Urban Accupuncture

Architecture as a catalyst for environemtal and water conservation in the context of the Kilimanjaro Informal Settlement

Student Name: **Kenneth Main**

Supervisor Name: **Matteo Fraschini**

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This dissertation is presented as part fulfillment of the degree of Master of Architecture (Professional) in the school of Architecture and Geomatics, University of Cape Town.

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Abstract

The following dissertation will attempt to establish an approach to dealing with the issue of waste contamination and water conservation in the natural and urban landscapes of the riverbed, its rivers' edges and its man-made peripheries. This research locates itself at the northern boundary of the city of Windhoek along a stretch of polluted riverbed in the Kilimanjaro Informal Settlement (KIS) where public environments are undefined, unhealthy and in many ways disconnected from the greater metropolitan areas. In the creation of an architectural approach 'urban acupuncture' will be explored in an attempt to create Architecture that has the potential to influence areas beyond its physical boundaries and which can re-establish and re-imagine the value of the river for its unseen influence in shaping the city as rapid urbanisation is taking place. In this section of the city, particular aspects of environmental degradation, water conservation and lack of basic infrastructure form a basis of inquiry to which an urban framework has been proposed. Drawing on theories of landscape urbanism, this urban framework acts to establish an alternative and more efficient infrastructural system which collects, stores, recycles and reuses wastewater for both drinking and irrigation purposes. Seen as the bi-product of this urban framework, the KIS Agricultural Learning Centre has been proposed which provides the necessary link between this infrastructural insertion and both the public and social constructs of the Kilimanjaro Informal Settlement.

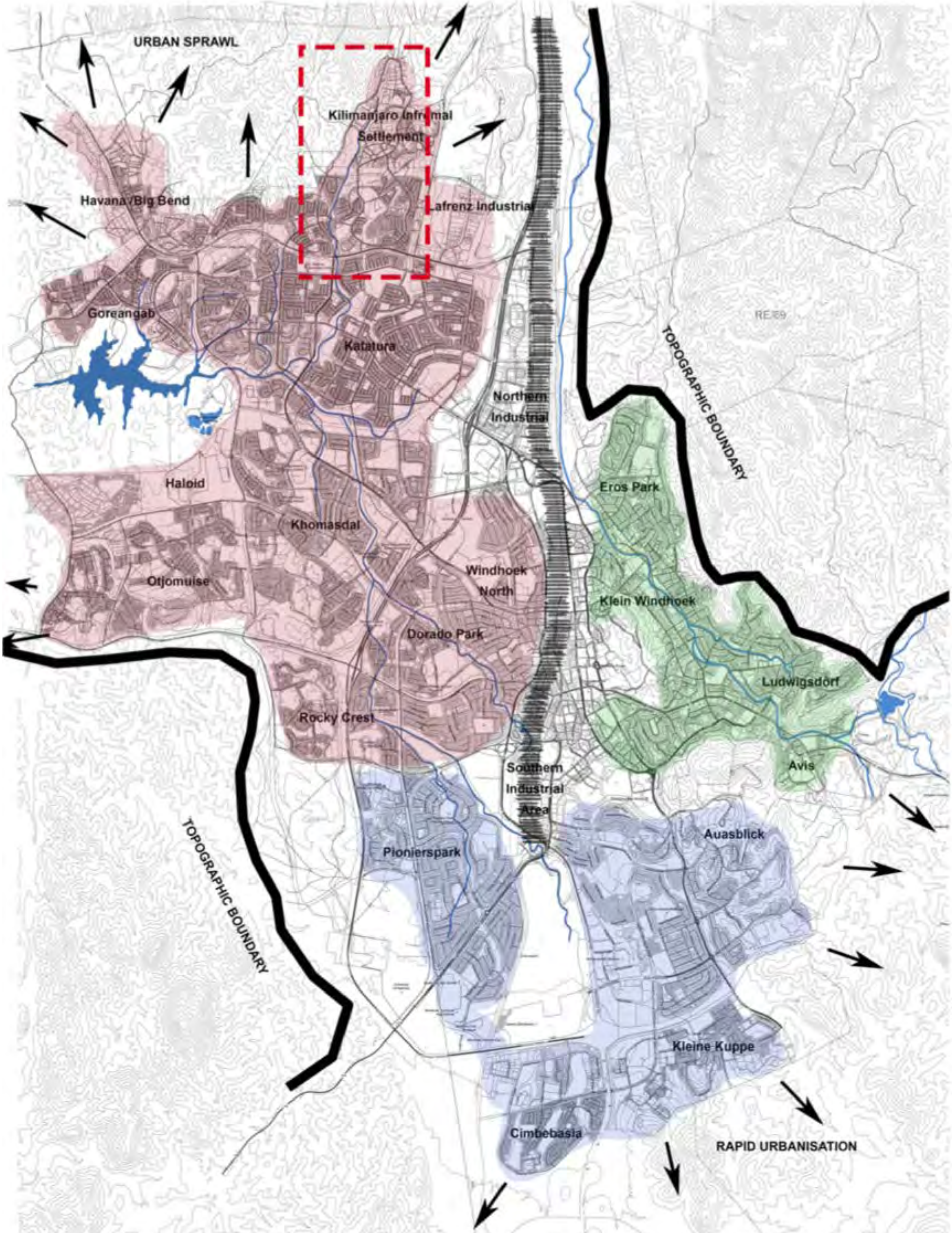
List of Abbreviations

KIS	The Kilimanjaro Informal Settlement
WWTP	Waste Water Treatment Plant
UGPT	Use and Get Paid Toilet
VPUU	Violence Prevention through Urban Upgrading

Glossary

Biological Waste	This refers to both human and organic waste that can collect through a number of sources such sewer infiltration, domestic wastewater run off or direct contamination.
Living systems	Refer to the objects in the environment that behave in a similar manner to that of a living thing yet do not possess life.
Non- Living systems	Refer to the objects in the environment that are resistant to change and which do not naturally respond or adapt to a change in their surrounds.
Wastewater	This refers to all surface water runoff. This includes rainwater, domestic water runoff and raw sewage infiltration.

Contents



Rapid Urbanization and Urban Sprawl in Windhoek *Green: high Income, Blue: Mid, Red: Low Income*

Introduction

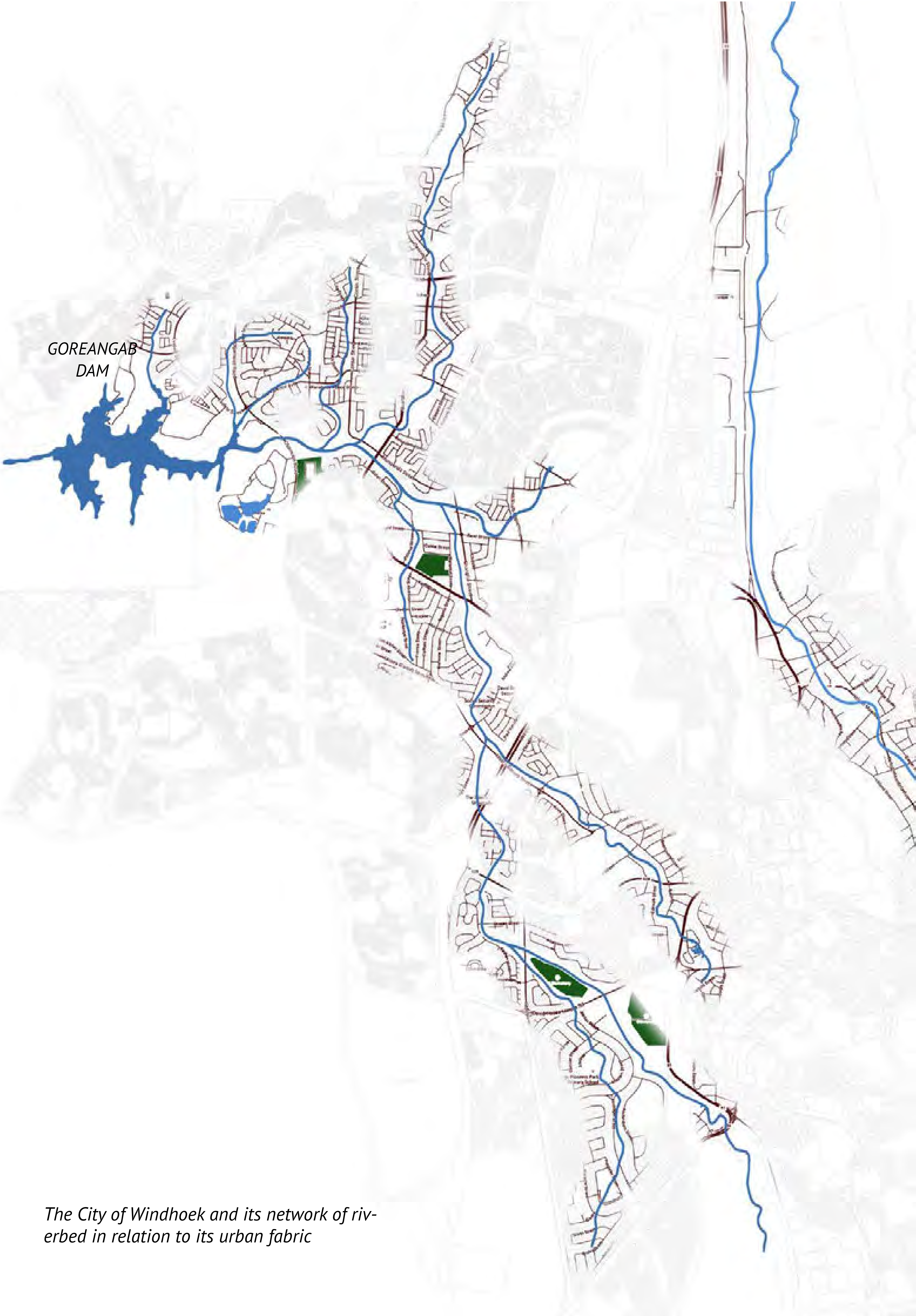
It is often forgotten or unrealized that the greatest problem facing the contemporary world and which is inherent in almost all cities stems from the nineteenth-century city growth patterns that saw the rise of industrialization and modernism which celebrated the city as 'an assault on nature' (Charlesworth & Adams, 2011). With the industrial revolution came a disruption in the relationship between human settlement and the natural environment, causing the mass movement of populations from the countryside into urban areas igniting in situ growth of urban population (Roberts, Ravetz & George, 2009).

Figure 1

In the context of Africa and the global south, the momentum of urbanization has in the past 15 years accelerated past the developed world or global north, showing no signs of slowing down. This has resulted in an unprecedented phase of rapid urbanization which now sees 22 million people being added to Africa's population each year (Cartwright, 2015). Africa is thus becoming part of a new revolution, an urban revolution which aims to accommodate this rapid influx of people and which presents a significant opportunity due to the fact that these cities are yet to be built. Although urbanization has brought about much advancement to the way of living, uncontrolled and unaccounted effects have emerged placing tremendous pressure on the already degraded natural environments of many African cities. Although urbanization is rapidly occurring at an uncontrollable rate it does, however, still have the potential to be managed through well-planned and implemented strategies that will determine the safety, productivity and livelihood of Africa's future social and economic growth (Cartwright, 2015).

In the country of Namibia, unmanaged city growth, in the form of urban sprawl and rapid urbanization has already started to impact the functionality and sustainability of its capital city, Windhoek. In the years following Namibia's independence Windhoek's population has risen from 147 thousand in 1991 to 359 thousand in 2015 with almost all this growth occurring on the peripheries of the city (Menge, 2007). This has placed tremendous pressure on the government for the delivery of services as well as on the natural environments in and around the city. Stemming from the legacy of apartheid planning and previously disadvantaged backgrounds, large portions of Windhoek's population find themselves in these ever growing peripheries where poverty holds a grip on their potential for a better future, which in more recent years has been exacerbated by more frequent periods of drought that have begun to exhaust mans most valuable natural resource: water.

Part of the city's growth has, however, occurred along its network of dry river beds, which have played a significant role in shaping, dividing and connecting the city and its inhabitants into its contemporary state, paying tribute to the way topography and the value of ecology can influence city growth. In the context of Windhoek and its network of dry riverbeds, there exists an opportunity to re-establish and re-imagine the value of the river for its unseen influence in shaping and connecting the city in an effort to redirect its current trajectory of informal growth towards a more sustainable and environmentally conscious way of living which better utilizes this ever more precious resource.



The City of Windhoek and its network of riverbed in relation to its urban fabric

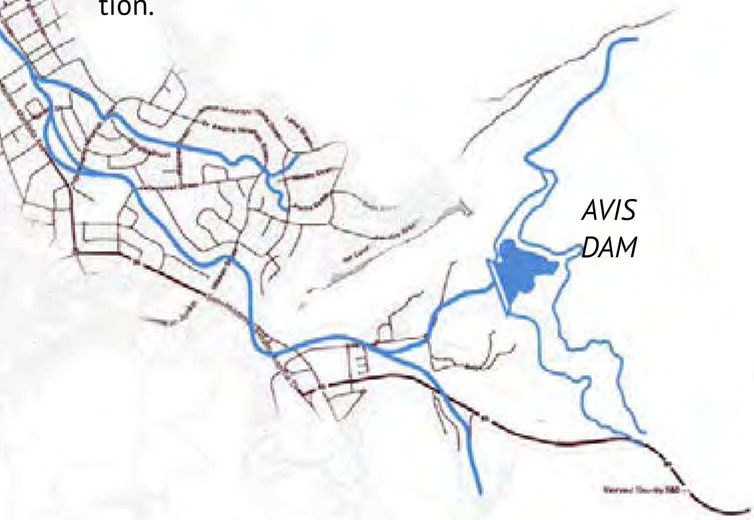
Shaping a City

The river and its historical influence

Throughout its history Windhoek has been shaped by a number of factors including racial segregation and industrial development. However, none has had more influence than that of its geographical characteristics that situates the city in a valley between two mountain ranges which have created these networks of riverbeds. Since Windhoek's establishment in 1840, these rivers have been both valued and respected for their yearly flash floods which turn these uninhabited dry spaces into raging torrents of water which act to refill dams in and around the city providing much needed water in the otherwise dry sub-Saharan climate (Menge, 2007).

