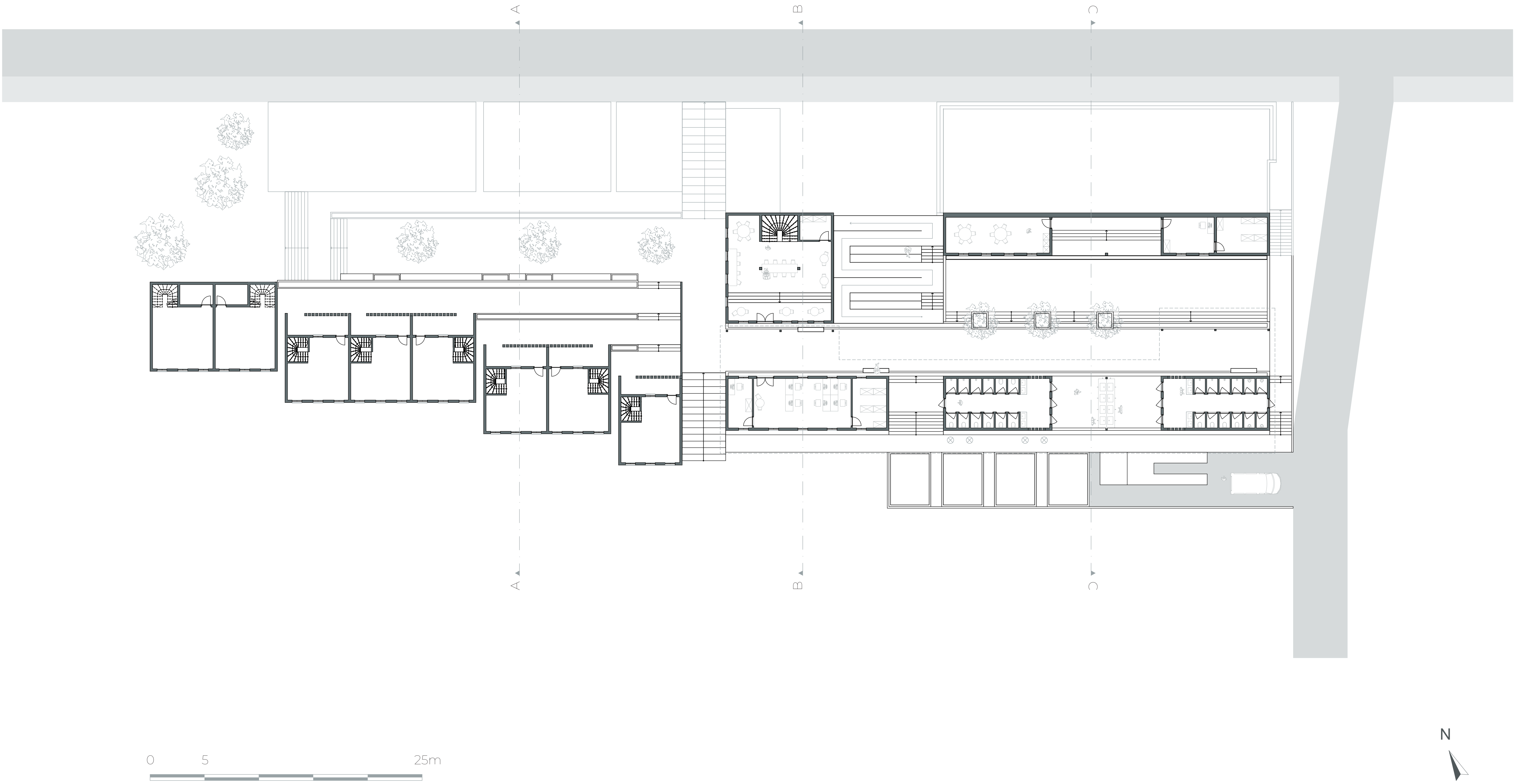


Figure 31 - Floorplan of the final plan. *Source: own work*

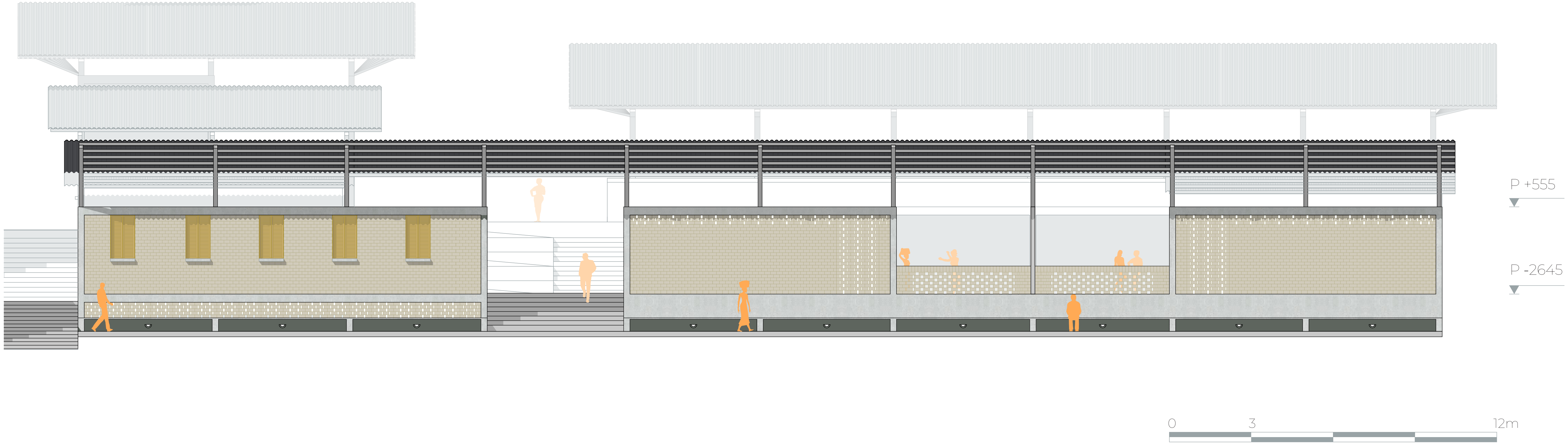
NORTH FACADE COMMUNITY CENTRE

NORTH FACADE COMMUNITY CENTRE WITH HOUSING

Figure 32 - Facade drawings of the final plan. *Source: own work*

Figure 33 - Visualization of the North facade *Source: own work, enhanced with AI*

SOUTH FACADE COMMUNITY CENTRE



SOUTH FACADE COMMUNITY CENTRE WITH HOUSING

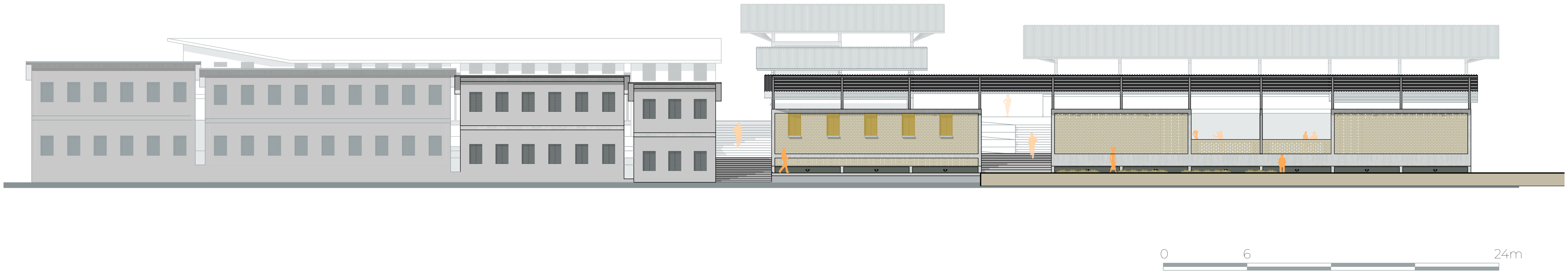


Figure 34 - Facade drawings of the final plan. *Source: own work*

SECTION HOUSING A-A

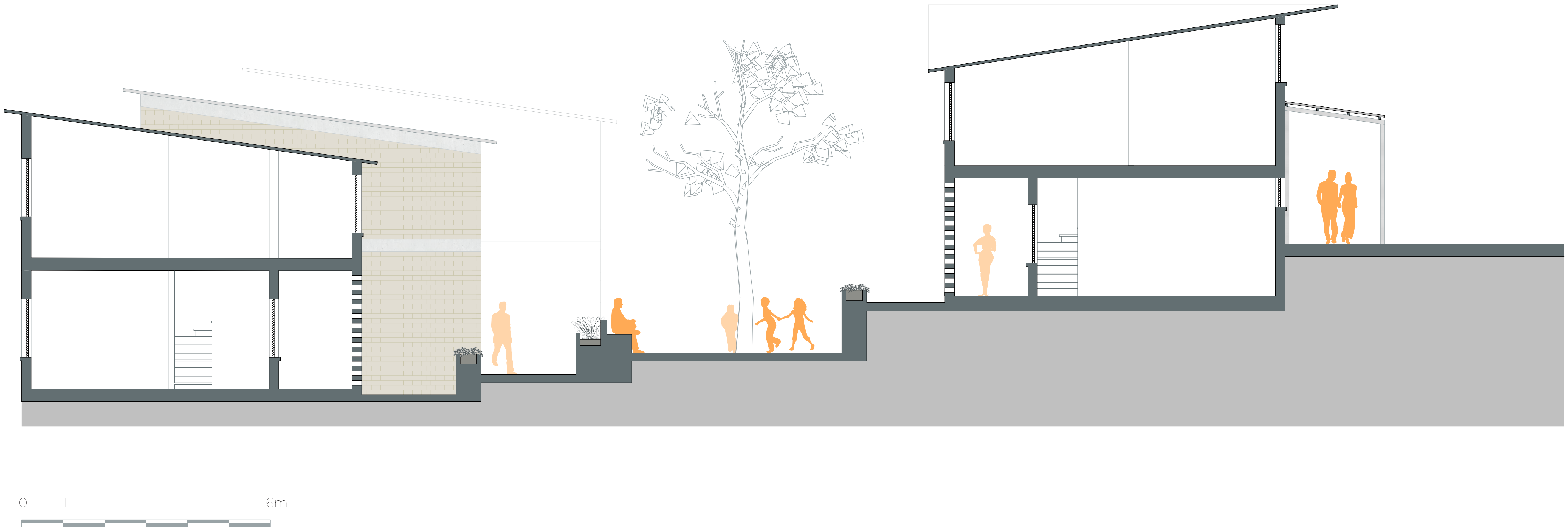


Figure 35 - Section drawing of the final plan. *Source: own work*

Figure 36 - Visualisation of the pedestrian route. *Source: own work, enhanced with AI*

SECTION COMMUNITY CENTRE B-B

Figure 37 - Section drawing of the final plan. Source: own work

SECTION COMMUNITY CENTRE C-C

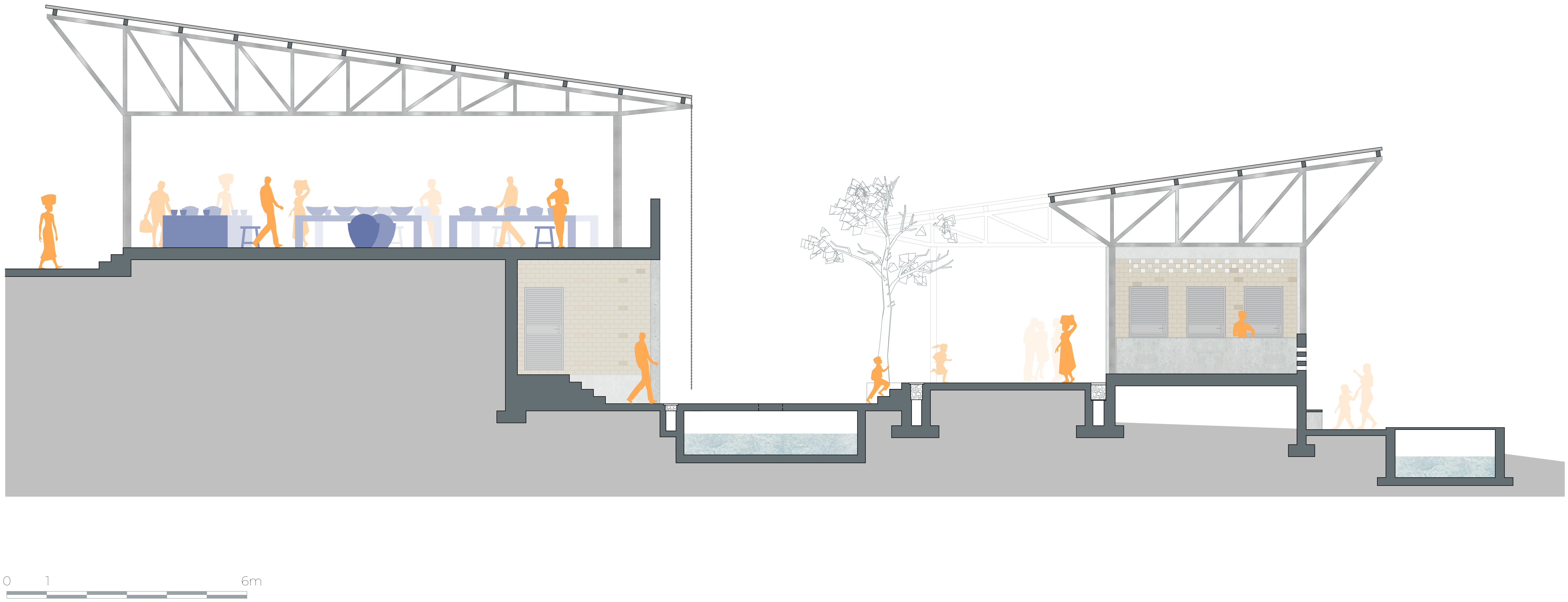


Figure 38 - Section drawing of the final plan. *Source: own work*

Figure 39 - Visualisation of the pedestrian route. *Source: own work, enhanced with AI*

Figure 40 - Visualisation of the design. *Source: own work, enhanced with AI*

3.3 CLIMATE DESIGN

The design responds to the extreme climatic conditions of Windhoek through a set of passive and active strategies. Cross ventilation, shading and partially sunken volumes are integrated into the building section to reduce heat gain and improve thermal comfort. In addition, the building operates mostly independent from the municipal network through a series of decentralised systems: rainwater is harvested and stored for daily use, greywater is recycled and reused, and wastewater is treated on site. These strategies are not treated as technical add-ons but are work together with the sloping terrain, as elaborated below.