As the city grew, these reserved natural spaces served a multitude of uses such as agricultural land, places of cemeteries and natural public space, which together with annual flash floods maintained their reservation. In more recent years, however, these spaces have been largely walled and forgotten due their 'reservation' and lack of public use, leaving them uninhabited, undefined and most notably polluted.

These 'forgotten spaces' do, however, provide a continuous, undeveloped platform in which architectural agency has the potential to contribute to the re-establishment of these now urban environments and their ecological systems, which are threatened by the processes of urbanization.



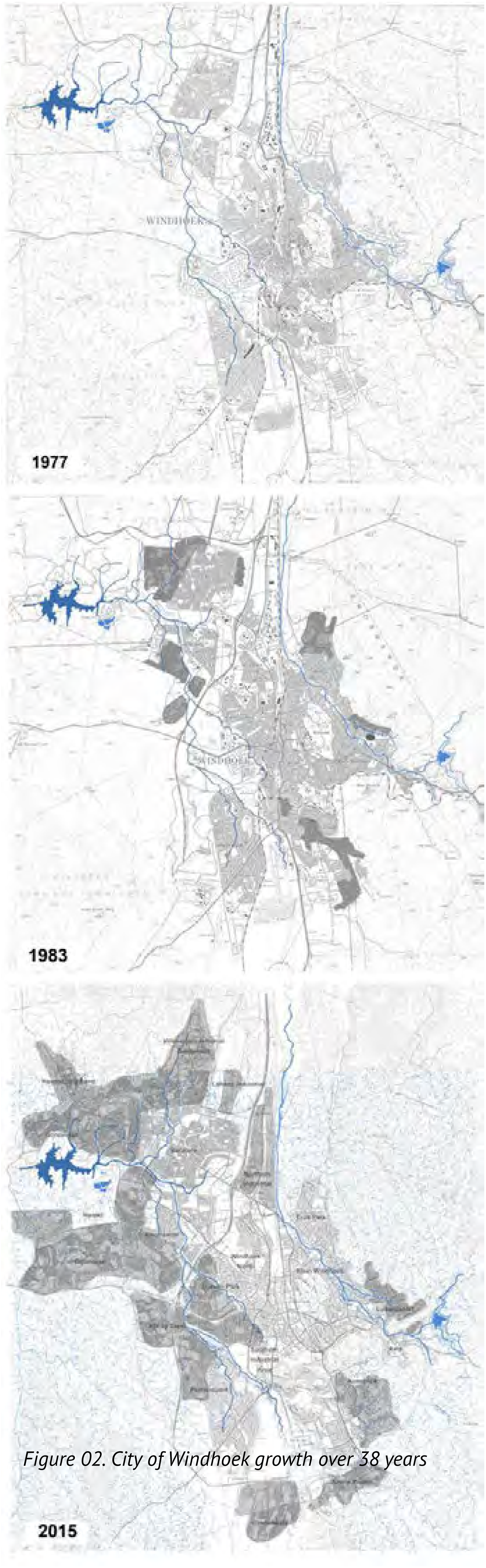


Figure 02. City of Windhoek growth over 38 years

Figure 3. The Kilimanjaro Informal settlement in relation to the Goreangab Waste Water Treatment Plan.

Locating Site

The Kilimanjaro Informal Settlement

Although the opportunity for city-wide enhancement can perhaps be achieved through the rejuvenation of the river, the realm of architectural agency focuses the scope of intervention to a smaller urban scale, where populations and built environments are more manageable and in which more finite issues can be identified and addressed. Thus, a particular district of Windhoek will form the site of inquiry. This area is located along the northern boundary of the city in an area known as the Kilimanjaro Informal Settlement (KIS), which exhibits some of the more problematic issues concerned with the rivers, their edges and most significantly water conservation. Through investigating the worst conditions of the city, it is believed that what is created may spark the growth of a sustainably integrated city wide project which utilizes this complex and interconnected network of riverbeds.

Defining the Issue

Raw sewage overflowing from an overloaded municipal man hole near children who use the riverbed as a flat and make shift soccer field.

Following the 'urban' revolution which has seen the emergence of unmanaged rapid urbanization, these once valued and influential natural public spaces within the city and the ecological habitats contained within are becoming increasingly **polluted**. Pollution in this case exists in a number forms including sewage infiltration from overloaded and leaking sewer lines that run along the riverbeds, biological (Human) waste due to lack of sanitary facilities, wastewater runoff from all forms of domestic water use due to the lack of stormwater collection and lastly from the general disposal of rubbish and organic waste. Pollution, specifically in areas of informal development has led to a number of public and environmental health issues, which can be traced to the interactions between the public and their natural environment. Throughout the year this pollution manifests along the river beds and their edges until infrequent 'yearly' flash floods transport this collected waste 14 kilometers down stream to the Goreangab Dam. In the year 2000 (unconfirmed date) the pollution in the Goreangab dam raised an issue for concern, which like most environmentally focused issues was never fully resolved. In other parts of the city both sewage and wastewater (including surface runoff) typically makes its way into the cities sewer system where it is transported to the nearby Goreangab Wastewater treatment plant (GWWTP). Here it is treated and used to partly supply Windhoek with fresh drinking water. To date, Windhoek is one of only three cities in the world that directly reclaims treated waste water (Including sewage water) for drinking water and which has done so for the past 35 years (Menge, 2007).

Historically, Windhoek has been supplied with water from a number of natural sources. After its establishment in 1890 by German colonialists, Windhoek derived its water from hot-springs in and around the area. As its population grew, notably in the 1930's these springs became insufficient requiring alternative methods to extract water from the natural environment. As a result, boreholes were drilled to access Windhoek's underground aquifer for the first time. Over the next 10 years this method of water attenuation too became insufficient prompting the exploitation of the two rivers that run through Windhoek as well as the construction of Windhoek's first and only two dams: Avis and Goreangab. By 1960 it became clear that the use of river, aquifer and dam water (by which time included intake from Von Bach Dam over 50 kilometers away) was not sustainable. In 1968 reclamation of sewage water was first introduced after which the construction of the Goreangab dam Waste Water Treatment Plant (GWWTP) was started. Over the years various upgrades have increased the plant's capacity. However, in recent years even this has shown signs that it is no longer a sustainable means of supplying water to Windhoek's ever growing population that is experiencing increasing water restrictions and tariff rises each year (Menge, 2007).

This begs a fundamental question of how Windhoek will continue to provide water in the future, specifically in areas where basic infrastructure has yet to be sufficiently provided. As seen through its history a new way and next step towards managing this valuable resource is evidently required, which can help equip Windhoek and its ever growing population with a sustainable supply and management of both its waste, water and natural environments.

PART 1

Conceptualizing an approach

Dealing with an issue that exists at the scale of the Kilimanjaro Informal Settlement begs the question of how and exactly what type of architecture can make the biggest impact and exactly what is causing the issue to occur. In order to address these questions, the conceptualization of an approach has assisted in determining the most effective type of architectural agency that is required and the method in which it is introduced into this urban environment. Following this conceptualization, a theoretical framework can be created, which can guide an approach to dealing with this issue, which is informed by its place within the urban composition while maintaining its contextual assignment. In the creation of a strategy the following part will explore and theorize the river and its edges at the scale of the settlement which will guide and focus the scope of intervention towards the creation of an urban framework.

Precedent Analysis

As a point of departure for mapping and identifying a methodical process, reference will first be made to three examples, where an urban approach to dealing with architectural insertion was adopted.

With reference to guiding urban organization and re-imagining the functional response of architecture, Tschumi, in his Parc de la Villette explored the notion of deconstructivism and fragmentation, making use of a theoretical grid to organize the landscape upon which he locates 25 cultural and entertainment pavilions. This award-winning project has become known as an unprecedented type of park through the idea that it is based on culture rather than nature and through a fragmented approach was able to provide space for multiple cultures (Souza, 2011).

Through its incremental construction over 16 years, the park provided a continuous form of public interest and change in scenery until its completion in 1998, where through this gentle public introduction and engagement became part of the identity of both the landscape and its people. The result was a series of individual installations which portrayed a unifying generic composition of materiality and most significantly colour. The success of this project lies within the way Tschumi envisioned Parc de la Villette as a "place of culture where 'natural and artificial' are forced together into a state of constant reconfiguration and discovery" (Souza, 2011), as opposed to the typical functional view of a park as a public green space.

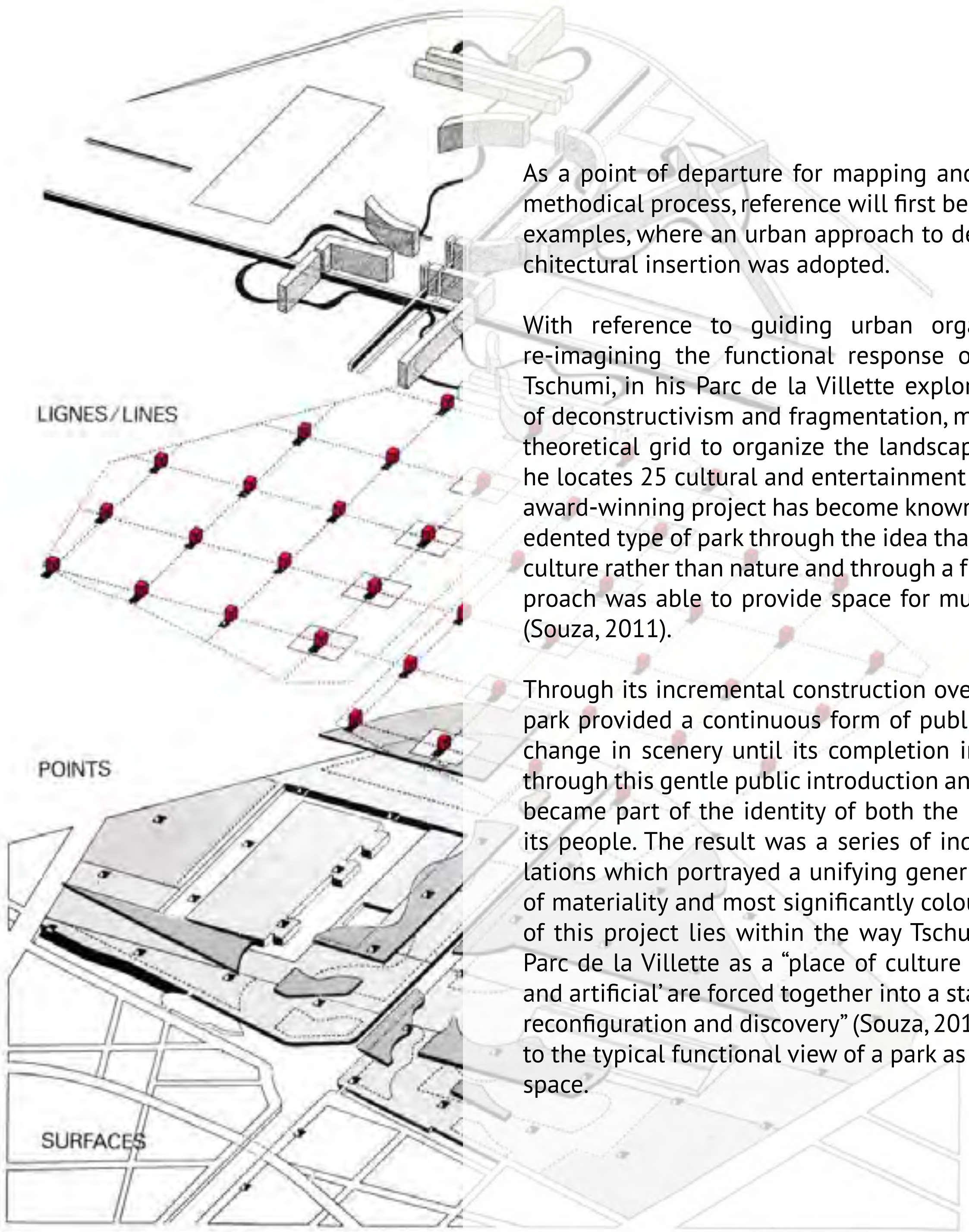


Figure 4. Tschumi's theoretical grid

A local example of an approach to urban upgrading is the Violence Prevention through Urban Upgrading (VPUU) project in Khayelitsha, which adopts a holistic approach to urban upgrading in the way it integrates all forms of development and not only the physical upgrading of urban public space.

The project is aimed at reducing violent crime and improving social conditions within informal areas of Cape Town, which is believed to path the way for improved social standards and the introduction of sustainable community projects, used to empower local residents (VPUU, 2016). In order to guide the decision- making process, the principles of surveillance and visibility (eyes on the street); Territoriality (owned space); Defined access and movement; Image and aesthetics (Dignity); Physical barriers: Maintenance and management (pride and ownership) have been established to create a strategic framework, which holistically responds to specific sites while maintaining continuity throughout its development. With this framework, issues of site were then categorized into a hierarchical order according to their pertinence, as either Emergency, Temporary or Permanent.