The section below illustrates several climate principles in more detail. Cross ventilation is applied where possible to improve thermal comfort inside. The roofs are supported by high trusses, providing shade while allowing warm air to rise and escape through the gap beneath the roof. Several volumes are partially sunken into the ground, using the thermal mass of the earth for natural cooling. Solar panels are placed on the roof to generate energy for the internet café, stored within the building. Solar street lights are used to illuminate the paths after dark, contributing to safety throughout the design.

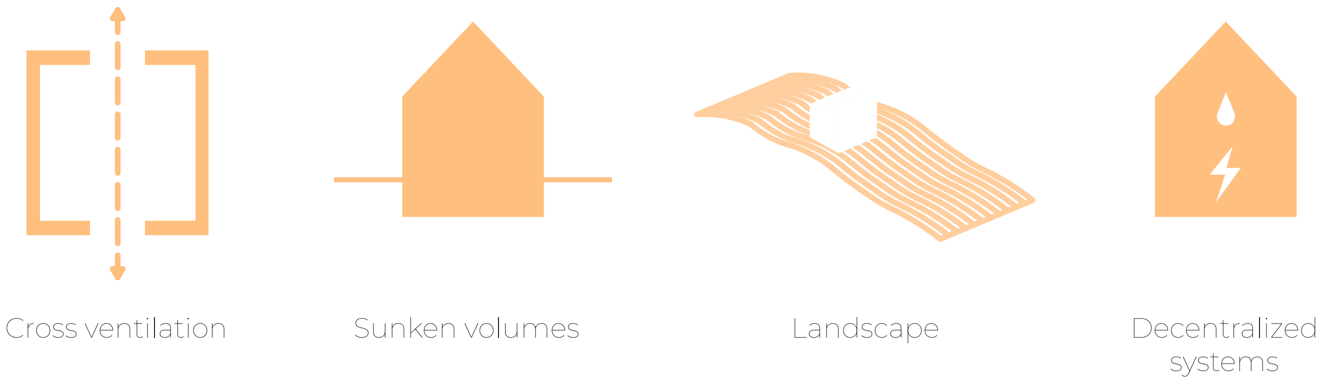


Figure 41 - Design Principles. *Source: own work*

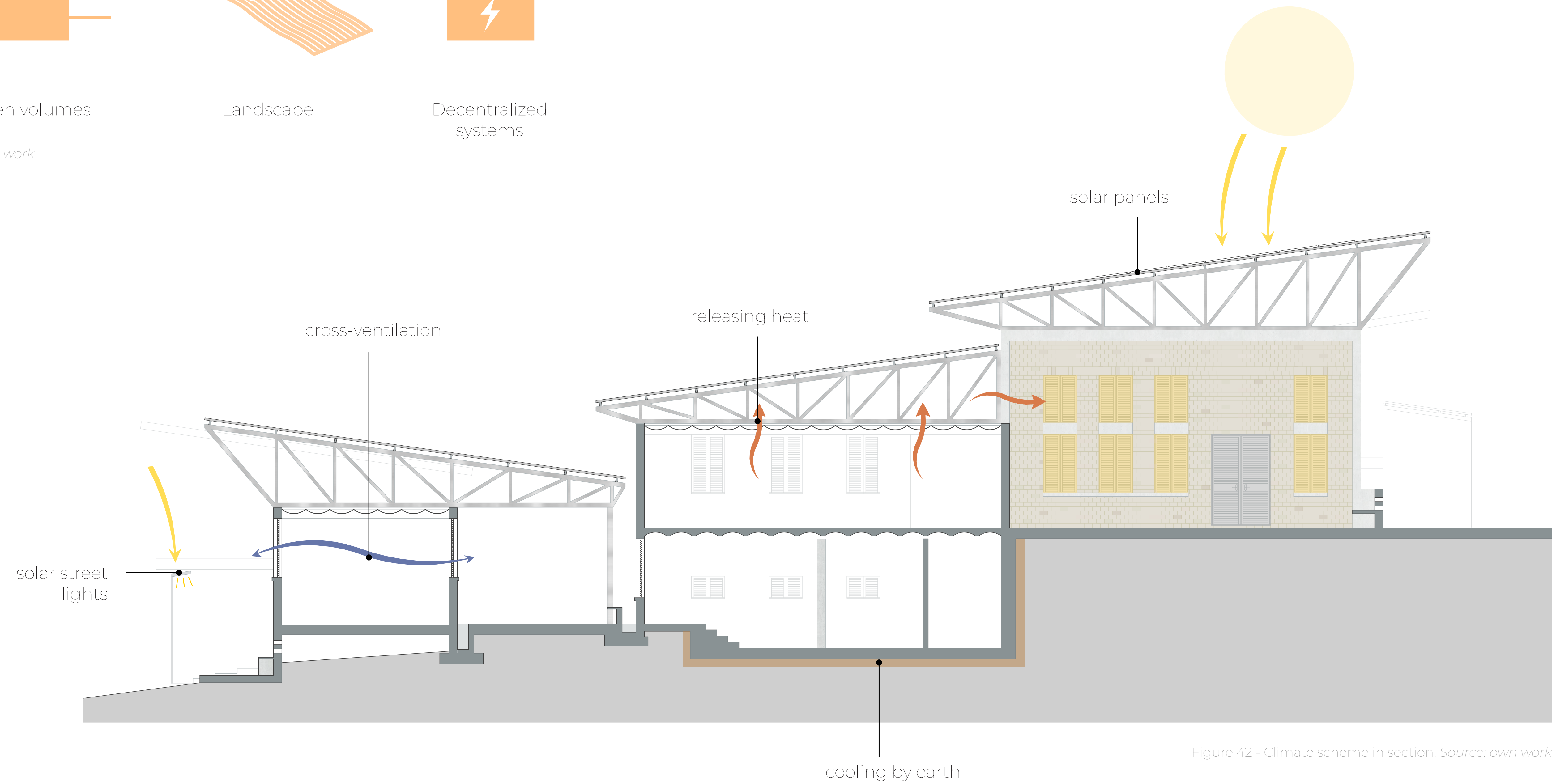


Figure 42 - Climate scheme in section. *Source: own work*

In addition to the climate strategies above, the building integrates a number of decentralised water systems. A detailed elaboration of the techniques and calculations can be found in the appendix. Based on these calculations and information from casestudies, the following daily water demand was determined for the building:

Figure 43 - Water demand for the WASH functions. Source: own work

To supply and manage this water with minimal dependency on the municipal network, a series of installations have been integrated into the design. The dimensions of these systems are based on case studies from comparable contexts, as elaborated in the appendix. The diagram below shows the flow of water through the system, from rainwater collection to storage, treatment and reuse.

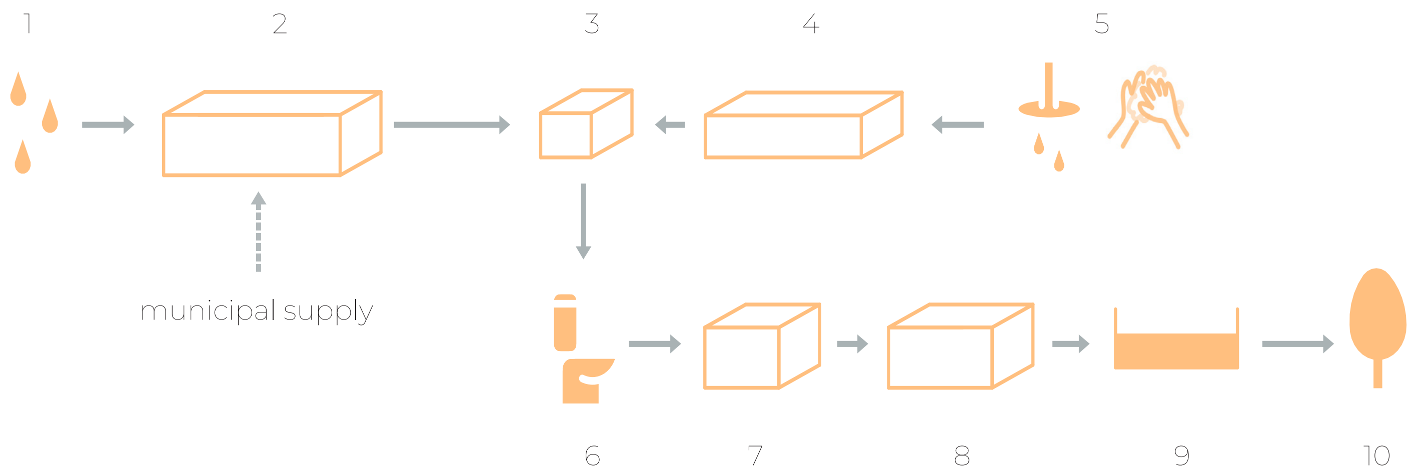


Figure 44 - Water through systems. *Source: own work*

Rainwater (1) is collected and stored in the rainwater tank (2). When needed, the municipal connection can top up this tank. Water from showers and handwashing (5) is treated in the greywater recycling system (4) and then directed into a temporary buffer tank (3). Rainwater can also be added to this buffer tank (3). From there, the water is pumped to the toilets (6). Wastewater from the toilets is treated in a septic tank (7), followed by an Anaerobic Baffled Reactor (ABR)(8), and then further purified through constructed wetlands (9). The treated water can optionally be collected and used for irrigation (10).

The functions and installations are positioned on the slope in such a way that gravity alone is sufficient to move water through most of the system. The drawings below show how these systems are integrated into the design.

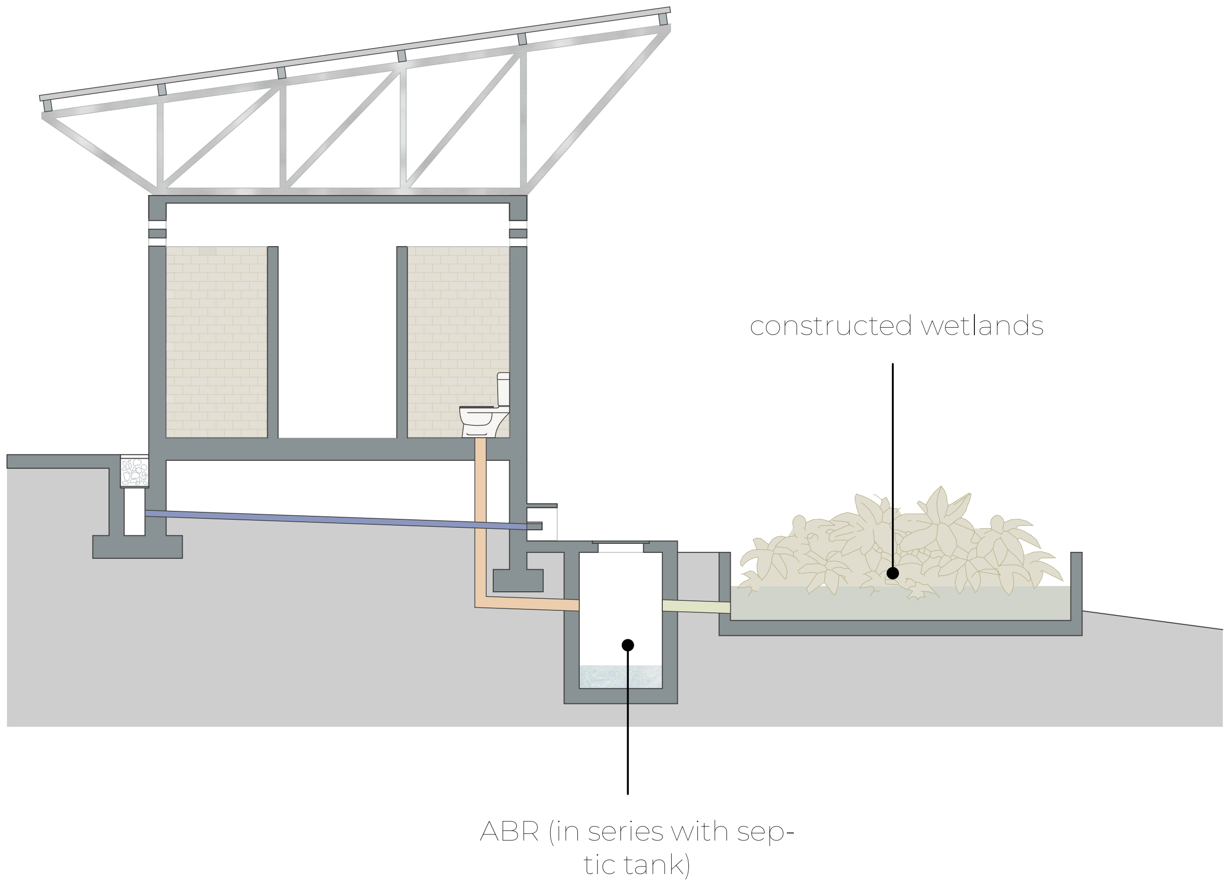


Figure 45 - Black water system in design. *Source: own work*

SECTION COMMUNITY CENTRE C-C WITH GREY- AND RAINWATER PRINCIPLES

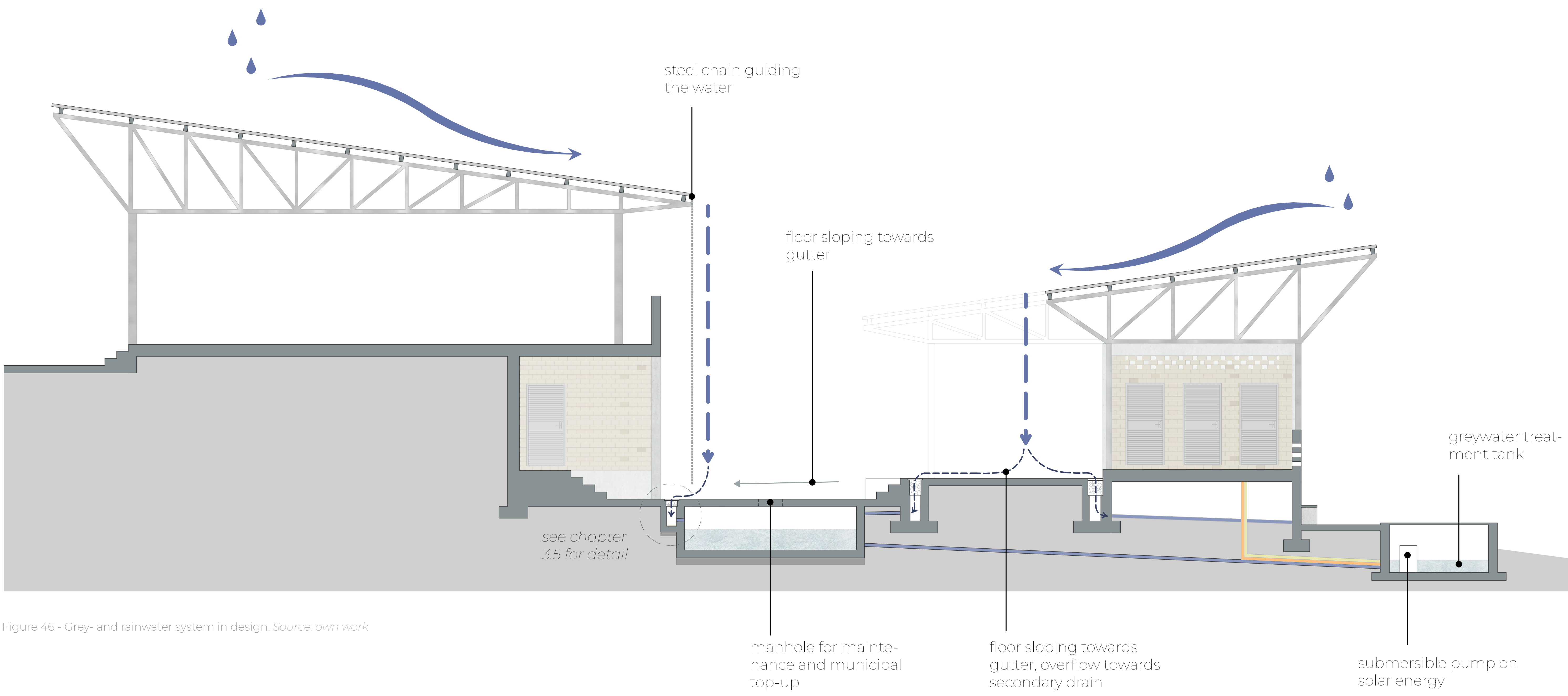
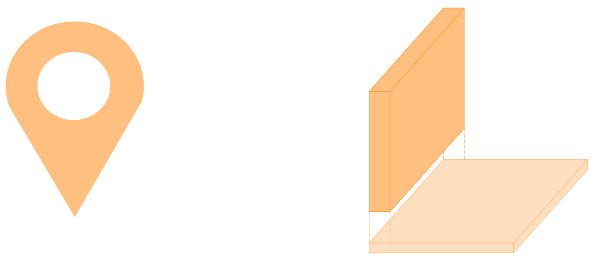


Figure 46 - Grey- and rainwater system in design. *Source: own work*

3.4 STRUCTURE AND MATERIALISATION

The design prioritises the use of locally available materials wherever possible. Namibia has limited natural resources, so not all materials can be sourced domestically. However, many commonly used materials are already widely imported and readily available in the country. An equally important consideration is keeping the construction low-tech, allowing the building to be built and maintained by local residents.



Local materials

Low- tech

Figure 47 - Design Principles. *Source: own work*

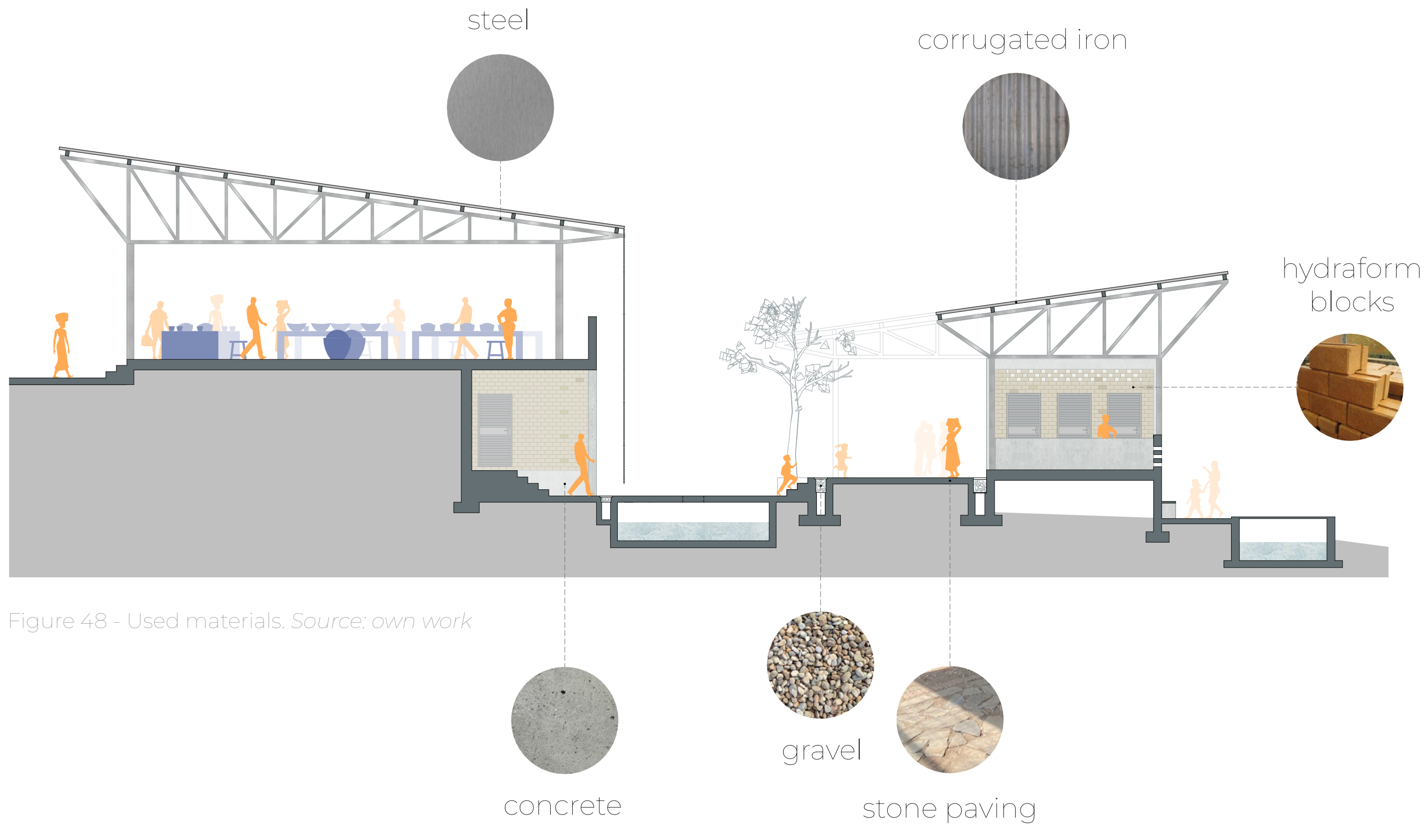


Figure 48 - Used materials. *Source: own work*

During the field trip, we visited the Habitat Research and Development Centre designed by Nina Maritz. The building demonstrates the use of local and sustainable materials in practice and served as an important source of inspiration for this project. I also had the opportunity to see the machine used to produce Hydraform blocks — load-bearing compressed earth blocks made from local soil and cement. This construction method has been adopted in the design.

Figure 49 - Pictures of the Habitat Research and Development Centre, designed by Nina Maritz. *Source: own work*

FLOORPLAN WITH MATERIALISATION

Figure 50 - Floorplan with materials. *Source: own work*

The construction consists of two methods. The volumes are built with load-bearing Hydraform block walls, supported by concrete columns and a ring beam, on which the steel roof structure rests. The roof consists of steel trusses with corrugated iron sheets on top. For the roof over the market square, a steel frame structure was chosen to allow for larger spans, providing more flexibility and functionality.

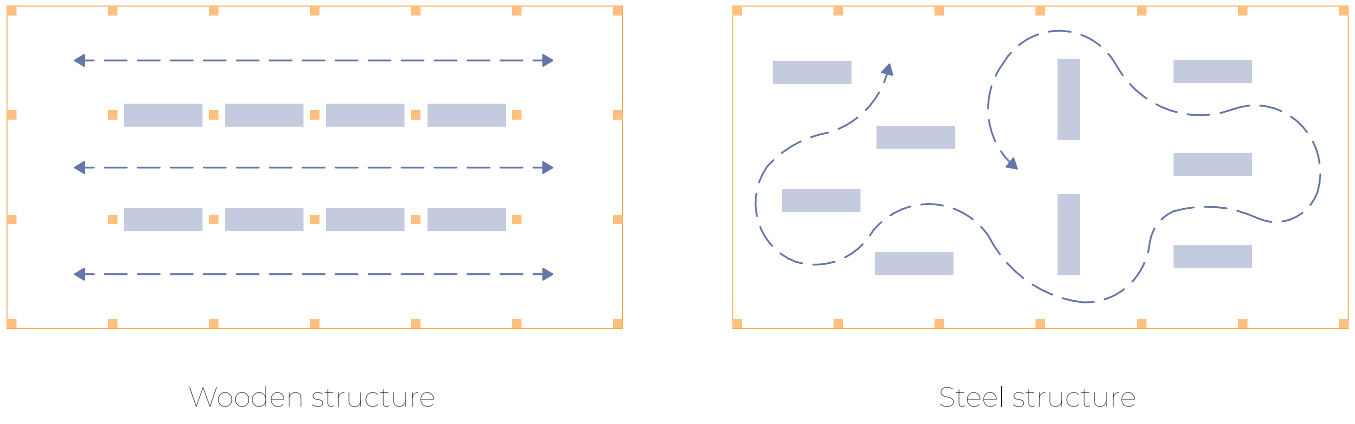


Figure 51 - Structural principal for flexibility. *Source: own work*

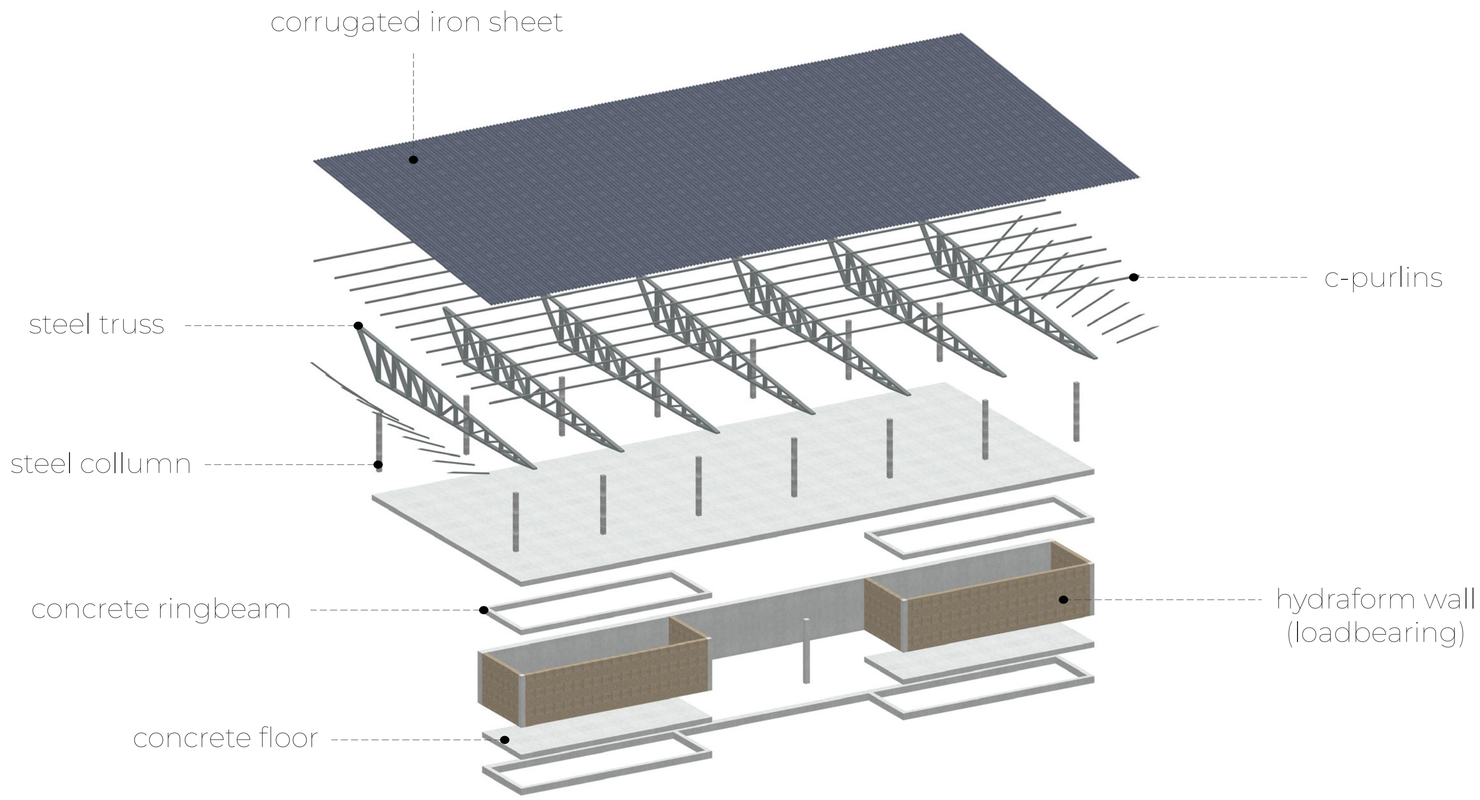


Figure 53 - Structural axonometric of square. *Source: own work*

The drawing below illustrates the structural spanning directions.