For example, in the Emergency category, sanitation was identified as the most pressing issue. In response, a series of three prototypes known as the 'sanitation stations' were developed according their contextually required capacity, which enabled this project and its designers to adopt a 'copy & paste' method of implementation, which addressed the issue on an urban scale over a short period of time while requiring comparatively little effort to do so.

As seen in this example, strategically identifying urban problems allows for the creation of effective architecture along these routes that minimize the necessity for large and weighty development which more often than not does not resolve the issue. This is particularly important in informal areas where money cannot be wasted.

Figure 5. VPUU Urban Framework

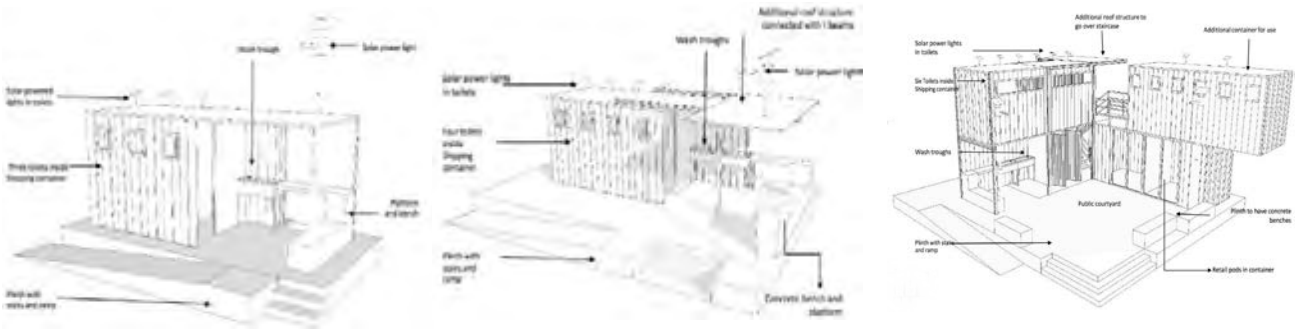


Figure 6. Small - Medium - Large 'Sanitation station' prototypes

The third example is located in Medellin, Columbia where in contrast to Namibia and South Africa and after political and policy change, the government took the initiative to focus its attention and subsidy towards the poorer areas of the city. During this time Medellin was not much different to Namibia. The gap between classes was forever increasing, informal growth was extremely high, crime was a major problem and living environments were unsuitable, while little was being done to address these major problems of the city. Like Windhoek, the city is confined by its topology and running out of space. In the year 2004 political and policy change sparked the initiative to address these ever growing issues. As a result a team of designers and thinkers was formed which adopted a strategic and incremental method which sought to address two overarching and far reaching issues: education and public space creation. These two issues were chosen due to their effectiveness for future growth and commonality within informal areas.

Figure 7. Medellin Metro Rail system providing a high degree of accessibility throughout the city

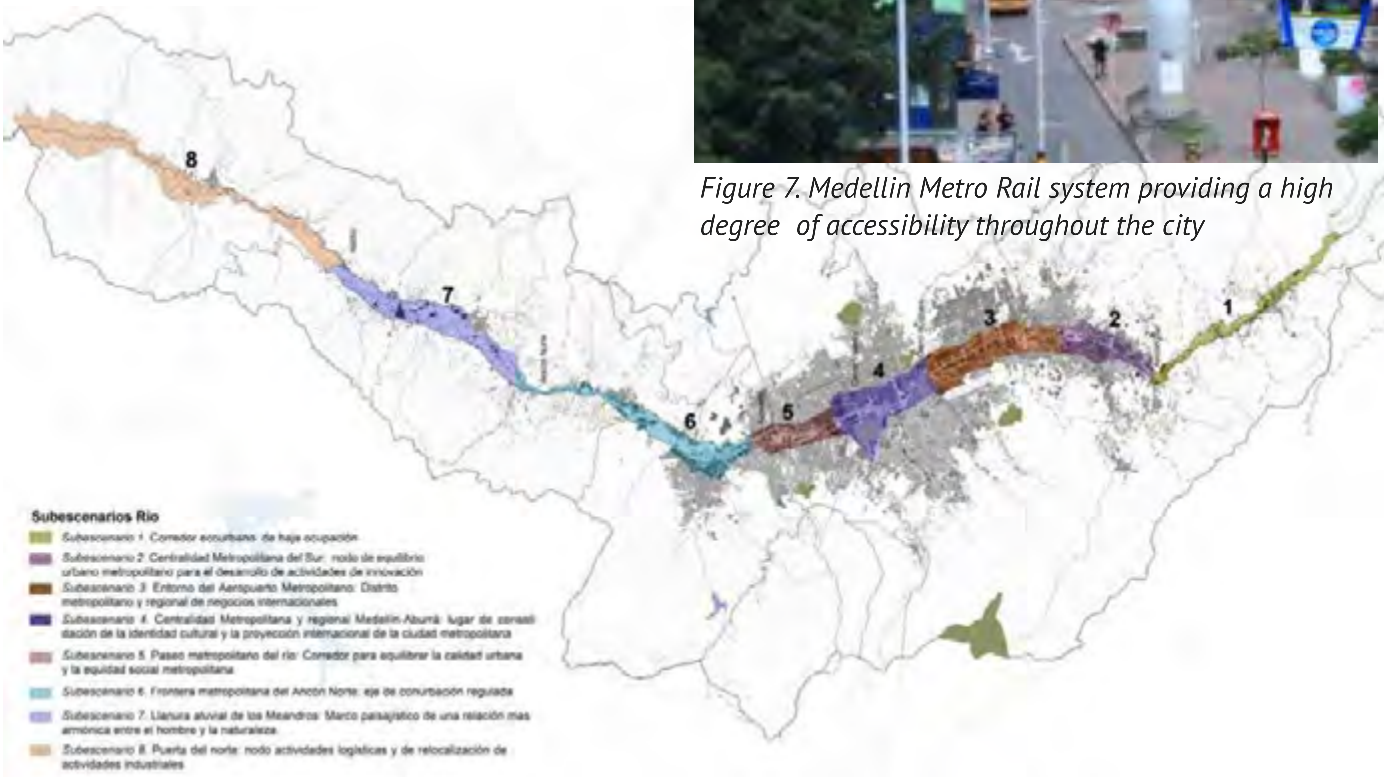


Figure 8. In this urban framework the city is separated into 8 different zones which each play a role in the overall urban upgrading initiative. Each zones addresses a particular issue which forms part of the overall objective.

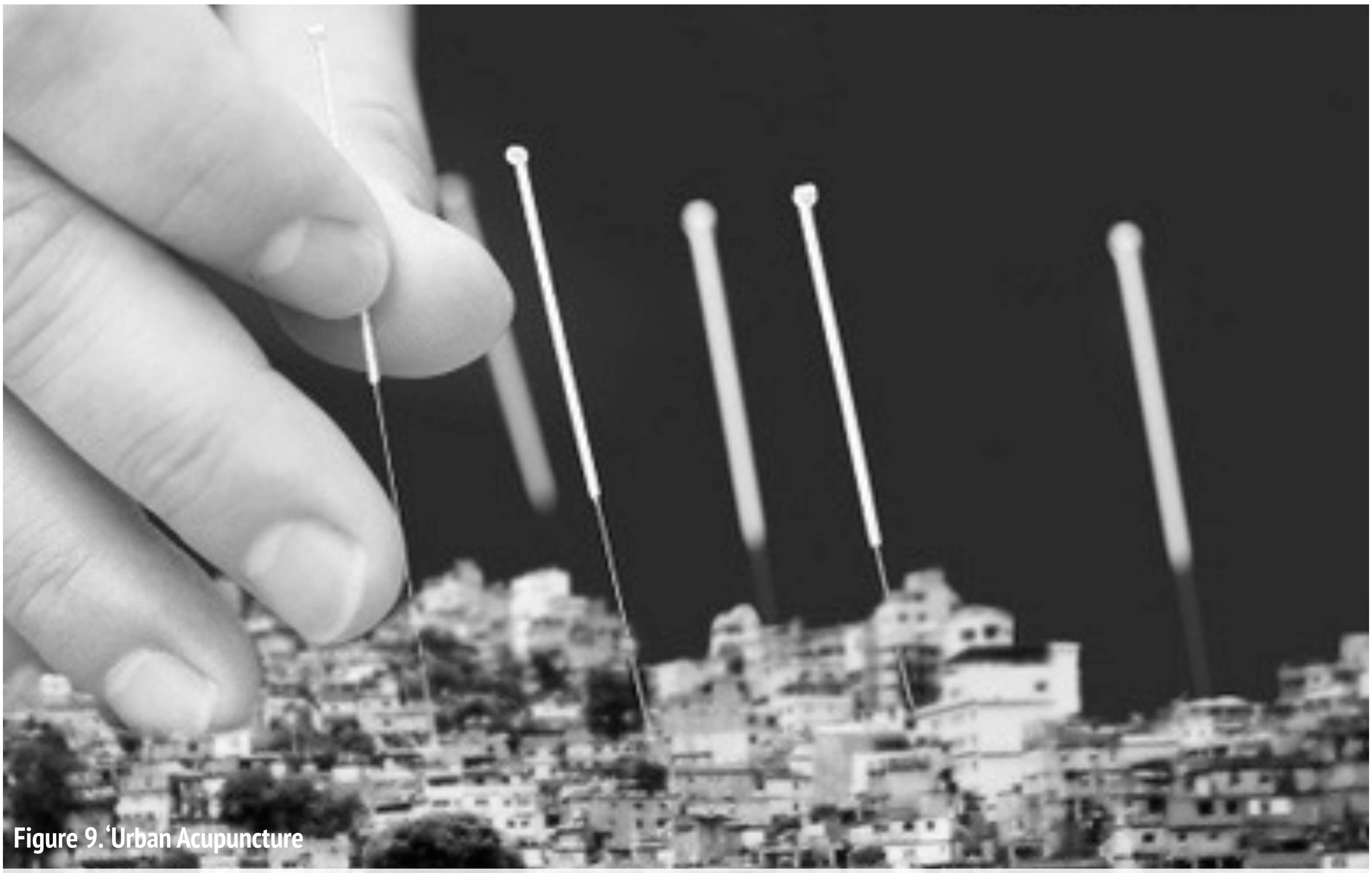
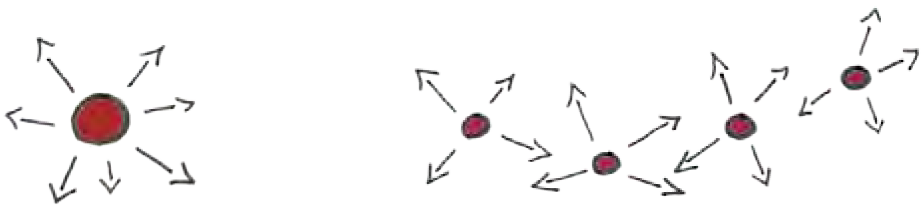


Figure 9.'Urban Acupuncture

"The notion of restoring the vital signs of an ailing spot with a simple healing touch has everything to do with revitalizing not only that specific place but also the entire area that surrounds its"
(Lerner, 2014: 01).

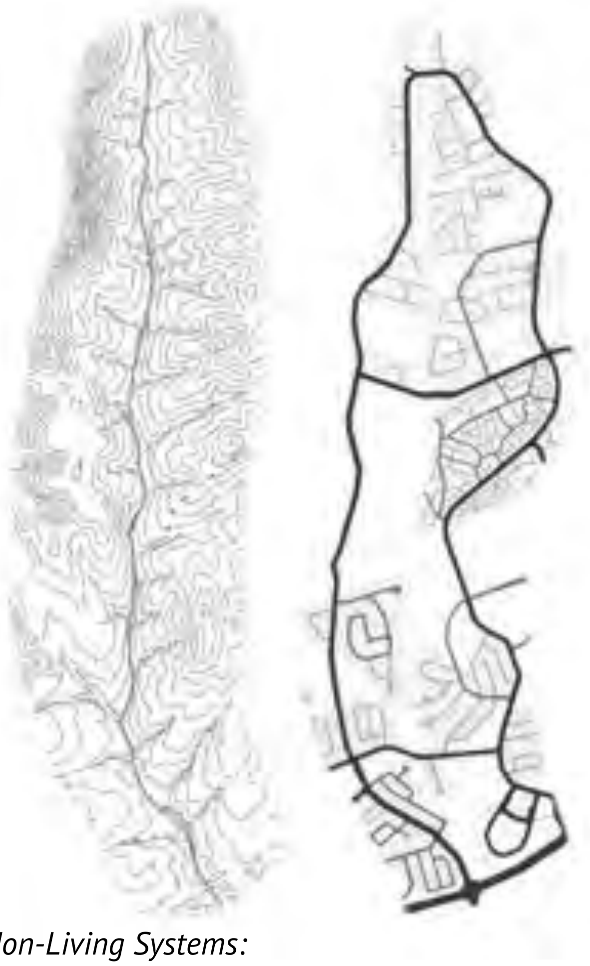
A metaphorical understanding of the effect of these architectural interventions can be seen through the physical effect that mass has on water: a single larger stone has the ability to make a big splash in a pond. However, many smaller stones of the same combined mass can make a series of smaller splashes, that if dropped in a particular sequence can reinforce one another's ripples and influence a larger area. The appreciation of the ability of architecture to make large impacts on its social contexts has been outlined by Jaime Lerner who views this method as a type of 'Urban Acupuncture'.