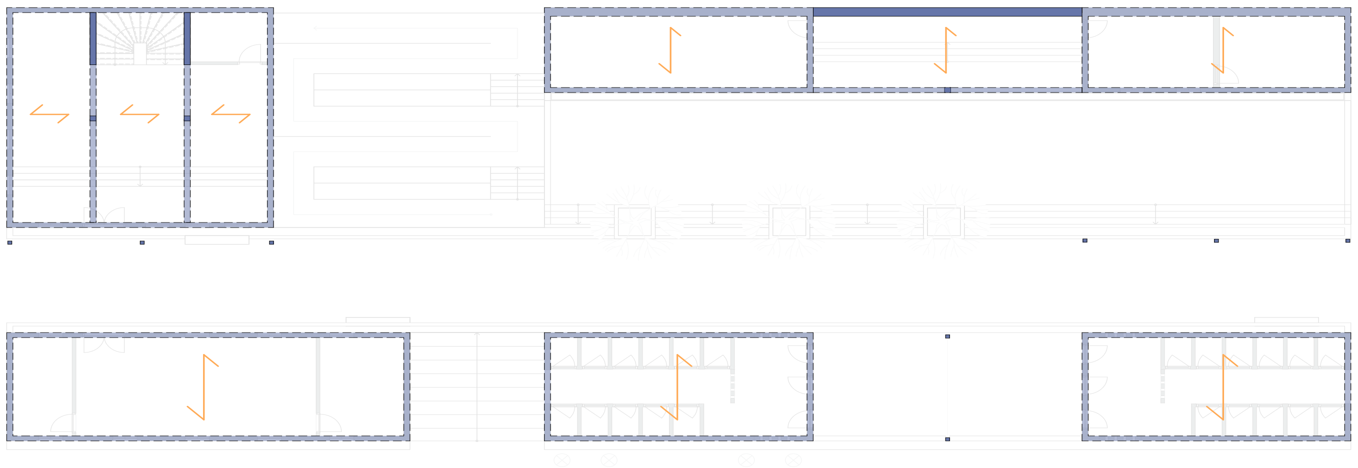


Figure 52 - Structural spanning directions. *Source: own work*

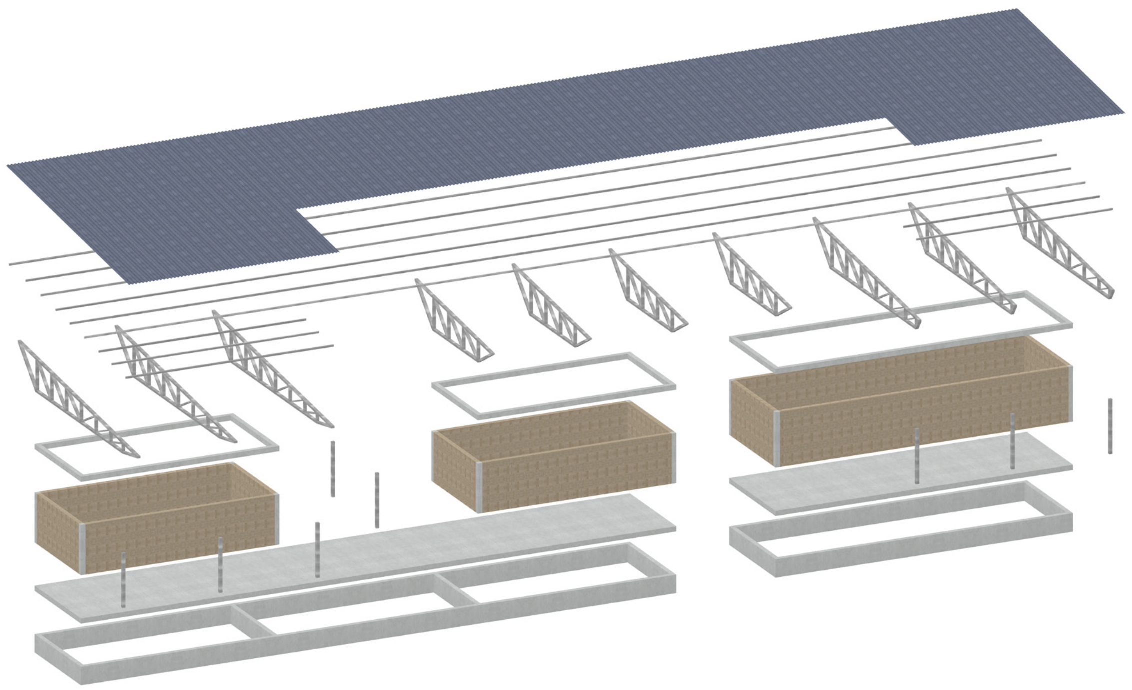


Figure 54 - Structural axonometric of WASH buildings. *Source: own work*

3.5 TECHNICAL ELABORATION

This chapter presents the technical elaboration of a building fragment. Building on the principles introduced in the previous chapter, the detailing continues to prioritise locally available materials and low-tech construction methods that can be executed by local residents. The fragment also shows how water is guided through and along the building.

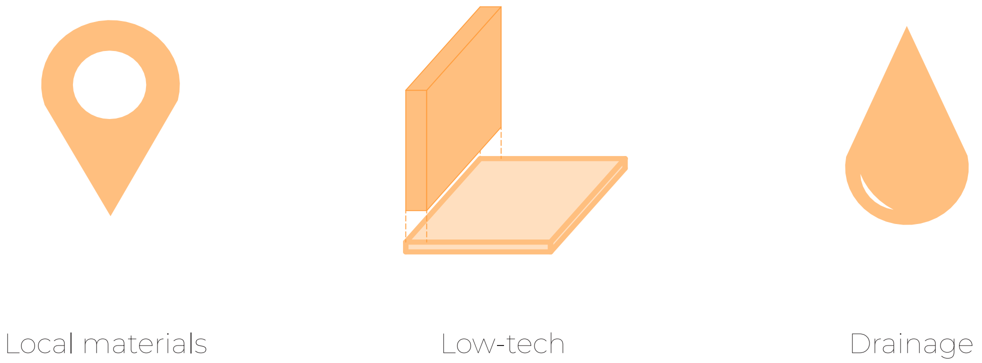


Figure 55 - Design principles. *Source: own work*

Figure 56 - Machine for hydraform blocks. *Source: Guus Teunen*

As mentioned before, the Hydraform block is used as the primary load-bearing wall construction throughout the project. The detailing incorporates four different floor types, each responding to the specific conditions and requirements of its location:

Rib and block floor

- earth infill block between reinforced concrete beams
- 50mm reinforced concrete
- compression layer
- 50mm cement screed

Stabilized earth floor

- 150mm stabilized earth
- 125mm reinforced concrete
- 50mm cement screed

Stone floor

- 230mm stabilized earth
- 100mm crushed stone
- 30mm sand
- stone finishing

Rib and block floor

- concrete infill block between reinforced concrete beam
- 50mm cement screed

The drawings on the following pages illustrate each type applied within the design.

BUILDING FRAGMENT

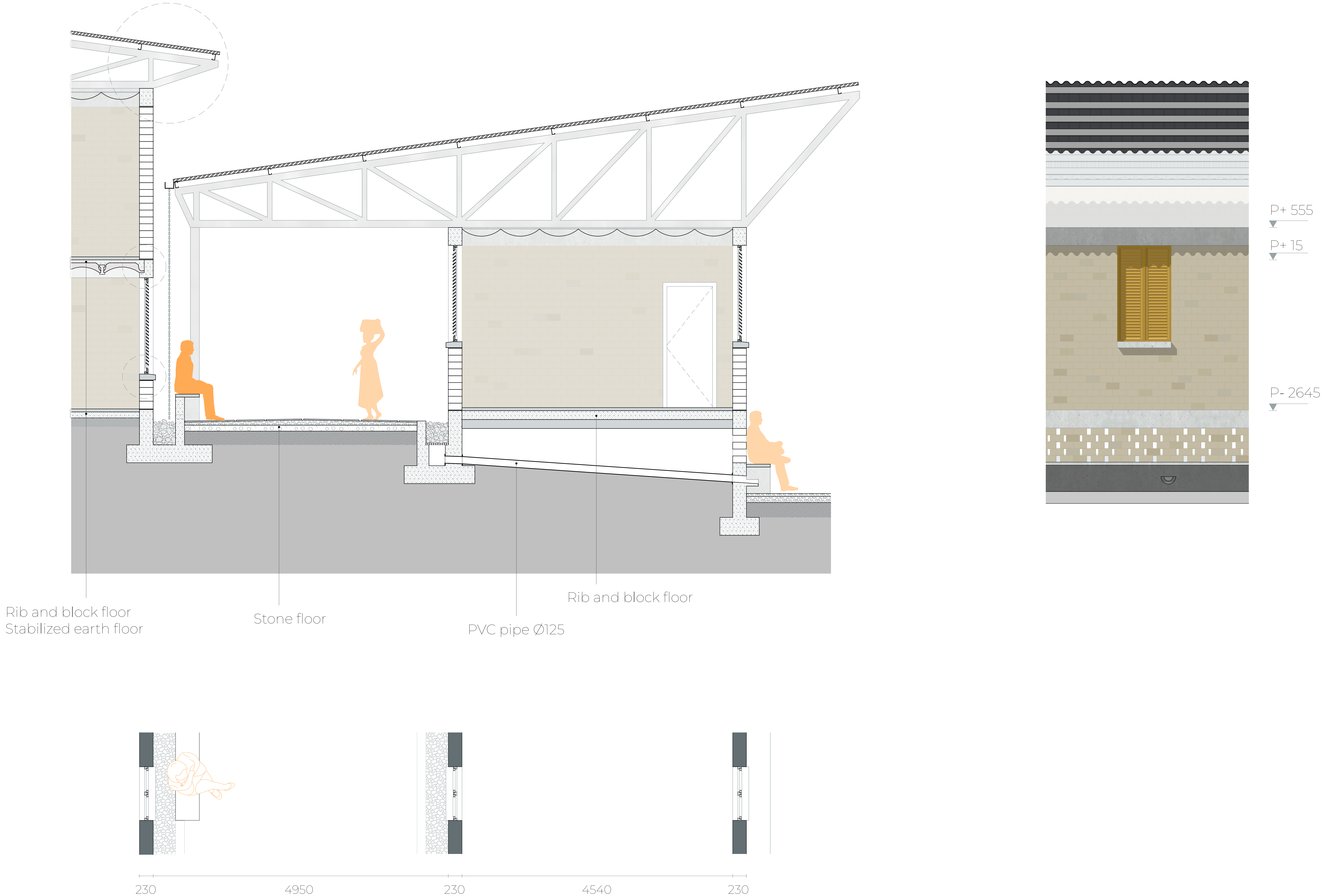


Figure 57 - Building Fragment. *Source: Own work*

Figure 58 - Visualisation of the facade. *Source: Own work, enhanced with AI*

DETAIL OF WATERTANK

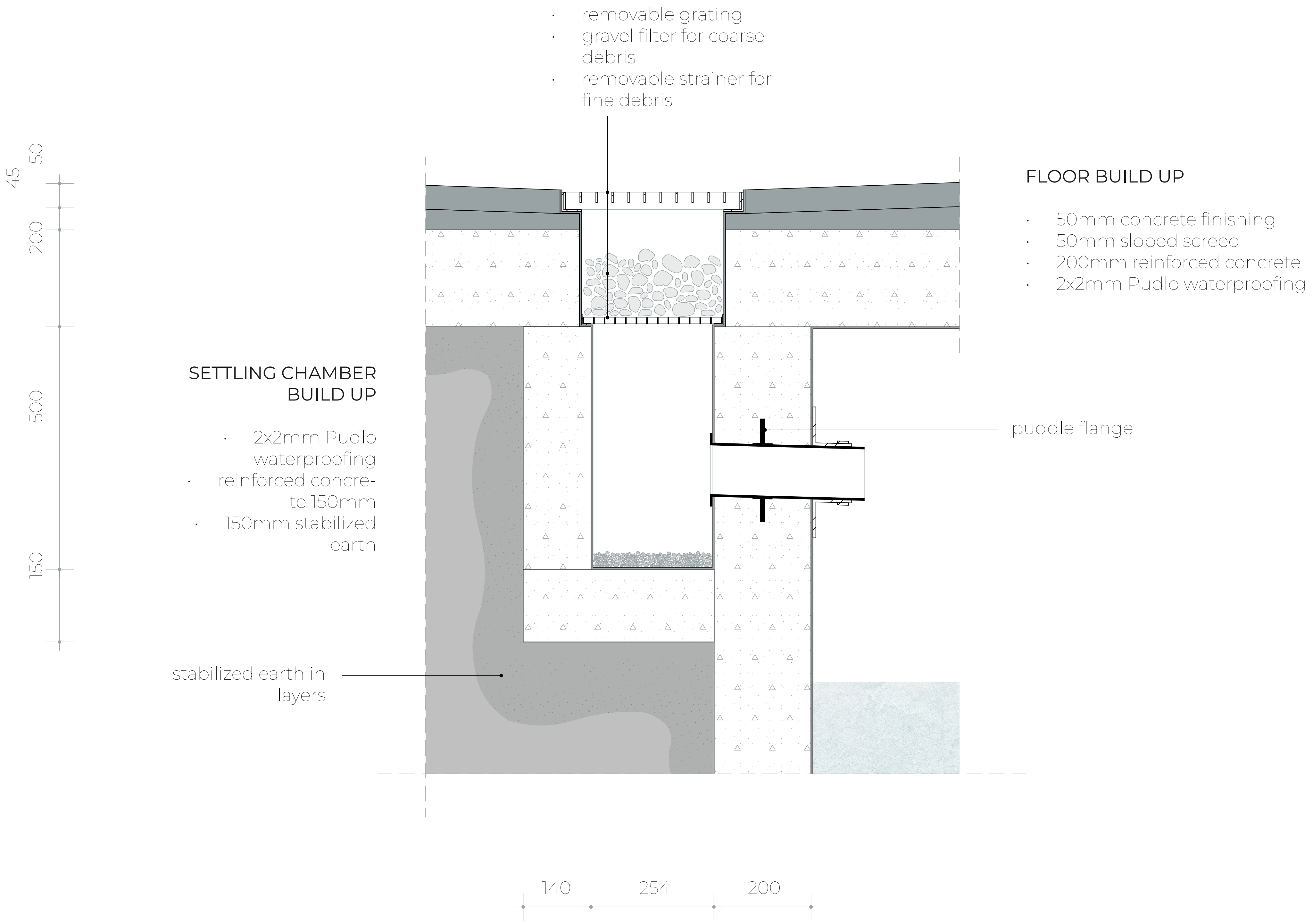
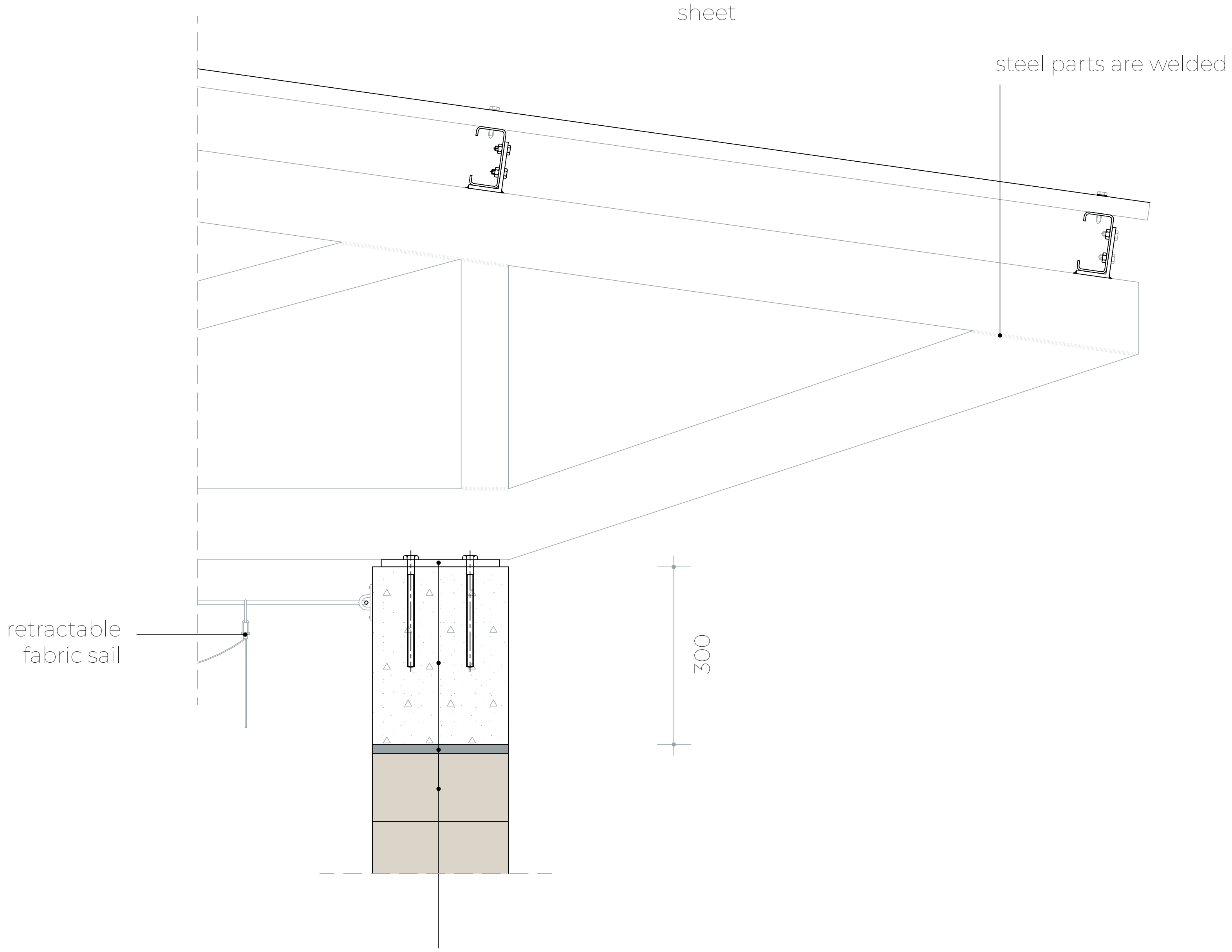


Figure 59 - Detailling of the underground water tank. *Source: Own work*

DETAIL OF ROOF CONNECTION

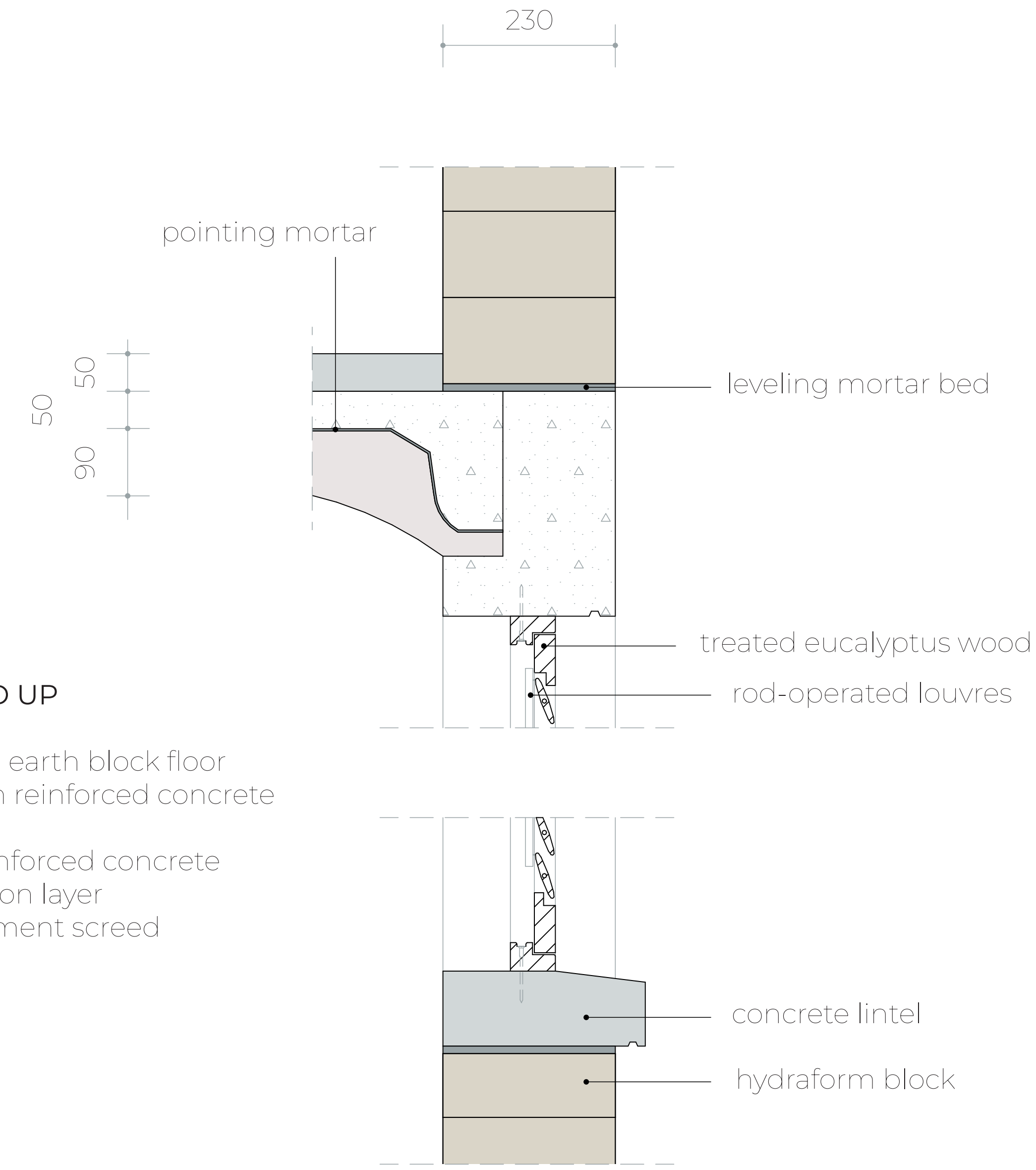
ROOF BUILD UP

- Steel truss (120mm chords and 80mm diagonals)
- c-purlin fixed to steen angle, welded to truss
- 50 mm corrugated roofing sheet



- steel plate for truss connection
- reinforced concrete ringbeam
- leveling mortar bed
- hydraform block

DETAIL OF FLOOR CONNECTION AND LOUVRE FRAME



FLOOR BUILD UP

- Beam and earth block floor bearing on reinforced concrete ring beam
- 50mm reinforced concrete compression layer
- 50mm cement screed

Figure 60 - Detailling of the roof and frame. *Source: Own work*

04

Conclusion.

In Windhoek's informal settlements, over 220,000 people live without adequate sanitation, public space or community facilities (Namibian Sun, 2025) (Weber and Mendelsohn, 2017). This project asks what architecture can do about that. It does so via the following question: How can architectural design activate community life in an informal settlement in Windhoek, through a neighbourhood intervention that responds to its social and spatial context?

The answer, as this project shows, lies not in a single gesture but in the careful layering of programmatic and spatial logic, technical systems and material choices responding to the context.

The starting point was an observation made during a fieldtrip to Brendan Simbwaye: a shared water point had become a spontaneous gathering place, where women collected water, children played and conversations took place. Yet the space itself offered little reason to stay. This moment captured both the challenge and the opportunity that defines this project. The informal settlement does not lack community spirit, but it lacks the spatial support needed for that spirit to turn into collective practice. Upgrading Brendan Simbwaye therefore requires not just better infrastructure, but a spatial intervention that rebuilds the conditions for community life.

Programme and spatial layout as generators of activity

The first sub-question addressed how the programme and spatial layout of the community centre can sustain activity and everyday presence for all residents. The answer lies in the principle of multifunctionality, as theorised by Jacobs (1961) and developed further by VPUU (2021): spaces that support a range of activities draw a more diverse group of people at different times of day, creating a natural and sustained sense of presence and safety.

The programme was shaped directly by community input. During the field trip we spoke with a local youth group and they identified some of their most urgent needs: electricity, a place to study, and sanitation. But they also had a lot of dreams for the future of the neighborhood in which the community played a big part. This was stimulated by functions like an internet café open market and community hall.

These functions are arranged along a gradient from public to private, creating a spatial sequence that guides people from the busy road to the more sheltered functions in the back. The market square is positioned directly adjacent to the main road, because it is the most public function within the design. It is open, visible and active throughout the day, drawing people in from the neighbourhood. It provides the local community with opportunities to sell products, contributing to local economic resilience. Besides the square, the library and internet café offer a quieter but still accessible presence, responding particularly to the needs of the youth who lack electricity and a calm place to study at home.

The south side of the plot is adjacent to housing and therefore a lot quieter. On this side, the WASH facilities are positioned, creating a more private sphere. These facilities are supervised by the workshop spaces and the office of the caretaker. The caretaker has a clear sightline over the facilities, in line with the eyes on the street principle (Jacobs, 1961). This emphasis on visibility extends beyond the WASH facilities, as two clear sightlines run through the buildings, ensuring that from any point within the space, there is always a visible way out.

Throughout the buildings, spaces to sit and stay are integrated into the design, creating opportunities for optional activities to emerge. Following Gehl's (1987) distinction between necessary, optional and social activities, these spaces are intended to encourage informal encounters and everyday social interaction.

The introduction of housing further reinforces the encouragement of encounters through space. Through the careful placement of the housing units, a secondary route is created through the site. This route provides a quieter alternative to the main road, particularly for children returning from school, while also generating additional everyday activity within the community centre. At the same time, it improves the accessibility of the WASH facilities by connecting them more directly to the surrounding neighbourhood. While the housing opens up towards the route, the side facing the busy road is kept more closed, responding to the Namibian cultural value of privacy within the home.

The housing is developed in phases, starting with improved units on a vacant plot. People can move from the existing shacks into these upgraded homes, after which the former structures can be removed. This creates space on the site for the future development of the community centre.

Decentralised systems as architectural elements

The second sub-question addressed how decentralised, low-tech systems for water, sewage and energy can be integrated as architectural elements of the design, rather than treated as technical add-ons. In Brendan Simbwaye is no municipal connection for water, sewage or electricity, besides the one water tap point. Rather than treating this absence as a barrier, the design takes it as a point of departure.

The total daily water demand for the wash facilities is approximately 10,750 litres, this is managed through a system that combines rainwater harvesting, greywater recycling and on-site wastewater treatment, with a municipal top-up connection available as a backup. This collection system is not hidden: rainwater is collected via sloped roofs and guided along visible steel chains into an underground storage tank. These chains are visible from the market square, while the roof overhangs that direct the water form part of the architectural expression of the building. The gutters continue this water route, visibly embedded within the floor.

Besides that, solar panels are placed on the roof, generating electricity for the internet café and stored within the building. Solar street lights illuminate the pedestrian paths after dark, directly contributing to the safety of residents, particularly women and children using the WASH facilities at night.

By making these systems visible and legible, the design goes beyond solving a technical problem. It suggests how decentralised infrastructure can be feasible, maintainable and integrated into architectural expression, offering a possible reference for future interventions in similar settlements.

Responding to topography, climate and local materials

The third sub-question explored how the design can respond to the site's topography, climate and locally available materials. The site in Brendan Simbwaye is located at one of the highest points in the settlement, with a slope of approximately fourteen percent. Rather than treating this as a constraint, the design treats it as an organising principle.
The difference in height is used to naturally create boundaries between the more public and private functions. Several volumes are partially sunken into the ground, using the thermal mass of the earth for passive cooling. The sloped terrain also naturally directs rainwater towards the collection points, improving the efficiency of the water-related systems and reducing the reliance on mechanical pumping.

The building volumes are designed according to the principle of cross-ventilation. Two volumes oriented perpendicular to the prevailing south-eastern wind create a natural airflow through the space between them. The roofs are supported by high steel trusses, creating a gap that allows warm air to rise and escape. Together, these passive strategies significantly reduce internal heat loads without the need for mechanical cooling.

The primary structural material is the hydraform block, a load-bearing compressed earth block made from local soil and cement. The choice for this material was informed by the visit to the Habitat Research and Development Centre during the fieldtrip. Although Namibia has limited locally available raw materials, the project prioritises the use of locally sourced resources wherever possible, supplemented by materials that are already widely used in the region to ensure availability and familiarity within local construction practices.

The construction is kept deliberately low-tech, allowing the building to be constructed and maintained by local residents without specialised knowledge or imported expertise.

A design that works with its context

Taken together, the three sub-questions lead to a shared conclusion: architectural design can activate community life in informal settlements by combining the opportunities of the site with design that encourages to meet and a functional program that meets the ambition and aspirations of the people living in the neighbourhood.

The community centre and housing in Brendan Simbwaye do not solve all the problems facing the settlement. They are, as VPUU (2021) would put it, a small and manageable intervention designed to act as a catalyst. But by combining functional infrastructure with spatial quality, by making technical systems legible and beautiful, by introducing a route that restructures movement at neighbourhood scale, and by grounding the design in the culture and context of its place, this project demonstrates what architecture can contribute to a place where the resources are scarce and the need is great.

The shared water point observed during the fieldtrip showed what was possible: people gathering, children playing, conversations happening. This project is an attempt to build upon that moment, to create not just the infrastructure for daily life, but the conditions for community life to take root and grow.

05

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Appendix.

Water Without Networks

Decentralised Water and Sanitation Strategies for Community Buildings in Windhoek's Informal Settlements

Research paper

Elke Jaspers | 598807
Architecture | Extreme Studio
Joost Woertman & Atze Boerstra
5 June 2026

Table of contents

Introduction

Over 220,000 people in Windhoek live in informal settlements (Namibian Sun, 2025), without access to basic services like water and sanitation. The municipality's capacity to respond to this rapid urban growth is limited, and connecting these settlements to centralized infrastructure is not a realistic short-term solution. In this context, decentralized systems for on-site water generation and treatment offer a promising alternative. However, Windhoek's arid climate requires a critical assessment of available systems and their performance under such conditions.

This research paper supports the graduation project *Grounding Community*, which explores how architectural design can activate community life in an informal settlement in Windhoek. A key ambition of the project is to integrate decentralized water and sanitation systems not as technical add-ons, but as integral architectural elements. To establish the theoretical and technical foundation for these design choices, this paper addresses the following questions:

Main Research Question

Which decentralized water and sanitation strategies are suitable for a community building in Windhoek's informal settlements?