One large Effect VS Multiple Small Effects

Upon examining the way in which these projects approached issues on an urban scale it can be concluded that a strategic and somewhat incremental approach can act as a useful tool in guiding the creation of architecture that is effective on an urban scale, however, still maintains its social and formal function towards its immediate surroundings. From the analyses of these particular precedents and the theoretical notion of 'Urban Acupuncture' one can begin to appreciate the effectiveness that architecture can have on both its immediate and larger surrounding contexts.

Living Systems:
Ecological & Settlement



Non-Living Systems:
Topography & Movement Network

In the next phase of conceptual development KIS and its physical layers will be theorized in an attempt to identify the most effective sites for incremental architectural insertion along the river's edge. The particular area of interest, being the river, is one that exists as an ecological system in which the issues of pollution and water conservation are located. For this reason the conceptualization of site will be done through an ecological understanding of the elements that comprise KIS.

Ecology is defined most simply as the study of living systems and their relationship to one another. A living system is seen as an integrated whole whose characteristics emerge from the relations between its individual parts. Each element of the whole reflects the whole. However, the whole is not defined through the individual element. A non-living system, on the other hand, refers to the built or man-made elements of an environment which exists in a hierarchical structure of components, that together form the whole. The interaction between elements serve the whole. However, the whole does not emerge from these interactions (Foerster, 1984). In this definition, one can begin to differentiate between what is a living and non-living system. Through the evolution of ecological theory, the living system's definition has been refined with the inclusion of the elements of human and community equipping ecology's application to the social realm of architecture. Through this 'human ecology' has been established which views a living system as a simultaneous organization of biotic elements and culture (Berry & Kasarda, 1977).

The study of living systems has influenced architecture and design in a number of ways, although evidence suggests that designers do not always truly comprehend the functionality of a living system, resulting in rather superficial architectural creations which merely make use of vegetation within buildings. With regard to this and with reference to the differentiation of living and non-living systems of the environment, the following section has been separated into four particular layers which are categorized into two main headings: Living Systems and non-living systems.

Living Systems

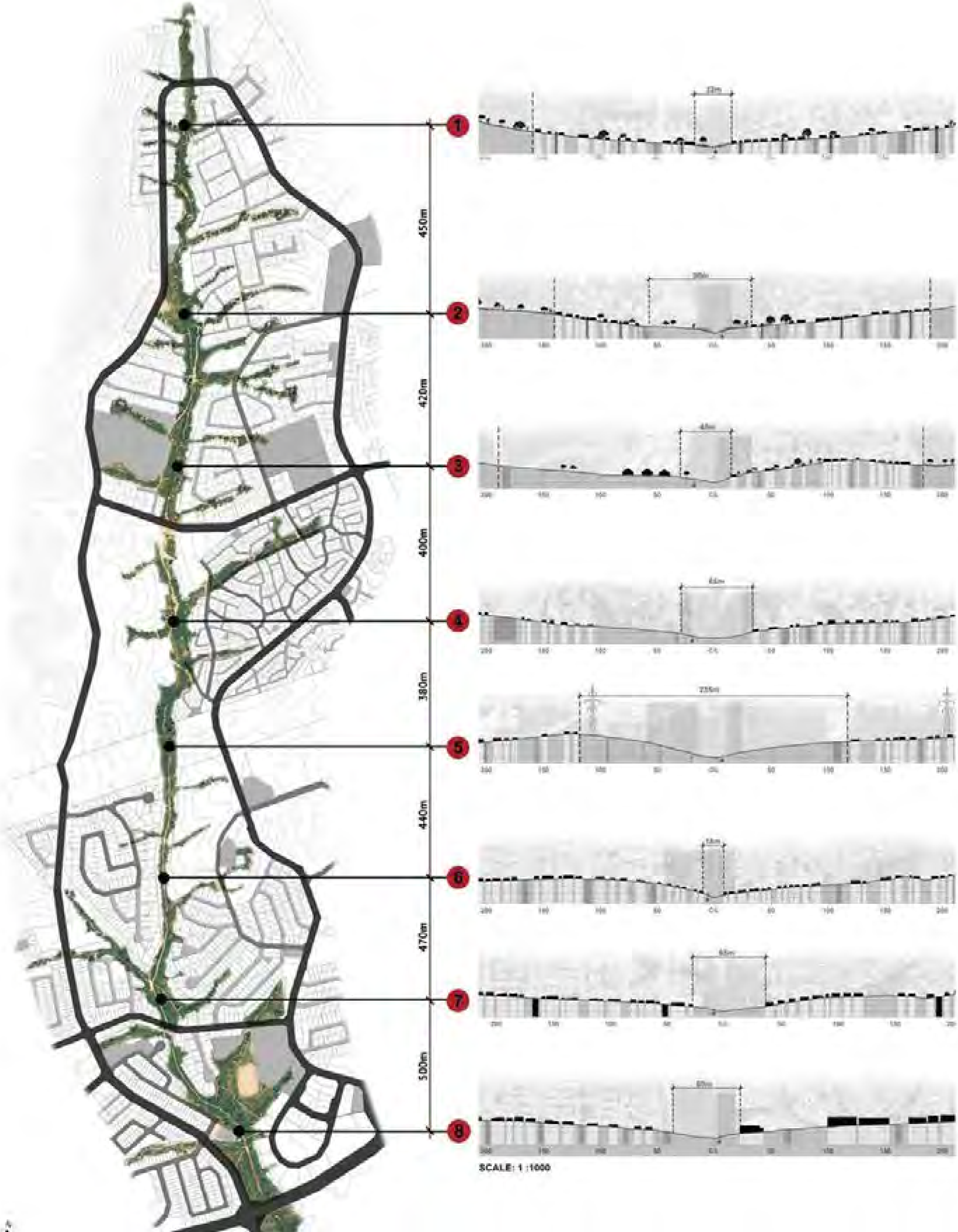
Henceforth, a living system will not be defined by the possession of life but rather through the way in which it resembles a living thing. In this regard, the spatial organization and social make-up of KIS resembles that of a living system, which exists through interactions with the built environment. Made up of individually functioning parts, this system, when working in unison, performs its purpose as a settlement providing its inhabitants with various functions and activities. In the case of KIS, however, this living system can be seen to lack specific nutrients such as public amenities in the form of usable and healthy public space, which jeopardizes its sustainable existence, however, does show opportunity for recovery with specific reference to society's greatest asset: education. In KIS there are but only three schools and a series of scattered crèches in the area, that equip its youthful population with a means of a brighter future. There is, however, additional reserved land for future educational facilities that at this stage imparts a particular functional use for this project that can assist and establish a link between these valuable assets of society.

An accompanying layer that exists as a living system is that of the natural environment of KIS. By virtue of the site's topography and the nature of informal development, this layer, that additionally contains the river, has reserved large areas of space which now serve as some of KIS's only public open green spaces. Interactions between these two 'living' systems exhibit a high degree of porosity due to the fact that nature is uncontained and, therefore, unbound by the imposed spatial organization of the built environment, which forms intersections in parts and links to the greater undeveloped areas surrounding KIS.

Non-Living Systems

Perhaps the most influential layer of the sites non-living systems is its topography, which has been the overriding force in the formation of the river, its natural landscapes and its surrounding built environment, which has inadvertently reserved particular areas of the river's edge. A similar symbiotic relationship can be seen between the 'non-living' network of roads and the 'living' organization of programmes of the area. Although simultaneously developed, the network of roads has guided and since negated the organization of different programmes, much the same way as topography has influenced certain ecological habitats along the river. Composed of a hierarchy of movement, the road network and topological layer are both seen as non-living systems due to the fact that they are resistant to change and do not naturally adapt or change when interacting with other elements of the environment as opposed to the living systems that do.

An important understanding is reached that outlines the fact that a living system requires a non-living system to function and work effectively. For example, the natural environment and its diversity could not exist if it were not for the relatively unchanging topography. Likewise, there would be little spatial order and organization if it were not for the defined and relatively unchanging network of roads. Although this is in fact a simple and rather obvious observation, it does establish the importance of fixed elements within the environment, which act as platforms for living systems to exist.



Urban Strategy

Selecting & Linking Site(s)

From the analogy of site and its living (dynamic) and non-living (static) systems and with reference to the three precedent analyses, the formulation of an urban strategy can begin to take shape, which uses multiple sites of insertion as a form of 'urban acupuncture' which can allow for a greater effect over larger areas using less physical intervention. As shown to the left, eight sites would ideally be selected which attribute three underlying spatial informants, which evenly distribute them across the river's edge.

1. Distance. To allow a continuous and regular insertion of architectural agency which addresses the issue of site, each site is located within 500m from each other providing a comfortable walking distance in order to encourage pedestrian use.
2. Proximity to educational zones. Seen as society's greatest asset, locating site in close proximity to existing educational zones can assist in establishing a safe and integrated route for children along this settlement-wide intervention.
3. Unused space. From the urban mapping of KIS, particular areas that exist as living systems allow for the insertion of non-living, architectural intervention which can act as a platform for communal use.

As previously concluded, these sites are defined as non-living systems, which each exists within a hierarchical order that together form a whole in the urban strategy to which new 'living systems' (people and their activities) can be inserted and integrated. Although these selected non-living systems (sites) are regular and form a level of continuity in the landscape, they are however physically disconnected from one another. It is at this point of disconnection, where the interaction of the living system (the people and their social activities) provide the point of connection. The insertion of multiple sites at different scales into this landscape must, therefore, not only be individually integrated into their respective contexts, but be holistically connected to one another in order to form a unified whole, in which they interact with both themselves and their contexts. It is, therefore, crucial that these sites are in some way socially unified, as through social unification individual sites can begin to cater for 'local' formal (non-living) and social (living) multiplicities of urban life as well as to impart their unifying functionality towards the inhabitants of KIS. To achieve this, clarification of individual programme must first be established (part 4) after which the space between can be programmed towards the public. This can allow for chance encounter, indefinite function and as stated by Tschumi, an "irruption of events" (Dovey & Dickson, 2002).

A view down the river looking south from the most northern part of KIS. **Photo Credit: Kelt Elves**

PART 2
Technological Analyses

"One hundred square miles of rainforest are being lost each day. Species are going extinct at the unprecedented rate of three per hour. Chemicals once thought relatively harmless to humans are turning out to affect immune and endocrine systems. The list of environmental damage is endless… In search of comfort, convenience, and material wealth, we have begun to sacrifice not only our own health, but also the health of all species. We are starting to exhaust the capacity of the very systems that sustain us, now we must deal with the consequences."
Van Der Ryn & Cowan, 1996: 3

The contemporary city, in many ways draws refernce to the per-industrial city in the fact that once again we are suffering from issues of sustainable living. However, this time there seems to be an overabundance of technological solutions rather than a lack of them. With industrialization has come great advances in the way we live and function, but it has also caused a great disruption in the relationship between man and his environment (Roberts, Ravetz & Geroge, 2009), leaving natural environments within cities polluted. This situation we find ourselves in is only made worse by the growing phenomena of climate instability in which life's most valuable resource [water] is becoming ever scarcer.

In the context of Windhoek, scarcity of water, more frequent droughts and lack of infrastructural provision and management thereof are affecting these areas of informal development, where pollution and human waste have found their way into its riverbeds, which through the nature of informality have come to exist as public space (Menge, 2007). The Kilimanjaro Informal settlement is but one such area where the issue of biological and human waste pollution exists, which is exacerbated by the lack of public environmental awareness due to limited education among the poverty-stricken population. In this technological analysis, the site of inquiry lies in the dry riverbeds of this settlement which pose particular challenges in terms of their spatial definition, rejuvenation and natural preservation, which will determine their sustained existence in the future of the settlement and city. In addition, an under-developed public realm presents an opportunity for the integration of alternative technologies that do not rely on twentieth century networks of weighty infrastructure, at this early stage in the growth of most areas of KIS.

The following part will thus look at various types of technologies concerned with the river's edge, its poverty-stricken peripheries and issue of biological as well as human waste contamination. Technological exploration in the form of wastewater treatment, human waste treatment and earth retaining systems will form separate sections of the study for their overall integration into an architectural device that can assist in the creation of sustainable and water conscious Architecture along the river's edge.