Sub-questions

- What are the climatic and infrastructural conditions of Windhoek's informal settlements that affect water and sanitation provision?
- Which decentralized water and sanitation technologies are available, and what are their technical requirements and limitations?
- Which spatial design principles ensure safe and inclusive access to shared water and sanitation facilities?

Methodology

This research is based on a combination of literature review and case study analysis. Academic sources and technical reports are used to identify relevant decentralized water and sanitation strategies, while selected case studies provide insight into their practical application and spatial integration.

Following this research phase, a field visit to Windhoek will be conducted. Insights from this visit will be integrated into the following design process and are further elaborated in the graduation report.

1 Water Scarcity and Informal Settlements in Windhoek

To understand the challenges that decentralised water and sanitation systems must address, this chapter first examines the climatic and demographic conditions of Windhoek. It outlines the city's water resources and the specific challenges faced by residents of informal settlements.

1.1 - WATER RESOURCES IN WINDHOEK

Namibia is the most arid country in Southern Africa, and Windhoek relies on several water supply systems, including groundwater, water recycling, and surface water runoff. The city has a local steppe climate, with a rainy season typically lasting from January to April and an average annual rainfall ranging between 300 and 350 mm (Atlas of Namibia, 2019; figure 1). High evaporation rates further limit the ability to harvest sufficient water from surface sources (Atlas of Namibia, 2019).

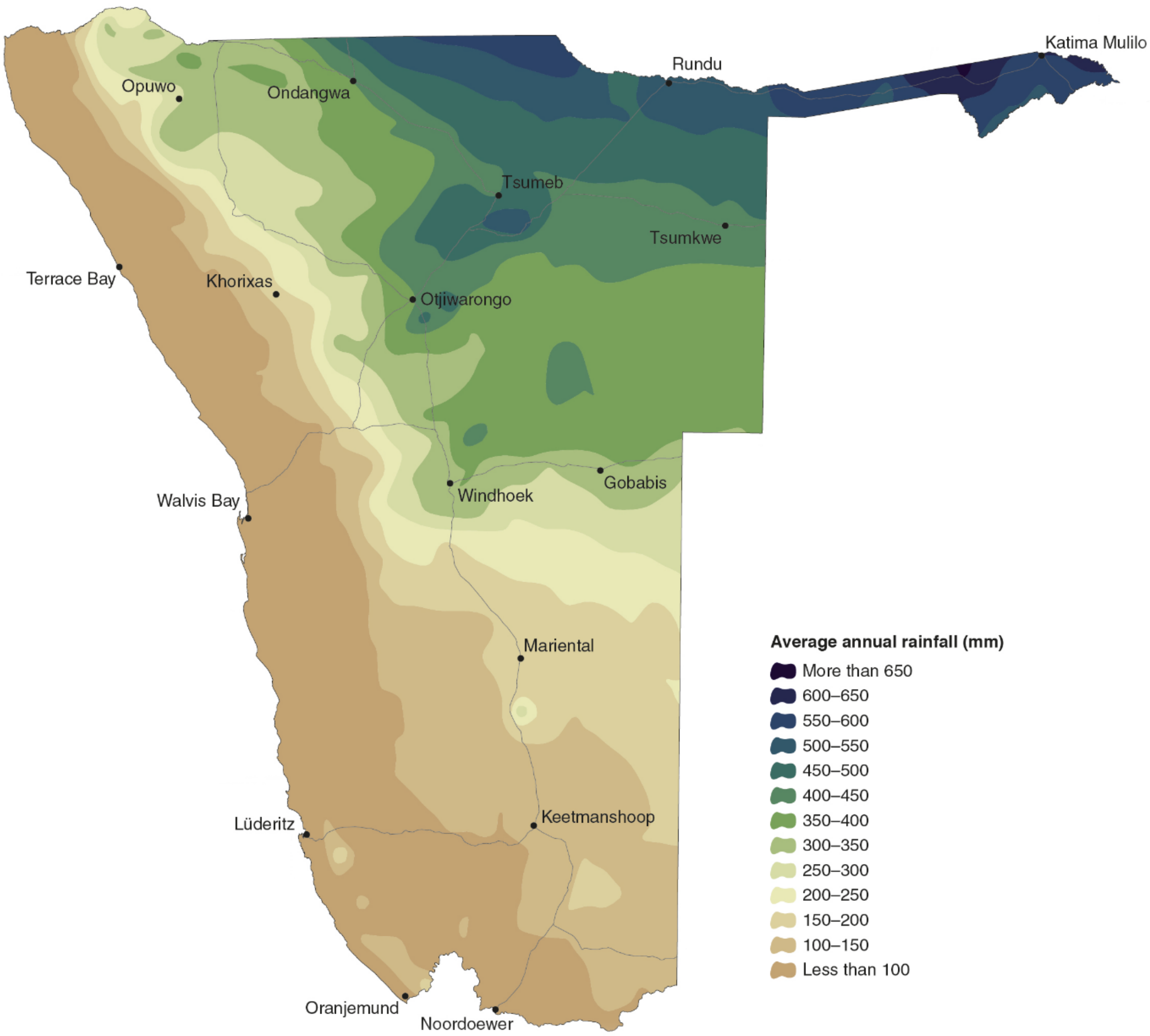

Figure 1. Annual Rainfall Namibia. Source: Atlas of Namibia (2019)

Although surface water from dams is officially the largest source (table 1; adapted from Mapani et al., 2023), these figures are based on designed capacities under "normal" rainfall conditions and do not reflect current realities. Since the last major rainfall in 2011, dam levels have often remained critically low, transforming the Windhoek aquifer into the city's primary water lifeline. As a result, groundwater is now heavily relied upon to make up for the shortfall (Mapani et al., 2023).

Water sources	Potential yield (mm³)	Percentage (%)
Surface water Omatako, Von Bach & Swakoppoort dam (95% assured yield)	20	56
Groundwater Berg Aukas & Boreholes, Kombat Mines, Coblenz Boreholes & Seeis Boreholes	6.7	18
City of Windhoek aquifer/boreholes	1.7	5
Recycled Water Old Goreangab recycling plant & New Goreangab recycling plant	7.5	21
Total	**35.9**	**100**

Tabel 1. Water Sources in Windhoek. Source: Mapani et al. (2023)

To cope with these challenges, Windhoek has adopted additional strategies beyond conventional sources. The city is one of the few worldwide to directly incorporate reclaimed water into its potable supply, and possibilities for rooftop rainwater harvesting are being investigated (Ward, 2007). These measures are essential to ensure water security in the face of rapid population growth, environmental pressures, and climate change (Mapani et al., 2023).

1.2 – URBAN DEMOGRAPHICS

Windhoek is home to over 486.000 people and almost half of them is living in informal settlements. According to an article of the Namibian Sun (2025), there are currently more than 220.000 residents of Windhoek living in informal settlements and this is growing rapid annually. Weber and Mendelsohn (2017) identified approximatly 56.000 informal housing structures in 2016. If the growth rate continues, there will be 99.000 shacks by 2031.

Since the city has largely been able to maintain services only in middle- to high-income areas, the majority of informal settlement residents rely on shared public water access points and communal sanitation facilities. The household size in informal settlements varies per area. In Goreangab, households consist of 4.6 people on average (Uhlendahl, 2010). Within these households, women and girls are primarily responsible for water-related and domestic tasks, research indicates that 70-90% of such activities in African informal settlements are carried out by women (Dinkelman & Ngai, 2021). This combination of large households and gendered responsibilities underscores the heavy daily burden placed on women in accessing essential water and sanitation services.

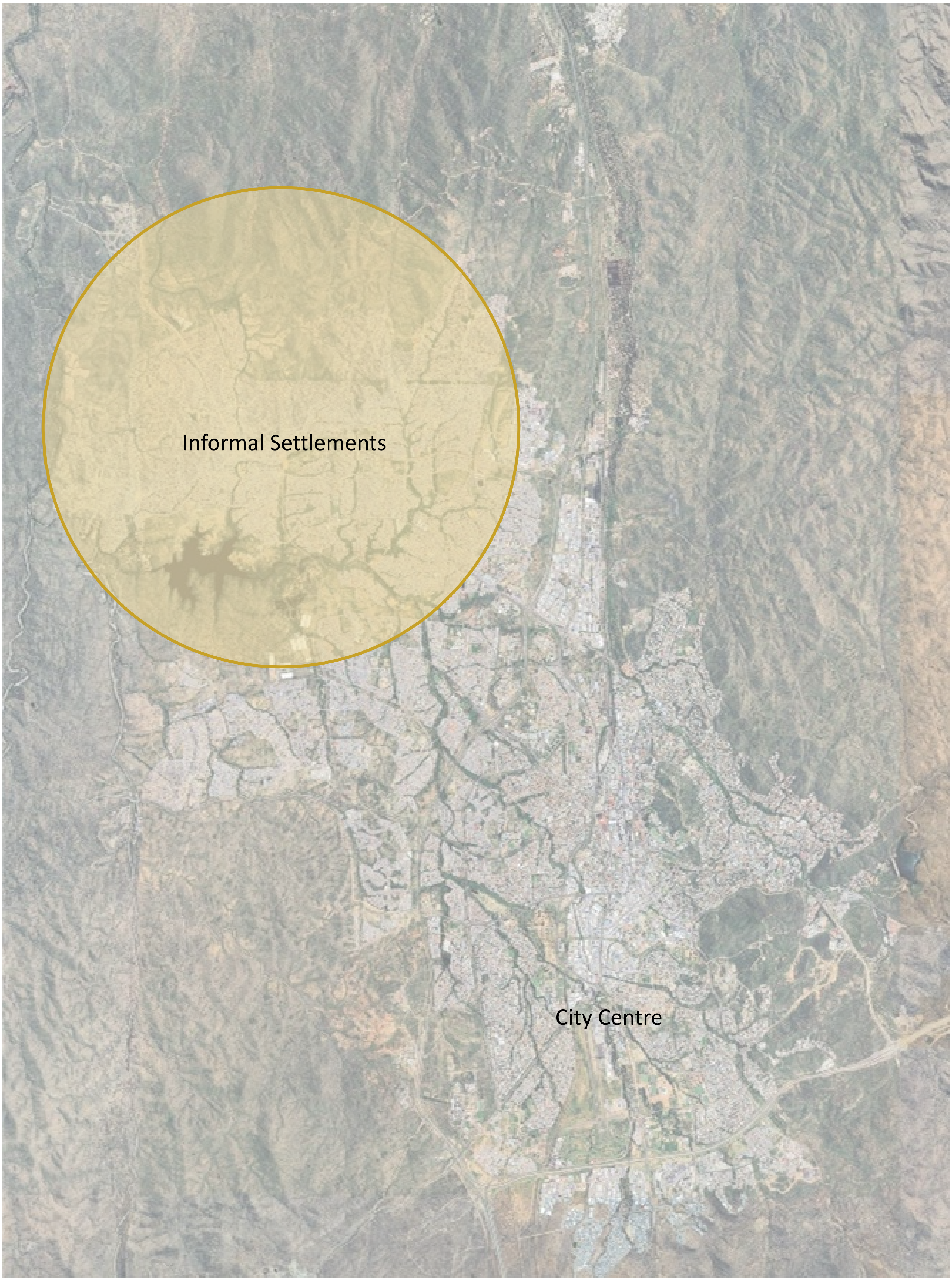

Figure 3. Informal Settlements in Windhoek. Source: Google Earth (2026)

2 Water Demand and User Needs

According to Uhlendahl (2010), residents of informal settlements in Windhoek consume on average 27 litres of water per person per day. Placed within the hierarchy of water needs, this amount is only slightly above the minimum required for short-term survival. It should be noted, however, that data from Uhlendahl is from 2010, and the situation has likely worsened since then due to population growth and increasing pressure on water infrastructure (Mapani et al., 2023), meaning todays consumption levels may be even lower.

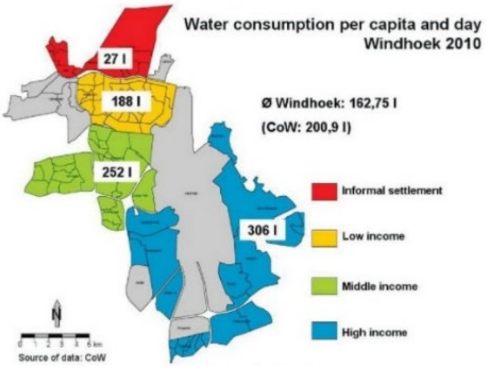

Figure 4. Water consumption per day in Windhoek. Source: Uhlendahl (2010)

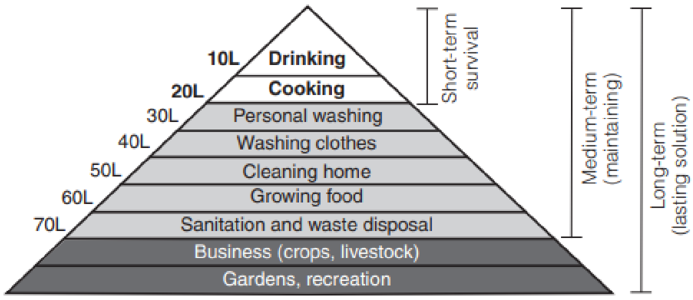

Figure 5. Hierarchy of water needs Source: WHO (2013)

Decentralized water systems present a promising approach for addressing the water shortage challenges. Maniam et al. (2022) argue that decentralized rainwater harvesting and greywater recycling systems can provide affordable and safe water reuse options for informal settlements, especially in areas lacking centralized infrastructure. To design an effective decentralized water system for Windhoek's informal settlements, it is essential to understand the daily activities and water-related needs of residents. Based on existing literature on informal settlements in sub-Saharan Africa, several key functions and water demands can be identified.

2.1 – PRIMARY WATER-DEPENDENT ACTIVITIES

Household activities form the primary water demand in informal settlements. Women and girls bear the majority of water-related and domestic tasks, including water collection, laundry, and childcare (Dinkelman & Ngai, 2021). Empirical evidence from Windhoek confirms that cooking and laundry account for the largest share of household water use in informal settlements (Uhlendahl et al., 2010; see figure 6). Beyond these domestic activities, access to adequate sanitation facilities is an equally pressing need. However, the absence of toilets in houses or nearby public toilets remains a significant challenge in informal settlements (von Wietersheim, 2023).

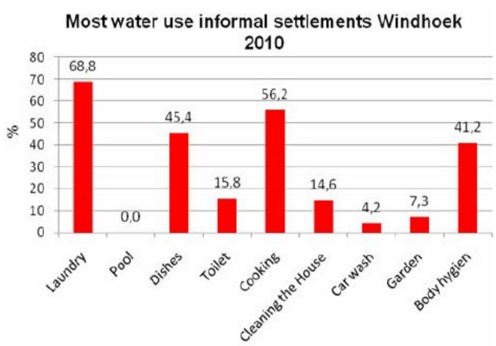

Figure 6. Water use Informal Settlements. Source: Uhlendahl et al. (2010)

2.2 – WATER DEMAND

To understand the scale of water provision needed, it is important to first establish what the minimum daily water requirements are. The Sphere Handbook (2018) defines minimum survival water needs for drinking, basic hygiene, and cooking, as shown in table 2.

Type of Need	Quantity	Comments
Survival (drinking and food)	2.5 to 3 lpd	Depends on climate and individual physiology
Basic hygiene practices	2 to 6 lpd	Depends on social and cultural norms
Basic cooking needs	3 to 6 lpd	Depends on food type, social and cultural norms
Total	**7.5 to 15 lpd**	**Lpd: Litres per day**

Table 2. Minimum survival needs. Source: Sphere Handbook (2018)

Beyond the quantity of water, physical access is equally important. The Sphere Handbook (2018) defines the maximum acceptable distance to a water point as 500 meters, while WHO guidelines (2018) define basic access as within a 30-minute round trip. These standards underline that proximity is not just a matter of convenience but a basic requirement for dignified living.

An extended overview of all functions and their water needs, safety benefits and health risks can be found in the appendix.

2.3 – WATER DEMAND ACCORDING TO CABS

While the Sphere Handbook (2018) provides minimum survival standards, empirical data from existing community ablution blocks (CABs) offers insights into actual water consumptions patterns in well-managed communal sanitation facilities. CABs are facilities that provide both water and sanitation. Crous et al. (2013) conducted detailed end-use monitoring of four CABs in Frasers informal settlement, South Africa, measuring water consumption per fixture type over a period of several months.

The data reveals that laundry facilities account for the majority of water consumption, representing approximately 60% of total water use. This is followed by showers (18%), toilets (16%), hand wash basins (5%), and urinals (3%). Table 3 shows the individual water requirements in (L/day). The research noted that the laundry facilities were not only used for washing clothes but also for collecting water to take home for domestic purposes such as cooking, drinking, and cleaning.

Fixture type	Water consumption (L/person/day)*	Percentage of total
Laundry facilities	21.8	59%
Showers	6.4	17%
Toilets	5.9	16%
Hand wash basins	2.0	5%
Urinals	1.0	3%
Total	**37.1**	**100%**

*Table 3. Water demand in Community Ablution Block. Based on Crous et al. (2013). *Calculated from average household consumption (82 L/HH/day from CABs only) divided by average household size (2.2 persons)*

The authors note that these numbers represent water consumed at the CABs only. When accounting for water collected from remaining standpipes in the settlement (estimated at 18% additional consumption), the total household water demand increases to approximately 44 L/person/day. This means that water requirements are almost 3 times higher than minimum survival standards.

3 Decentralized Water and Sanitation Strategies

With the water demands and user needs established in the previous chapter, this chapter examines which decentralized technologies are available to meet them. The strategies are assessed on their technical requirements, limitations, and suitability for Windhoek's arid climate and limited infrastructure.

3.1 – CURRENT USED STRATEGIES

The table below provides an overview of the most commonly used strategies, comparing their technical requirements, social considerations, and sustainability potential.

Criteria	**(Rooftop) Rainwater Harvesting**	**Greywater Reuse**	**Blackwater Reuse**	**Municipal Supply (waterpoints)**
Technical				
Water supply potential	Rainfall x Roof Area x Runoff Coefficient = Water Supply Rainfall Windhoek: 300-350 mm/year (Atlas of Namibia, 2019) Runoff Coefficient: 0.65 (Ward, 2007) Roof area: n.d. (50 for example) = 11.375 L/year = 31 L/day = +/- 3 people's daily needs*	Recyled water makes up for about 21% of the water sources in Windhoek (Mapani et al., 2022) The exact amount of recycled water potential at the building scale depends on the primary water use		Research (Aihuki, 2020) indicates that the water available at collection points is insufficient to meet all the needs of most households in informal settlements, forcing them to prioritize and make trade-offs among their water uses
Space footprint	Roof area + storage reservoir	Nearly all grey and black water is collected and treated at a central reclamation plant to produce safe drinking water. Windhoek prioritizes large-scale recycling rather than individual household reuse. *(not the case in informal settlements)*		Different water tap points installed by the municipality.
Infrastructure requirements	Gutters, pipes, storage tank	Pipes, filter, storage tank	Pipes, filter, storage tank	Pipes, tap, pay system
Social				
User convenience (maintenance)	Depending on the system design. Low-tech and low-maintenance solutions are preferred			Long queues and occasional maintenance issues
Safety considerations	When rainwater is used for human consumption, appropriate purification is required to ensure it is safe and meets drinking water standards	When greywater is used for human consumption, appropriate purification is required to ensure it is safe and meets drinking water standards	Requires thorough purification before it can be safely reused. Because of its high contamination, it is usually used for irrigation.	Long walking distances, no electricity
Sustainability				
Circular potential	Depends on the use of the collected water	High potential	Low potential because of high contamination (unless treated at large scale reclamation plant)	Depends on the use of the collected water

*Table 4. Water collection methods. *Minimal water need (L/person/day): 7.5 - 15L. Source: Sphere Association, 2018.*

3.2 – ATMOSPHERIC WATER GENERATION

There is a need for new and sustainable technologies that further address the water shortage issue. Atmospheric water generation (AWG) is a process that extracts water from humidity present in the ambient air (Raveesh et al., 2021). It could resolve the problem of water scarcity in arid regions (Hamed et al., 2010). There are multiple types of AWG, each with different characteristics. However, not all types are suitable for the Windhoek environment. This is summarized in table 5.

AWG	Method	Energy	Water Production	Required Humidity	Feasibility
Active Refrigeration					
VCR	To cool air so that water vapor condenses and turns into liquid water	High Demand Cooling system	1-4 L/kWh	>30% (bot works best at high R.H.)	Low High energy demand and very dependant of climatic conditions
TEC			20-820 mL/h	60-100%	Not Feasible High energy demand and R.H. Windhoek too low*
HVAC Condensate Recovery			70-1880 L/day	Works best at high R.H.	Low High energy demand
Water Vapour Concentration					
Sorption	To separately treat the water vapour, reducing cost and energy requirement	Low demand - solar energy	Depends on the sorbent material Most work well at R.H.< 30%		High Can work at low RH and the hot climate of Windhoek can provide the necessary solar energy
Membrane Separation		High demand - cooling system (but better then AR techniques)	Depends on the exact system	Works best at high R.H.	Low High energy demand
Passive Cooling					
Dew Harvesting	Collecting water from air moisture that naturally condenses on cool surfaces, usually overnight	Low demand	maximum of 0.8 L/m²/day	20 - 40% with advanced systems (but works best at high R.H.)	Low Technically feasible but not practically viable
Fog Harvesting	Mesh nets intercept fog, formed droplets drip into collection gutters into storage tank	Low demand	0,5–3,3 L/m²/day (Shanyengana et al., 2002) based on an ideal fog circumstances	High - Requires Fog (95%)	Not Feasible R.H. Windhoek too low*

*Tabel 5. Atmospheric Water Generation Methods. *Relative Humidity in Windhoek: highest levels occur in February, reaching 56%, while the lowest is recorded in September at 17%. Average R.H. is 34%. Source: World Weather & Climate Information (2010-2026).*

3.3 – SORPTION

As shown in the table above, sorption appears to be the most promising AWG type for the conditions in Windhoek. In an experimental investigation by Kumar and Yadav (2015) a solar glass desiccant box type system (SGDBS) has been tested at NIT Kurukshetra, India. This location has similar climate conditions to Windhoek.

The solar glass desiccant box works through a simple day-night cycle (see figure 8). At night, side windows are opened to let air flow through. The composite material (calcium chloride mixed into sawdust) naturally attracts and absorbs moisture from the air because it has a strong affinity for water. This absorption continues until the material becomes saturated with water, usually by around 1:30 AM.

During the day, the windows are closed and the box is exposed to sunlight. Solar radiation heats up the water-soaked material to temperatures around 77°C. This heat causes the absorbed water to evaporate back out of the material into the enclosed air space. As more water vapor builds up inside the box, it eventually condenses on the cooler glass surface. The water droplets then slide down the angled glass and collect in a tray at the bottom.

The system produced 180 ml of water per kilogram of material per day when using a 60% calcium chloride concentration. Maximum water production occurred during peak sunlight hours between 12:30 and 1:30 PM. Although the system shows promise, the limited scalability and need for further research make it unsuitable for direct application in the graduation project.

3.4 – GREYWATER RECYCLING

Greywater is wastewater generated from bathing, hand washing and laundry, and does not include toilet waste. It represents a promising source for on-site water reuse. A case study by Godfrey et al. (2010) in rural schools in Madhya Pradesh, India, demonstrates how a simple and low-cost greywater reuse system can work effectively in a semi-arid context with limited infrastructure, conditions comparable to those in Windhoek's informal settlements.

In this project, greywater from bathing and hand washing IS collected and treated through a series of simple filtration stages using local materials. The treated water was then reused for toilet flushing and kitchen garden irrigation. The system resulted in a 60% increase in water availability. Importantly, the system was constructed using locally available materials and maintained by the community itself, making it both affordable and replicable. These qualities make greywater reuse a suitable strategy for community buildings in informal settlements with limited access to centralized infrastructure.

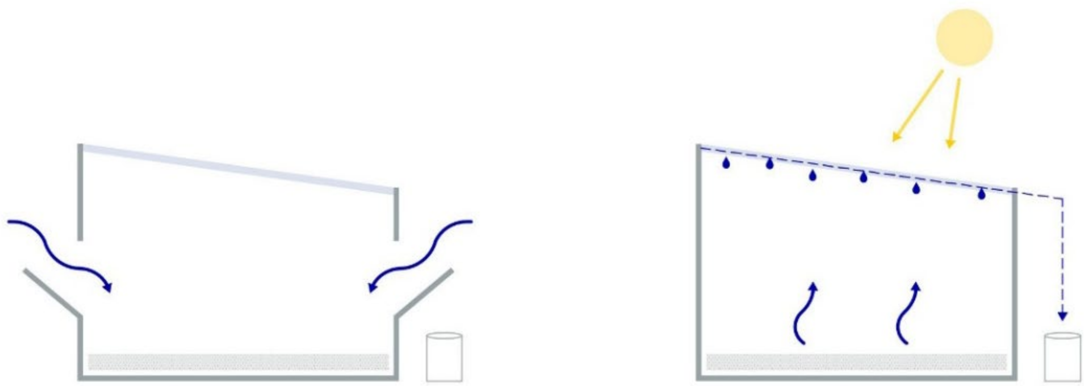

Figure 7. Solar glass desiccant box type system. Own work based on research of Kumar and Yadav (2015)

3.5 – SYSTEMS FOR TREATED WATER

While greywater can be partially reused on-site, wastewater from sanitation facilities still needs to be treated before it can be safely discharged or reused. In contexts where a connection to the municipal sewage network is not available, decentralized treatment systems offer a practical alternative. A reference project in South Africa demonstrates how such a system can work in practice.

In the eThekwini demonstration-scale DEWATS (Decentralized Wastewater Treatment System), wastewater from sanitation facilities is first collected in a settler tank, where solid waste sinks to the bottom. The water then passes through an anaerobic baffled reactor (ABR), a series of chambers in which bacteria naturally break down the remaining organic matter (Arumugam et al., 2023). After this, the water flows through constructed wetlands, where plants and soil further filter out harmful substances (Arumugam et al., 2023). The treated water is finally stored and reused for irrigation. This makes the system not only a sanitation solution but also a contribution to water availability and food production within the community.

3.6 – CAPACITY

The systems described in this chapter, namely rainwater harvesting, greywater reuse, and decentralized wastewater treatment, can together significantly reduce the dependence on external water supply. However, complete water independence is unrealistic in Windhoek's arid climate, and decentralized systems should therefore be seen as a meaningful complement to rather than a full replacement of external water sources.

Once the number of users and the specific conditions of the site are known, a more detailed calculation can be made based on the water consumption data presented in chapter 2.5 to determine how much water can actually be saved through on-site generation and reuse.

4 Safe Design Principles

As established in the previous chapters, adequate sanitation facilities are a critical need in informal settlements. However, the provision of these facilities presents specific challenges, particularly for women and girls who are responsible for the majority of water-related household tasks (Dinkelman and Ngai, 2021).

Research shows that shared sanitation facilities frequently do not meet the needs of women and girls due to concerns about accessibility, cleanliness, privacy, and personal safety (WHO, 2022). Similarly, travelling to water collection points has been associated with increased risks of sexual violence and psychological stress (Graham et al., 2016).

These safety concerns are an important consideration for any intervention that provides communal water and sanitation facilities.

4.1 – SAFETY AS A PUBLIC GOOD

To address safety in public space, this research draws on the framework developed by Violence Prevention through Urban Upgrading (VPUU), a Cape Town–based organisation that promotes safety as a public good in low-income neighbourhoods. The VPUU manual (2021) outlines a set of interconnected design, management, and spatial-use principles aimed at reducing crime and improving both actual and perceived safety.

Rather than applying these principles in a generic manner, they are used in this research as an analytical framework to assess and inform the future design. Particular emphasis is placed on principles related to visibility and surveillance, defined access and safe movement, ownership of space, maintenance and management, and inclusive design, as these are especially relevant to the everyday safety experiences of women and girls. A detailed overview of the VPUU safety principles is provided in the appendix.

4.2 – FEMALE-FRIENDLY PUBLIC AND COMMUNITY TOILETS

The VPUU guidelines are intended for public spaces in general. However, because the building will provide communal water and sanitation facilities, it is important to also consider safe design principles specific to these functions. For this purpose, the guide on female-friendly public and community toilets developed by UNICEF, together with WaterAid and Water & Sanitation for the Urban Poor (SWUP) (2018), has to be considered when designing. A detailed overview of the guidelines is provided in the appendix.