Section 1
Wastewater Treatment

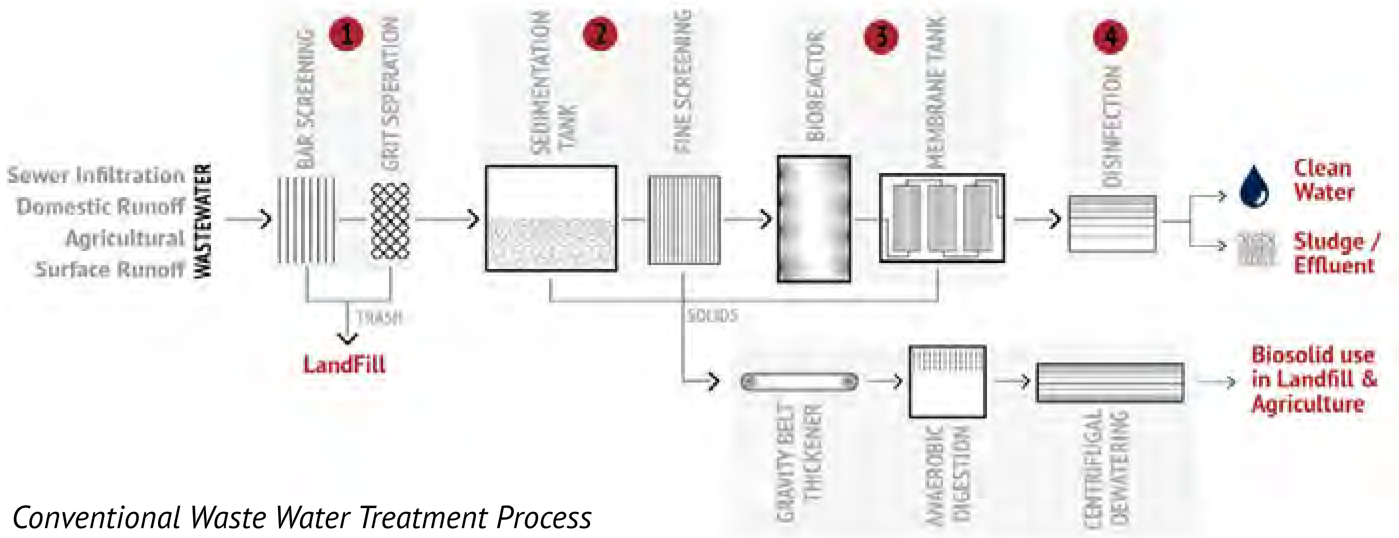
Fresh water is a marvelous resource. However, it is not infinite. It represents as little as 0.1% of the world's water which circulates in natural cycles through precipitation and evaporation. Through the growth of cities such as Windhoek, man has, however, infiltrated this cycle with pollution and waste, leaving the cities' natural environments in a state of decay. Nature does, however, have the capacity for self-purification which has been known since the early Roman times and which in recent times has led to new ways of managing wastewater, specifically in the context of informal settlements, where designers seek to address fundamental issues associated with rapid urbanization (Izembart & Le Boudec, 2005).

Water treatment is, however, a technology that architects know very little about, yet the history of the profession shows that ignorance can lead to isolation in the fact that the planning and spatial organization of these systems are left to the discretion of engineers and town planners who often relegated water treatment plants to the outskirts of a city. The placement of these plants more often than not segregate parts of a city and in many ways induce the direction of future growth. In developing countries, this often prompts informal growth to occur close to these plants that seeks relatively inexpensive connections to infrastructural networks which in some cases has led to establishment of informal settlements in floodable areas (Izembart & Le Boudec, 2005).

In light of global impact awareness and climate change, innovation has more recently striven to incorporate the use of natural and more localized processes of self-purification which are considered more reliable, integrated, cheap and easier to maintain. The following wastewater treatment technological analyses will look at some of these processes and the part they play in creating healthier and more sustainable public environments.

Shown in this image, one of the many open patches of land where reedbeds can be established **Photo Credit: Kelt Elves**

The Conventional Wastewater Treatment Method



Conventional Waste Water Treatment Process

Typically, wastewater comes from a number of sources including surface run off and sewer infiltration. It is generally treated in a series of stages that produces potable water which safe to drink.

1. Pre-treatment involves the screening and removal of grit which removes larger elements.
2. Primary Treatment separates suspended solids through the process of 'clarification' which use septic tanks, lagoons, activated sludge plants or by filtering in planted beds.
3. Secondary Treatment involves the breakdown of organic matter by bacteria that consume oxygen. In order for the bacteria to work effectively or become activated, a favourable environment must be created in which oxygen is supplied at a constant rate to convert bacteria into carbon dioxide and water. This can either be achieved by conventional mechanical aeration in activated sludge plants or by a more non-conventional and natural process through filtering plants or beds.
4. Tertiary Treatment involves the elimination of nitrogen and phosphorus as well as nitrates, heavy metals and pathogens through an additional process. Phosphorus cannot be transformed into gas but does, however, accumulate in a deposit that is conventionally treated in two ways.

4.1. To prevent phosphorus from directly contaminating surface water it can be spread over natural soil, occasionally by the process of irrigation during which it is absorbed by the roots of plants. This process can also be achieved in reed beds.
4.2. Physio-chemical additives can be used. However, the process is complex and costly.
4.3. In more recent times, however, more advanced and effective treatments such as ultraviolet ray exposure and ozonisation have been used.

5. The Finished Product is that of germ-free water that is suitable to be released into the natural environment. However, this process usually produces around 350 grams of sludge per cubic meter of water. This sludge is usually dumped in landfill and has led to environmental degradation in some areas (Izembart & Le Boudec, 2005).

The problem of environmental degradation through sludge deposits has prompted the development of alternative solutions to the conventional method of treatment, in which planted filters transform wastewater into clean water, carbon dioxide, nutrients and minimal sludge. There are typically three different types of planted filter systems that exist;

i) Lagooning which is based on ponds and lakes
ii) Subsurface disposal which is an adaptation in wetland areas
iii) Planted beds which are based on reed beds, all using the same methodical processes of conventional filtration.

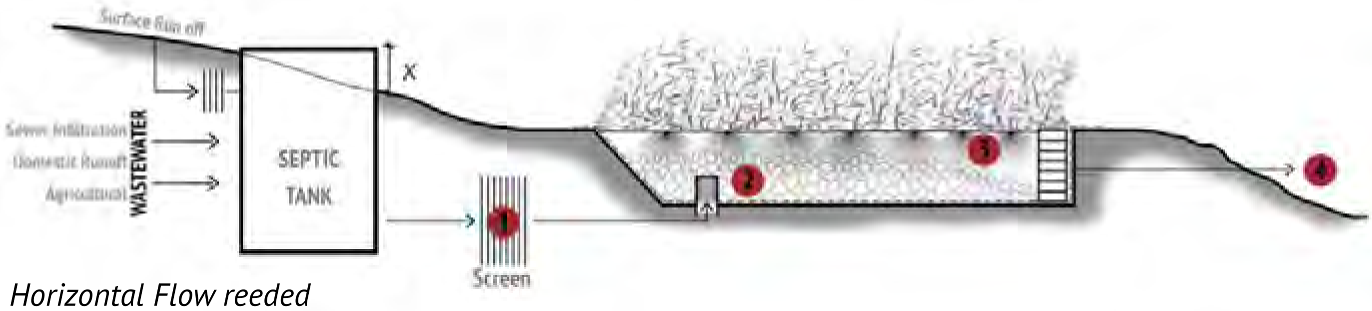
In the dry sub-Saharan climate of Windhoek, the latter of these three systems offers the most water-efficient method of natural wastewater treatment (Izembart & Le Boudec, 2005).

The Non-Conventional Reed Filtration Method

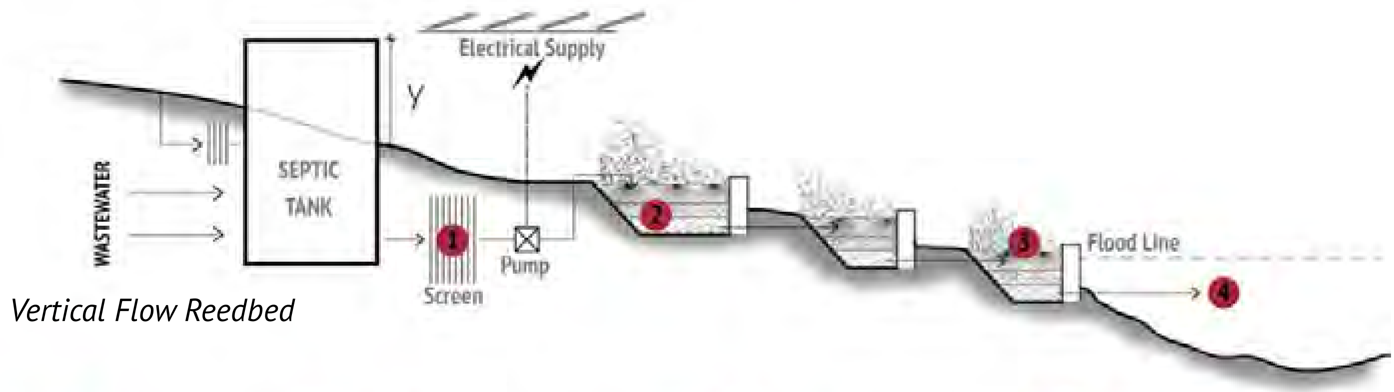
The use of Planter/Reed filtration systems has been in use in central Europe and Asia since the middle ages, in which concentrated organic waste was used in fish farming. Conventional methods and their staged process can be seen to originate from this more natural process that provides similar conditions through inexpensive and non-complex methods and which have been optimised through modern technologies. Although these systems tend to require larger areas of land they are often more effective at removing pathogens in a reliable and continuous manner, if designed properly (FAO Corporate Document Repository, n.d.) In this system plants and vegetation serve as the main actors in the filtration process. They prevent loss of water by providing shade in summer and insulation in winter, maintain infiltration at the surface of the bed through movement of stems, reshape the gravel bed through constant root growth and provide some of the oxygen and organic acids which favour the development of bacteria. In comparison to other processes this process requires the least surface area to function (around 2-5 sqm per inhabitant). Probably the most notable advantage of this particular system in the context of KIS is that wastewater never appears on the surface of these beds resulting in no possibility of direct human contact or odor, making it safe to build and live in close proximity to such systems (Izembart & Le Boudec, 2005).

With the reed bed filtration system there exists two possible models which depend on the desired direction of water flow, either horizontal or vertical. Horizontal flow systems require only one basin and can be built on flat or sloping ground. When these systems are well designed and properly built, they produce water that is safe to be disposed of into the natural environment. However, phosphoric and nitrogen contents may vary according to the quality at which the system functions.

A vertical system, on the other hand, consists of several basins which use gravity in the filtration process. For their effectiveness in treating water these systems have also been used in the secondary and tertiary stages for conventional treatment of domestic effluents.



Horizontal Flow reeded



Vertical Flow Reedbed

1 Preliminary Treatment
Wastewater is received through varying sources and screeened removing large elements

2 Primary Treatment
Filtration through graded gravel surfacebed removing large suspended solids through the process of clarification

3 Secondary Treatment
Plant roots provide constant supply of oxygen providing optimal conditions for bacterial growth to break down organic matter

4 Tertiary Treament
Elimination of nitrogen and phosphorous through irrigation over vegetation and soil

Technical Considerations

Although reed beds are considered relatively inexpensive and simple to construct it is important to note that these systems are prone to failure if sufficient time and money is not invested at the construction and installation phases which can ensure long-term durability and functionality of this system (Lismore city council, 2005).

Membrane

In successfully constructing this system it is critical that the reed bed be contained in a durable and water tight membrane in order to avoid environmental contamination through leakage. This membrane must be durable enough to resist being punctured by gravel, bacterial decay, external and internal root growth, and exposure to the elements over a minimum period of 15 years, as prescribed by Australian Governmental Legislation (Lismore city council, 2005).

Septic Tanks

Septic tanks play a vital role in the overall treatment process. There are many different kinds that all function as watertight storage chambers, usually containing two compartments. Waste water, including raw sewage, enters through an opening in the top of the tank. Heavy solids sink to the bottom and form a layer of sludge while lighter solids such as fat, oils and non-biodegradable fibres form a crust on the surface. Over time, this crust thickens and as a result a T- shaped inlet pipe is used to prevent blockage. The liquid then passes into the second compartment through a central point where a similar process occurs. However, it takes place in a more 'delicate' manner. A thinner layer of sludge and crust develop after which the liquid can be pumped out to continue on to the reed bed filtration system (Harper & Halestrap, 1999).

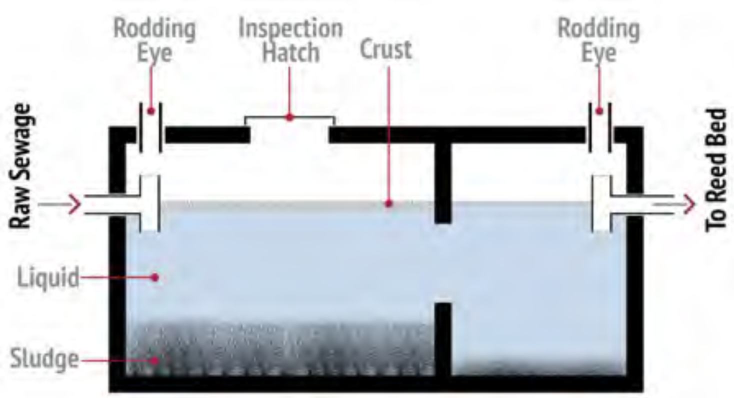


Figure 10. A typical view of large scale reedbeds

Maintenance
If well designed and constructed, a reed bed should require very little maintenance over its fifteen-year life span, although it does require regular checks for blockages of the inlet and outlet pipes of both the reed bed and septic tanks; cleaning the preliminary screening filter of effluent; pumping and cleaning septic tanks of built-up sludge and crust; altering the surface water height, which may be achieved through a ball valve inlet device and finally harvesting, which involves the removal of dead material ,mostly done for aesthetic reasons. (Lismore city council, 2005).