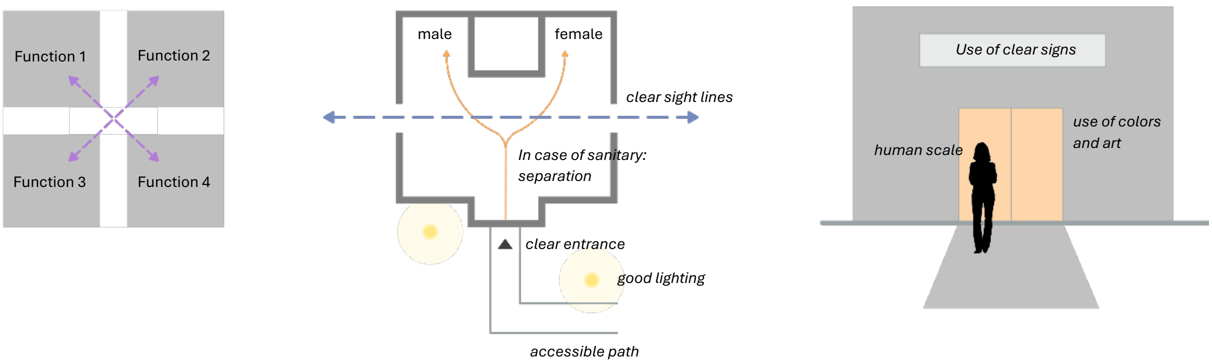

Figure 8. Safety Principles in Buildings. Own work based on manual of VPUU (2021) and UNICEF guide (2018)

4.3 – MULTIFUNCTIONALITY

According to VPUU (2021) one key aspect that is really important is multifunctionality. When facilities support a range of daily activities, they attract more frequent use by a broader spectrum of people, which increases visibility and fosters a greater sense of safety.

That is why it is imported to research which other functions are needed in the informal settlements. Beyond the directly water-dependent functions, education and recreation remain priorities, despite challenging living conditions. As noted in *This home is my home (2023)*, for those still attending school, education is the priority despite limited daylight hours for studying. Young people mentioned sports as activities that brought them joy and kept them engaged in the community.

Informal employment is a dominant economic activity. According to *Surviving like a bird (2020)*, informal employment includes trading, taxi driving, accommodation provision, mending clothes, and shoe repairs. Residents often lack formal employment and survive through selling goods at open-air markets, with one respondent noting: "I do not have a formal job; I just survive on selling things here and there, mainly meat at the open market in Okahandja Park because we do not have an open market."

Urban agriculture, while potentially beneficial for food security, faces significant barriers in Windhoek's informal settlements. According to *Surviving like a bird (2020)*, urban agricultural practice is not common in the study area, which could be attributed to lack of land, high cost of water, and the semi-arid climate with long-standing water restrictions.

An extended overview of all functions can be found in the appendix.

Conclusion

This research has examined which decentralized water and sanitation strategies are suitable for a community building in Windhoek's informal settlements. The findings show that Windhoek's arid climate, with only 300-350 mm of annual rainfall and an average relative humidity of 34%, severely limits the applicability of many water technologies. Rainwater harvesting and greywater reuse emerge as the most suitable strategies, while atmospheric water generation through sorption shows potential but requires further research before it can be applied in practice. For wastewater treatment, the eThekwini case study in South Africa demonstrates how constructed wetlands and anaerobic treatment can provide a viable alternative to municipal sewage connections. Together these systems can significantly reduce dependence on external water supply, though complete water independence remains unrealistic.

Beyond the technical dimension, the research highlights that safety and inclusivity are equally important design considerations. Shared water and sanitation facilities in informal settlements frequently fail to meet the needs of women and girls, and design principles from VPUU and UNICEF provide a clear framework to address this. These findings, combined with the water consumption data from chapter 2.5, will directly inform the design of the community center and provide the basis for a more detailed water demand calculation in the graduation report.

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Appendix

Function	Frequency	Water Need	Safety Benefit	Health Risk
Water supply and sanitation				
Water collection point	Varies from once per week to daily (Lewis, 2018)	High (Uhlendahl et al., 2010)	The sight of people attracts other people (Jacobs, 1961)	Reduces the risk of assault during the journey and the use of contaminated water (Lewis, 2018) (Graham et al., 2016)
Toilets	Daily (Sphere Association, 2018)	Depends on the system (dry or wet sanitation) (Special Rapporteur, 2011)	Active use of space increases natural surveillance (Jacobs, 1961)	Reduces diseases caused by open defecation (Tidwell et. al, 2019)
(Hand) washing	Daily (Sphere Association, 2018)	High (Uhlendahl et al., 2010)	Active use of space increases natural surveillance (Jacobs, 1961)	Reduces the risk of diseases caused by contaminated water (Lewis, 2018)
Laundry	Daily (Sphere Association, 2018)	High (Uhlendahl et al., 2010)	Active use of space increases natural surveillance (Jacobs, 1961)	Reduces the risk of diseases caused by contaminated water (Lewis, 2018)
Food Security				
Cooking	Daily (Sphere Association, 2018)	High (Uhlendahl et al., 2010)	Active use of space increases natural surveillance (Jacobs, 1961)	Reduces the risk of diseases caused by contaminated water (Lewis, 2018)
Food Growing Area	-	Medium (Warka Water, n.d.)	Collective ownership will improve community cohesion and reduce the risk of violence and crime (VPUU, 2017)	Reduces the risk of diseases caused by contaminated water (Lewis, 2018)
Care and education				
Childcare, primary school	Daily (Von Wietersheim, 2023)	-	Multiple functions lead to longer periods of activity and the ability for people to combine trips to the area (VPUU, 2017)	Common areas function as essential learning for young children (Elorduy, 2021)
Community				
Playground, social hub, library, gym	Daily to weekly (von Wietersheim, 2023)	-	Collective ownership will improve community cohesion and reduce the risk of violence and crime (VPUU, 2017)	The community helps people deal with daily challenges and makes them feel at home in their settlement (von Wietersheim, 2023)
Economical				
Marketplace, shop	Daily (Endjala and Botes, 2020)	-	Storekeepers and other small businessmen are typically strong proponents of peace and order themselves (Jacobs, 1961)	Having a job is the most important factor for a good life in informal settlements (Endjala and Botes, 2020)

Link to VPUU guide:

https://vpuu.org.za/download/vpuu-manual/

Link to Female-friendly public and community toilets: a guide for planners and decision makers:

https://www.wateraid.org/us/sites/g/files/jkxoof291/files/Female_friendly_toilet_guide.pdf

WASH Dimension Calculations

1 – USER BASE

Brendan Simbwaye has approximately 372 households and an estimated population of 1,172 residents. The population is considered very young (GIZ, 2026).

Age bracket (years)	Share of population (percent)
0-6	17
7-12	15
13-17	8
18-34	30
35-59	26
60+	4

Children under six are assumed to accompany a parent and are therefore not counted as independent users. Based on a site visit and data from Development Workshop Namibia (2021), approximately 10% of households have access to a private toilet. These residents are excluded from the calculation, as the community facilities are intended primarily for those without private sanitation. This results in the following estimated user base:

Parameter	Value
Total population	1172 people
Children under 6 (17%)	Excluded
Households with private toilet (10%)	Excluded
Estimated daily users	**875 people**

2 – FIXTURE COUNT

To determine the required number of sanitary fixtures, this project uses the Durban Community Ablution Block (CAB) as a reference case (elaborated in the research paper). The CABs were designed for 550 users but in practice serves up to 1100, meaning its design capacity is regularly exceeded by a factor of two. The design of the cabs consists of the following amounts:

Facility	Male	Female
Toilets	2	4
Urinals	2	-
Showers	2	2
Hand wash basins	2	2
Laundry basins	-	2

Since Brendan Simbwaye has 875 potential users (roughly comparable to the CAB's peak load) the fixture count is set above the CAB's design standard to ensure comfortable use during peak hours.

Facility	Male	Female
Toilets	4	8
Urinals	4	-
Showers	4	4
Hand wash basins	4	4
Laundry basins (shared)	8	

3 – DAILY WATER DEMAND

Not all users are expected to use every facility daily. Research in Windhoek's Goreangab informal settlement (Lewis et al., 2018) shows that the majority of residents collect water less than once a day: 29% collect water three times per week, 24% twice, and 19% once per week. Residents with prepaid cards reported not always having sufficient credit for daily water needs, prioritizing drinking and cooking over hygiene activities such as showering and laundry (Lewis et al., 2018). Daily showering and frequent laundry use is therefore assumed to be financially and practically infeasible.

Laundry is further assumed to be carried out by one person per household, consistent with research indicating that 70–90% of water-related domestic tasks in African informal settlements are performed by women (Dinkelman & Ngai, 2021).

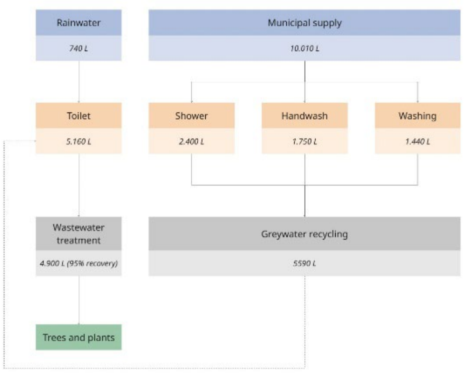
Activity	**Users**	**Frequency**	**Persons/day**	**Use (L)***	**Total (L/day)**
Toilet	875	Daily	875	5.9	5160
Handwash	875	Daily	875	2.0	1750
Shower	875	2x per week	375	6.4	2400
Laundry (water taken home included)	230	2x per week	66	21.8	1440
Total	**Approx. 10750 L/day**				

** Water consumption per fixture based on empirical CAB monitoring data (Crous et al., 2013). Laundry figures include water collected for off-site domestic use such as cooking and drinking, as observed in CAB studies (see research paper for more information).*

4 – SYSTEM OPTIONS

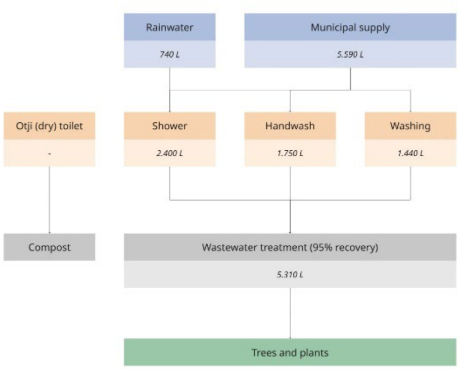
Three system configurations were considered for managing the water and wastewater demands of the project. The technical background and performance of these systems is elaborated in the research paper.

- Option 1: Greywater recycling only



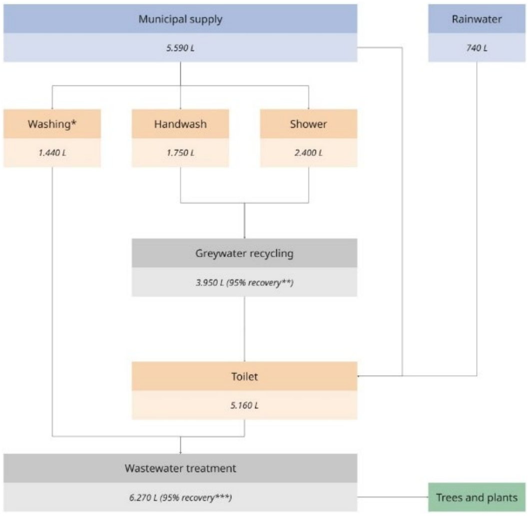
This option would reuse greywater from showers, washing and hand washing for toilet flushing. However, it would require an extensive network of separate piping and difficult water treatment methods within the system, adding significant construction complexity and maintenance demands. Given the limited technical capacity available in the settlement for ongoing maintenance, this option was considered impractical at this scale.

- Option 2: Dry toilets (Otji toilets)



Dry composting toilets would eliminate the need for a wastewater treatment system as well. However, at the scale required for 875 users, this system would be overloaded and difficult to manage. This option was therefore not suitable.

- Option 3: Greywater recycling + wastewater treatment *(selected)*



This approach combines a greywater recycling system for reuse in toilet flushing with a full wastewater treatment system: septic tank, Anaerobic Baffled Reactor (ABR), and constructed wetlands for blackwater and residual greywater. Rainwater harvesting provides the primary water supply. As elaborated in the research paper, both the greywater reuse system and the DEWATS approach have been successfully applied in comparable contexts: the greywater system is based on a case study from rural India (Godfrey et al., 2010), and the wastewater treatment system is informed by the eThekwini demonstration project in South Africa (Arumugam et al., 2023).

By applying the measures explained in option 3, daily water demand will be reduced by 48%.

**for rainwater supply the following calculation has been used: Rainfall x Roof Area x Runoff Coefficient*

Rainfall Windhoek: 300-350 mm/year (Atlas of Namibia, 2019)

Runoff Coefficient: 0.65 (Ward, 2007)

Roof area: 855 + 420 = 1275 325 x 1275 x 0.65 = approx. 269.350 L/year = approx. 740 L/day

5 – SYSTEM SIZING

Based on the calculations above and the case studies elaborated in the research paper, the following system sizing was determined for Option 3. The systems are designed to function as independently as possible from the municipal network, relying primarily on rainwater harvesting supplemented by greywater recycling and on-site wastewater treatment. However, a municipal connection via a manhole is included to allow the rainwater storage tank to be topped up when needed.

- Rainwater tank

  Rainfall in Windhoek is highly seasonal, concentrated between January and March with a peak in March. During this period, daily collection exceeds demand by approximately 1790 L (3000 L harvested vs. 1210 L required), creating a surplus that needs to be stored effectively. A tank of approximately 130 m³ is large enough to buffer around 70 days of this surplus and capture most of the seasonal yield, without oversizing to the point where the tank sits empty for most of the year. Any excess can be directed towards additional uses within the project.

- Greywater Recycling system

Based on the case study from India elaborated in the research paper (Godfrey et al., 2010), a greywater system handling approximately 2000 L/day requires a storage unit of 7350 × 1000 × 1000 mm. The estimated greywater production in this project is approximately 4000 L/day, requiring two units of this size, resulting in approximately 15 m³ of storage capacity. An additional tank of 5 m³ provides buffer for distribution.

- Wastewater treatment (septic tank + ABR + constructed wetlands)

Blackwater and residual greywater are treated through a three-stage system informed by the eThekwini DEWATS case study elaborated in the research paper. Wastewater first passes through a septic tank (8 m³), followed by an Anaerobic Baffled Reactor (14 m³) for further biological treatment. The water then flows through constructed wetlands for a final cleaning step before discharge or reuse. Based on the South African reference case (162 m² per 13.9 m³/day), the required wetland area for treating 6600 L/day is calculated at approximately 77 m².

The following systems will be used in the design:

Component	Dimensions	Capacity
Septic tank	3 x 1,5 x 1,8 m	8 m³
ABR	5 x 1,5 x 1,8 m	14 m³
Constructed wetlands	77 m³	6600 L/day
Greywater treatment	7,35 x 1 x 1 (unit x2)	15 m³
Storage tank	2 x 2 x 1,25 m	5 m³
Rainwater storage tank	130 m³	70 days buffer

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