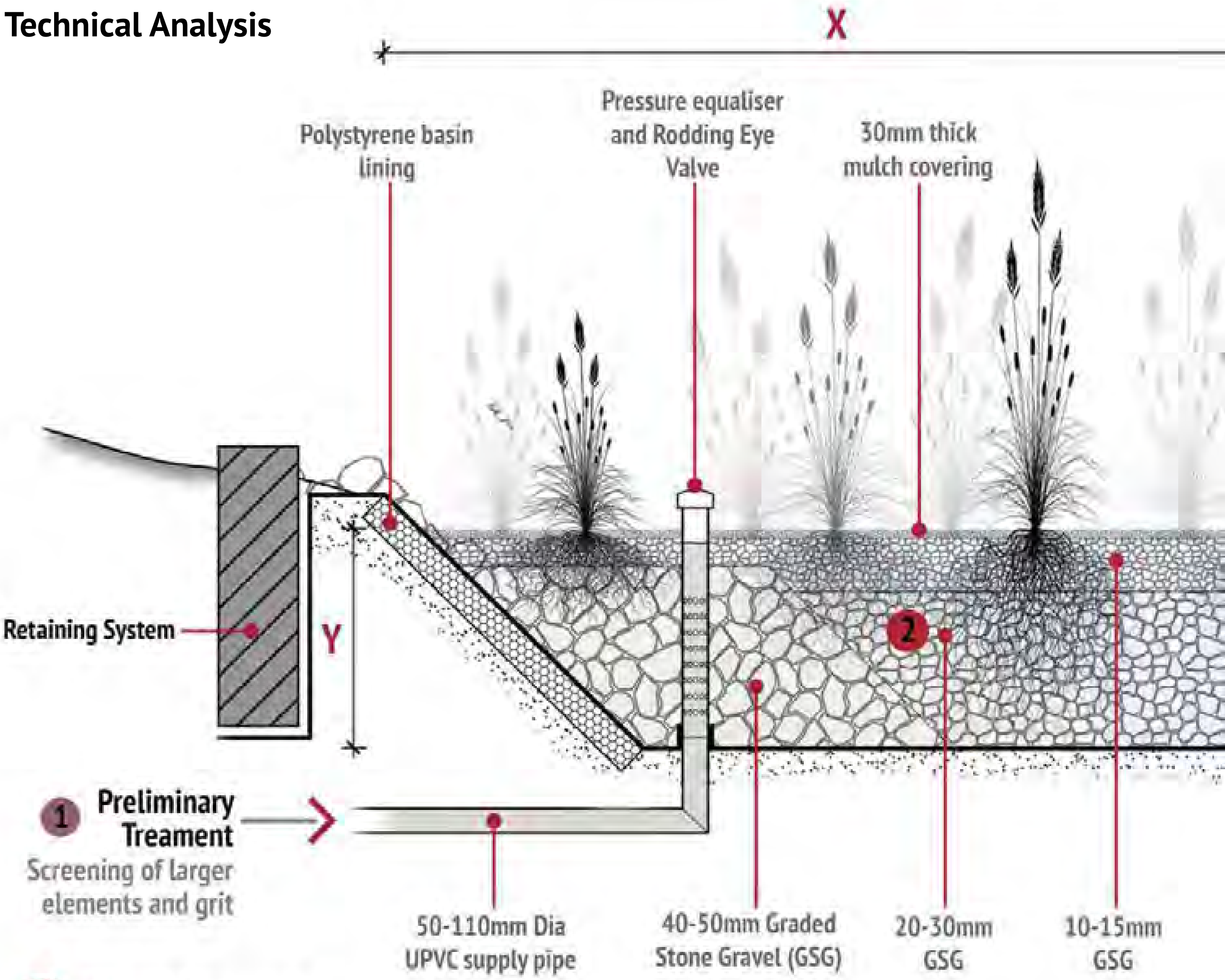
Plant Selection
In this system it is crucial that aquatic plants called Macrophytes are used which possess fibrous roots systems that absorb nutrients, provide oxygen and provide a food source for micro-organisms. There exists a variety of Macrophytes that range in appearance and growth height, although only particular types are appropriate for reed beds as seen in the Technical Analyses (Lismore city council, 2005).

Sizing a Reed Bed
In the application of this technology it is fundamental to understand the sizes and capacities of a reed bed and how they are efficiently designed. The most influential design factor in determining the spatial requirement of a reed bed is that of the amount of time and activity of residents who use it. This is achieved though either using a rule of thumb method in which surface area and depth are determined by the number of residents, as shown below or by the use of an engineer who usually only deals with more complex and larger scale projects.

Water Depth (m)	Surface Area/ Person (sqm)	X Number of residents = Total Surface	
0.30	6.5		
0.40	5	Example:	325 sqm = 12m Wide x
0.50	4	50 Residents	27m Long x 0.30m Deep
0.75	3	Ratio 1: 2.25	

Table 1 Reed bed Sizes. As shown in the example, once the total surface area of the reed bed has been calculated the length and width can then be determined which should ideally be configured in a ratio between 4:1 and 1:1.

Technical Analysis



2 Primary Treatment

Wastewater enters the basin through a UPVC perforated pipe. It is then filtered through a three layers of decreasing graded stone gravel which removes suspended solids solids through the process of clarification. This stone gravel usually requires replacement after 10 years due to build up of sediment.

3 Secondary Treatment

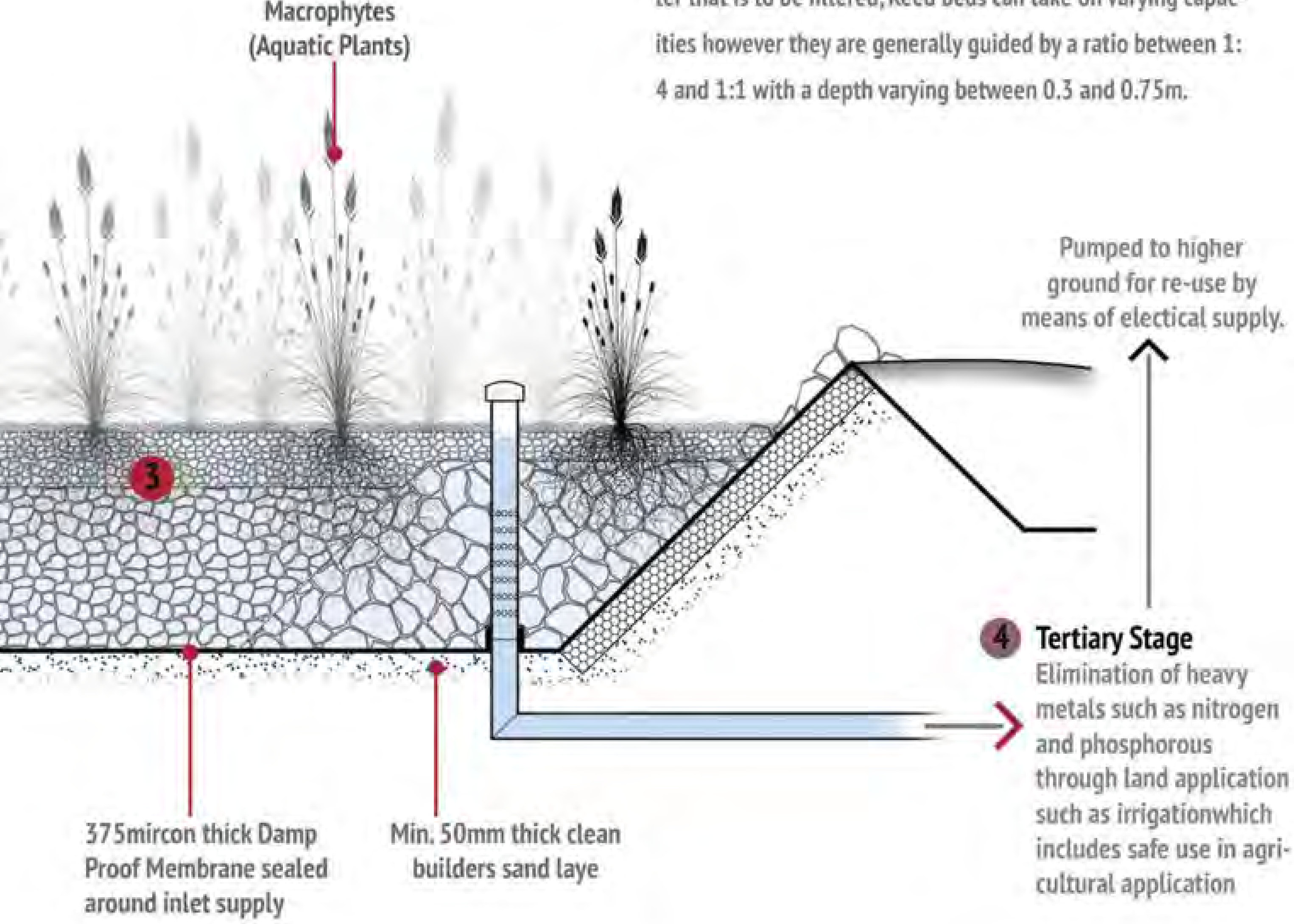
Water then runs past fibrous root systems which provide a constant supply of oxygen in which bacteria grow and break down organic matter into Carbon dioxide which feeds the plants and Cleans the water (Aerobic Digestion) which then again passes through graded stone gravel to eliminate any excess sediment. The water is pumped out of the basin and continues to the final stage of its purification.

Macrophytes

Species Name	Common Name	Average Hieght (m)
Baumea articulata	Jointed twigrush	2.5
Baumea rubiginosa	None	1
Bolboschoenus fluviatilis	March Clubrush	2.5
Eleocharis sphacelata	Tall Spikerush	2
Lepironia articulata	Grey Rush	4
Phragmites australis	Common Reed	4
Schoenoplectus mucronatus	Star clubrush	1

X : Y Reed Bed Sizes

Depending on the number of people and amount of wastewater that is to be filtered, Reed beds can take on varying capacities however they are generally guided by a ratio between 1: 4 and 1:1 with a depth varying between 0.3 and 0.75m.



Section 2

Small Scale Biological Waste Treatment

This section of will look at physical design and operation of dry toilet systems as well as their application in KIS. This system has been analysed for its functional use as a means of processing human waste, a process that cannot be performed through the reed bed system alone and which is additionally one of the identified issues of environmental contamination in the riverbeds of KIS.

Precedent Analysis

As a point of departure, reference is first made to an example where the problem of biological waste contamination was causing pollution and health problems in an area located in Musiri, India to which a similar technological solution was proposed and successfully implemented.

In this example a local network of latrines was leaking into the rivers creating chronic problems of water contamination and impacting environment and communal health. In this case, a community based consultation project was led by a civil society aid organization which created a somewhat simple solution to eliminate the need for water infrastructure entirely. This was achieved by installing dry composting toilets which not only addressed the issue of water contamination but turned the issue of biological waste into a resource, providing nearby farmers with composted faeces and urine for use on their fields. This method of turning waste into a resource was so successful that it led to the world's first "Use and Get Paid Toilet" (UGPT) where visitors were paid for their contribution. (Charlesworth & Adams, 2011: 64).

This example of a socially orientated intervention is testament to the fact that water and sewage systems do not need to follow the twentieth century model of networked and gravity fed infrastructures that require large amounts of water to transport waste in a non-sustainable linear process. The example of Musiri shows that an entire town can, in fact, function, sustainably, without a sewer system. More importantly, it shows how deeply personal toilet habits can be influenced and changed in a radical and sustainable way. With reference to these examples, the application of dry composting toilets and waste management in and along the riverbeds of KIS show great potential towards eradicating the problem of biological waste. This decentralized system has been shown to have knock-on effects, requiring less energy than conventional centralized articulation systems and has also encouraged community co-management, creating jobs and giving a sense of ownership to the inhabitants of the settlement. Giving a sense of ownership and entitlement is a particularly important notion in the context of informal growth which can ensure the sustained growth of such projects through communal participation and maintenance (Charlesworth & Adams, 2011: 64).

Figure 11. A woman standing next to a 'UGTP'.

Dry Toilet Systems

Conventionally, a Water Closet or Toilet is simply a compact collecting device which collects and transports human waste via large amounts of water to storage and processing plants. This method is, however, highly inefficient in the fact that kilometres of sewer pipes and mega litres of water are required to transport waste to areas of disposal or recycling after which kilometres of water pipes are required to send treated water back again to be used to transport more waste. In the context of KIS, this expensive and time-consuming provision of infrastructure has left the area with little more than a simple sewer system that is operating at capacity and to which few inhabitants actually have access. In light of this, there are, however, alternative methods of processing human waste that do not require weighty infrastructure or large amounts of water to do so, both of which KIS does not have and cannot afford (Harper & Halestrap, 1999).

There are typically three alternatives that each give rise to the 'class' of dry toilet systems:

1) Bucket Toilet
In this system waste is collected and removed from the toilet chamber and treated elsewhere. Seen as moveable sewage containers this system usually comes in the form of chemical toilets which are typically used for camping or emergency situations. They function to provide a temporary hygienic collection of waste for treatment at a later stage. In more recent years toilets such as this have become part of Government solutions to waste management in many parts of informal settlements in both Namibia and South Africa but are, however, a non- sustainable means of managing this ever-growing problem. In the case of the bucket system, frequent handling is required in a critically timeous manner. Failing to do so can often result in serious, hygienic problems (Harper & Halestrap, 1999).

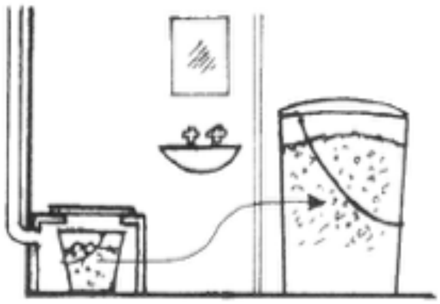


Figure 12. Bucket Toilet

2) De-Watering Toilet
In this system waste is reduced in volume by evaporating its 90% water content by means of electrical heaters and fans. Even in the case where no water is used for flushing, collected human waste consists mostly of water; Urine around 98% water and faeces around 70% Water. In all it is estimated than an average person excretes less than 50kg of solid matter each year compared to the half tone combination with water. Even this solid matter can be taken a step further and incinerated reducing it to a few kilograms of nutrient rich ash which can be harmlessly deposited into the natural environment. Both the bucket and de-watering systems allow the WC to retain its traditional compactness and be installed in small spaces without the need for reconstruction. However, they do require more frequent maintenance and an electrical supply. In both this and the following system of composting, waste is processed in-situ which is beneficial in that no material is directly handled until it is fully hygienic. Additionally, the handling is comparatively infrequent and timing is not crucial in the process (Harper & Halestrap, 1999).

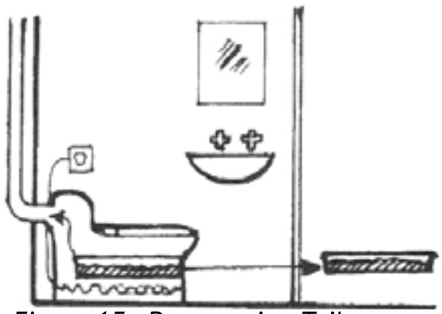


Figure 13. De-watering Toilet

3) Composting Toilet
Lastly, human waste can also be processed in-situ. Of all these systems, composting toilets are comparatively the most reliable and genuine of in-situ toilets systems, which come in a variety of shapes and sizes (Harper & Halestrap, 1999).

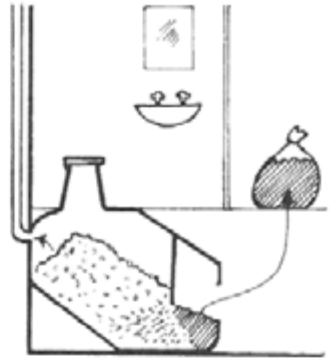


Figure 14. Composting Toilet

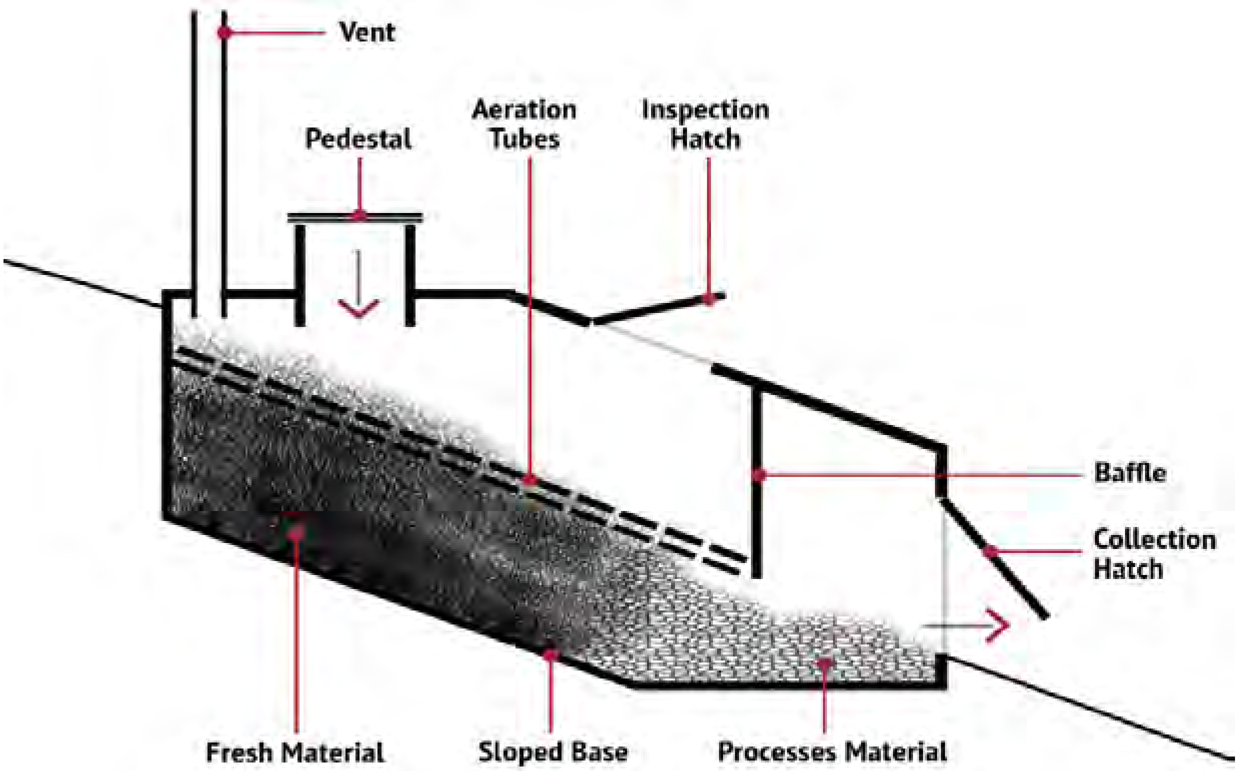
Figure 15. A nearly completed dry composting ablution block where the ventilation pipes can be seen to rise high above the roof where stronger winds can increase the rate of ventilation

Composting Toilet Systems

Composting toilet systems use natural processes to separate water from solid waste through decomposition and evaporation. These two natural processes have been optimized through the development of this system that processes human waste into water and usable fertiliser. In order for this system to work effectively, a specific balance of oxygen, moisture, heat and organic material is needed which produces a suitable environment for aerobic bacteria to transform waste into odor-free fertilised soil. When this procedure is correctly followed the end product is free of pathogens and viruses allowing it to be used in almost any application as a fertiliser. This reduces the need for commercial fertiliser which have been linked to the increase in environmental pollution, due to its nitrogen-rich properties (Lets Go Green. 2016).

When in use, this system constantly receives fresh material which has the potential to mix with previously processed material. To ensure that only processed material is extracted, it is crucial that new and old material do not mix. This can be achieved through two methods, either a continuous basis or a batch basis (Harper & Halestrap, 1999).

The 'continuous' processing design consists of a sloping chamber in which old material is simply pushed along by new material. There is, however, skepticism about the effectiveness of this design which is seen to function better when occasionally raked towards the point of extraction sizes (Harper & Halestrap, 1999). This system is relatively simple in its production as well as being ideal for sloping sights, making it a worthy technological device for KIS.



'Continuous' Processing Method

The 'batch' processing design, on the other hand, functions to segregate material into different compartments according to their stage of breakdown. It consists of two separate chambers that are used alternatively. When one chamber is filled the system switches to the other, which requires either the pedestal (WC) or chambers to be repositioned accordingly. In a Dutch-made adaptation, as seen below, a chamber is mounted on a pivot which allows the entire system to be rotated. When turned to different positions, by use of a ratchet, it is able to separate, agitate and empty in a sequential process (Harper & Halestrap, 1999).

In the context of KIS, technologies such as dry composting toilets show great potential for effectively addressing issues of human and biological waste contamination due to fact that they do not require weighty, expensive and timeous infrastructural provision in order to hygienically and appropriately process raw sewage.

Section 3
Earth Retaining Systems

Figure 16

This part of the paper looks at Gabion retaining systems which utilise found and local materials that are easy to obtain and which show evidence of financial viability in the context of KIS and its predominantly poor populations. In the context of the river, retaining systems offer ways to transform landscapes and manage territories along its banks improving its accessibility and use. This technology goes hand in hand with the creation of small scale water treatment plants at the river's edge which require flat and terraced landscapes. In an adaptive use, this technology offers the possibility of creating a hybrid system that is able to catch and store surface water runoff in an area where no storm water collection and drains exist, thus interrupting the direct contamination of the river's natural environments from its peripheries. In KIS, these systems particularly need to cater for the problems of flash floods to withstand the abrasive forces of water and erosion.

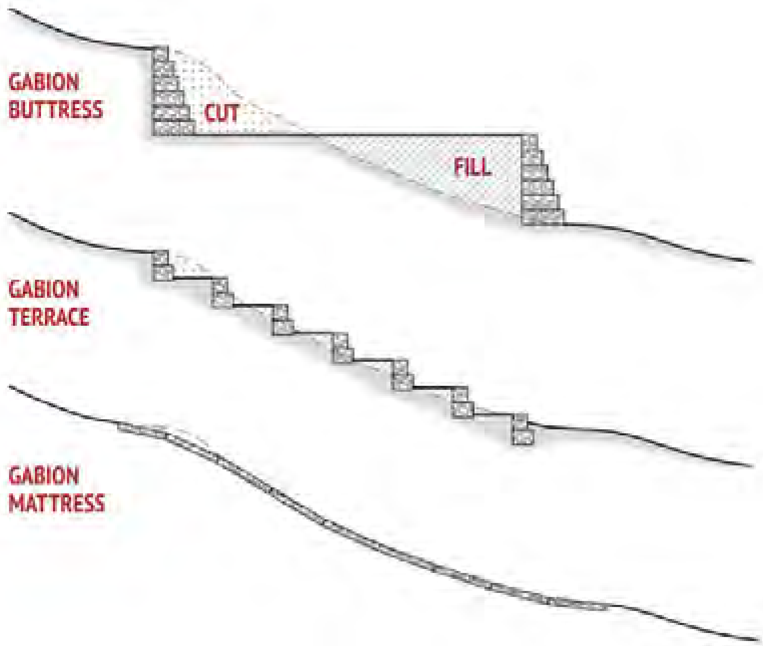
As gabion walls are formed by steel mesh there is virtually no limitation to their formal application which can range from retaining walls to benches to planter boxes and depending on both the type and colour of stone or mesh, can take a variety of natural appearances and aesthetic values. In the context of the river, where water has exposed and broken down the hardy bedrock, the availability of stone makes this type of technology ideal for application at the river's edge. (South African Landscapers Institute. 2015). In terms of the rivers ecological habitats which are in dire need of rejuvenation gabion walls offer natural habitats for insects, animals and birds which can allow for the preservation of some of the rivers species.

Gabion Structures

Used in internal and external architectural and engineered applications, gabions are most simply constructed by neatly filling woven galvanized mild steel (GMS) baskets with varying sizes of stone or gravel to from flexible, permeable and monolithic structures that help control erosion. As opposed to meticulously hand laying heavy stones or pouring large quantities of concrete (which requires large quantities of water) in order to form homogeneously strong retaining and watertight structures, gabions offer a lighter, more time-saving and more natural-looking construction. In many applications, gabion walls are the most effective landscape structural walling system available. As opposed to concrete or brickwork walls, gabion walls are able to withstand extreme pressure without cracking or becoming deformed. In addition to this, they are most ideal for retaining soil due to the fact that they are free draining, thus preventing water from damming and causing structural failure in times of heavy rainfall. If correctly and carefully constructed, gabion walls require no maintenance throughout their lifetime after which they can be de-constructed and returned to the earth (Gabion Systems. n.d).

Types of Gabion Structures and Technical Considerations

There are typically two types of gabions structures: boxes and mattresses, which enable the creation of varying, landscape formations as shown in figure 22. Gabion mattresses, also known as Reno mattresses are constructed in a similar fashion to gabion boxes which are usually used to cover large sloped areas in order to prevent erosion. Although the physical composition of these structures is somewhat simple they do, however, require well-planned and calculated installation.



Preparing a slope

With reference to figure 22, a slope can either be cut and retained or retained and filled in order to create a flat surface. Before doing either, soil conditions must first be analyzed, usually by a Geo-technical engineer, in order to safely excavate a slope and to prevent failure of the retaining system. Fill material must have a suitable compressive strength to resist loading and weathering which an engineer must again specify. Typically this fill is sequentially graded and laid in order to achieve maximum density (Modular Gabion Systems, n.d.)

Foundations

Depending on soil conditions, height of retainment and angle of slope, foundation requirements can vary accordingly in which it is fundamental that an engineer calculate the requirements. Typically concrete is used for foundations although in some cases it may consist of suitable compacted fill material, confirmed by an engineer (Modular Gabion Systems, n.d.)

Assembly

Pre-assembled GMS mesh baskets are generally delivered to site, although in some cases transport can cause damage to the zinc coating effecting their durability and life span. To prevent this, these baskets can also be assembled on site. Once assembled, these baskets are placed and fixed to each other and the foundation structure by means of spiral binders at each corner. They are then neatly packed with stone and closed off (top of basket bent over and crimped closed) in order to receive the next course. This process is repeated, usually in a buttressed assembly until the desired height is achieved (Modular Gabion Systems, n.d).

As shown below, this type of walling system can also instead be used as the secondary structural system of a building, where it is used as infill for a steel frame. In this case, the GMS mesh must be installed on site, around any such structural framing.

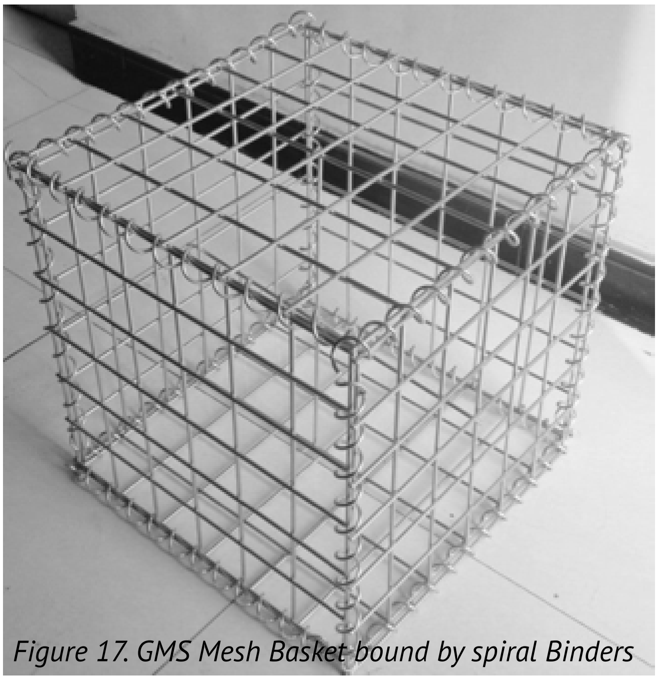


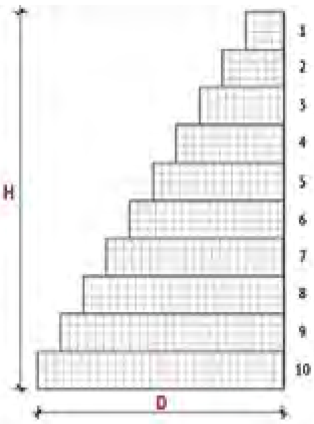
Figure 17. GMS Mesh Basket bound by spiral Binders

Figure 18 Two men carefully laying stone

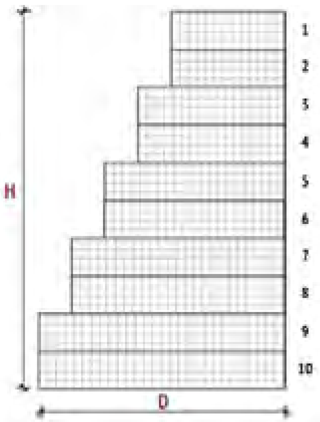
Design Guidelines

Gabion walls are generally viewed as gravity retaining walls due to the fact that they use their own weight to resist the lateral forces acting upon them. Whether they are stepped/buttressed on the internal or external face, the same principle applies, which is meticulously calculated by engineers in a series of formulas in which each and every acting force is catered for. Although these calculations are fundamental in safely constructing a gabion wall, there is, however, a general guide that can be used by architects in the spatial organization and design of these types of structures, as shown below (Modular Gabion Systems, n.d.)

No. of Courses	H Height (m)	D Depth (m)
1	1.0	2.0
2	2.0	2.0
3	3.0	3.0
4	4.0	3.0
5	5.0	4.0
6	6.0	4.0
7	7.0	5.0
8	8.0	5.0
9	9.0	6.0
10	10.0	6.0



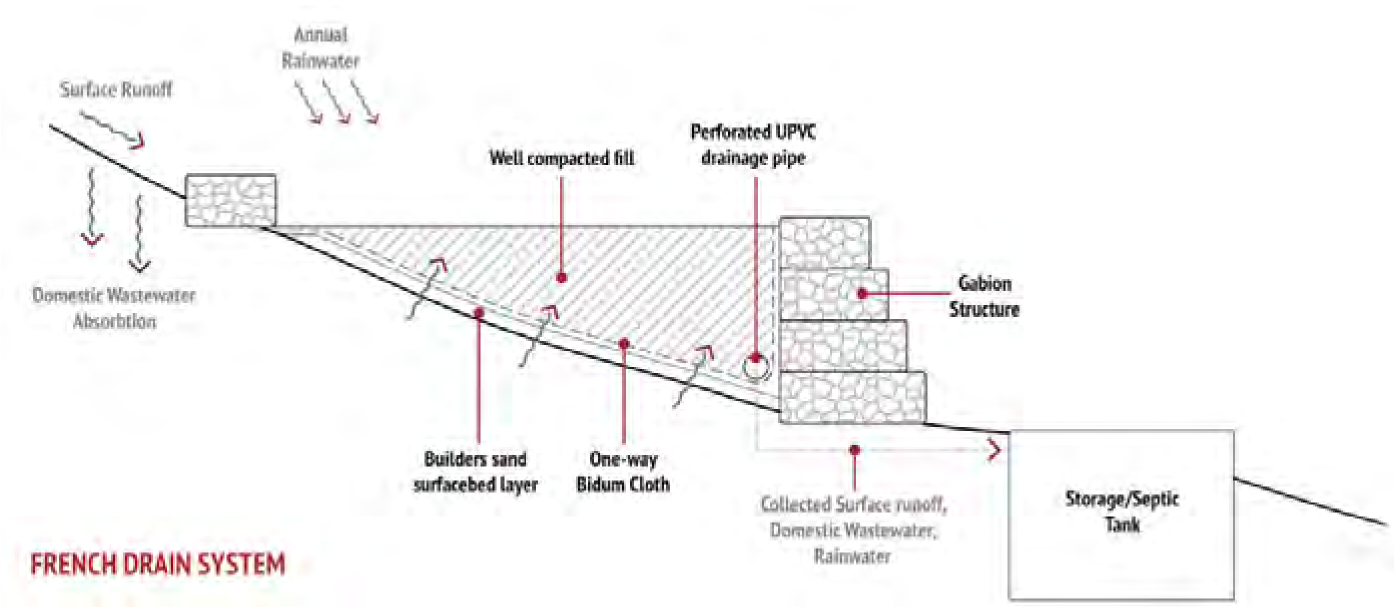
No. of Courses	H Height (m)	D Depth (m)
1	1.0	1.0
2	2.0	1.5
3	3.0	2.0
4	4.0	2.5
5	5.0	3.0
6	6.0	3.5
7	7.0	4.0
8	8.0	4.5
9	9.0	5.0
10	10.0	5.5



Design Guidelines for Gabion Retaining Structures

Drainage

In order to prevent finer particles of sand and soil from filtering through a gabion wall a geotextile filter or more commonly known as a one-way bidum cloth is required at the interface of the gabion and backfill. Its purpose is to release any water pressure without leaching soil behind the wall. In KIS, this can additionally act as a way to collect surface runoff and some sub-surface water, in an effort to minimise the pollution of the river's natural ecosystems (Modular Gabion Systems, n.d.).

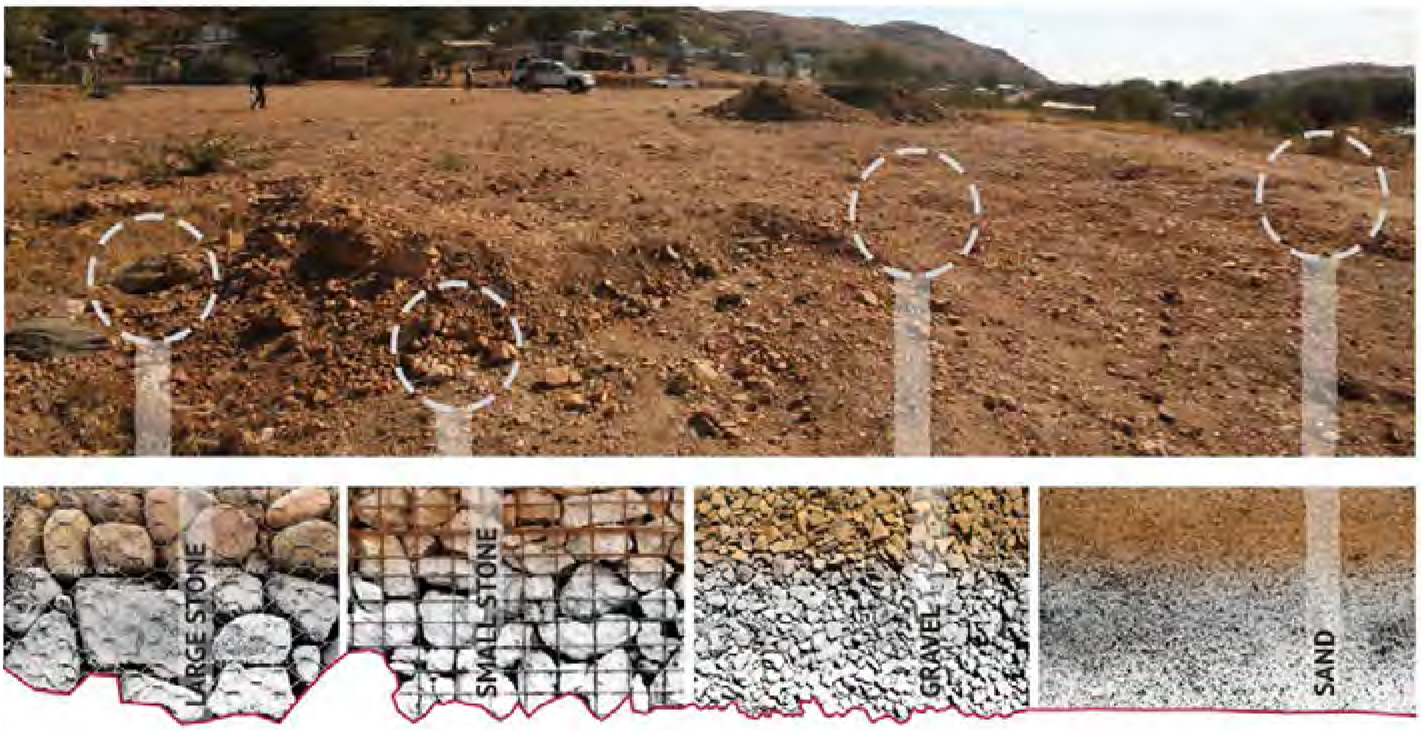


In light of this, gabion wall drainage and water collection systems show great potential for providing an alternative method of rainwater collection as opposed to the conventional weighty infrastructural systems that usually only collect surface run off from tarred roads. In some parts of KIS, tarred road are yet to be built and if this system is integrated at this early stage it could in fact become the main method of rainwater harvesting, which includes all surface runoff while at the same time transforming the landscape into more usable and publicly accessible spaces.

Section 4
Utilising Site

Through the millennia, earth and stone has served as the primary material in the transformation of man and his environment. In all parts of the world stone has in many ways become associated with a places vernacular architecture drawing ties to not only its materiality but its place within culture and general public familiarity.

Following the exploration of gabion technology and the way in which it utilizes on site material, the following section will explore the many other ways in which the material: Earth can be utilised as a building material. In KIS, earth as a building material appears to be non existent due to the simple fact that this method of building requires time and energy to suitably excavate and construct. Although this may be seen as a timeous and somewhat costly method (excavation) of material provision, it does however attribute a very low embodied energy which in the context of informal development and the growing global concern for the environment, deems this technological exploration a viable option.



The different grades of stone material that can be acquired from site excavations

Acquiring Material

In most cases, stone and any other building materials are typically delivered to site. Namibia itself has a wealth of minerals and other types of stone that are mined/quarried and exported, such as marble. Typically even this attenuation of natural building material comes with a high embodied energy, requiring industrialized processes to extract suitable quality rock. In this case however, an attempt is made to utilize the material that has been excavated on site. In this process the landscape is excavated and thereafter graded to produce a variety of stone sizes. Ie, large & small stone, gravel and sand which can be used in a variety of applications. In the definition of this sloped landscape, excavation not only provides building material, but establishes level platforms of more defined and usable space. As will be discussed in Part 5, this simple yet dual functioning method of landscape definition has highly influenced the over all design and development of the site where difference in levels have been used to define different spaces.


Figure 19. On site grading of material


Figure 20. Small stone sieve

In an architectural application there are typically three elements of a building that these different grades of stone can be used for. Ie. Floors, Walls, Roofs. Roofs in this case will not form part of the study.

Floors

Using the finer graded material such as sand and gravel, a durable and flat walking surface can be created through combination with cement. This surface can then be diamond polished or simply sealed to create either a smooth and more expensive or rougher and cheaper finish. As will be shown in part 5, hard wearing and durable floor finishes such as this are only used internally. In an exterior flooring application, this gravel can too be loosely laid over well compacted ground as a textured and walkable surface. Although a graveled surface does attribute to a lot of noise pollution when walked over, the strategic placement of such graveled areas can act as a form of audible security, where noisy footsteps reveal ones presence.

In a country rich with mineral deposits, variations in surface finish can result in a forever changing and somewhat different texture across all surfaces. However only through a physical and somewhat geographical analysis of this material will its true characteristic be shown. This includes the typical ratios of sand: Gravel: small rock: Large rock as well as the porosity and clay content, the latter of which plays an important role in the creation of Rammed earth walling.


Figure 21. Loose Gravel


Figure 22. Cemented Gravel

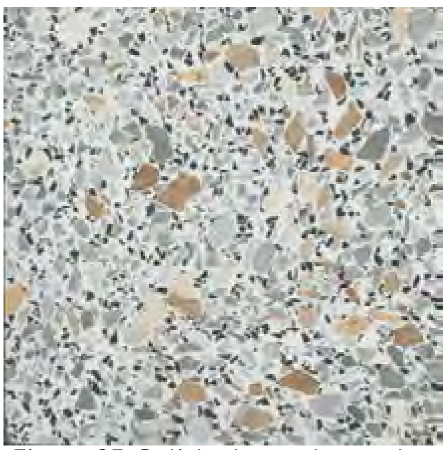


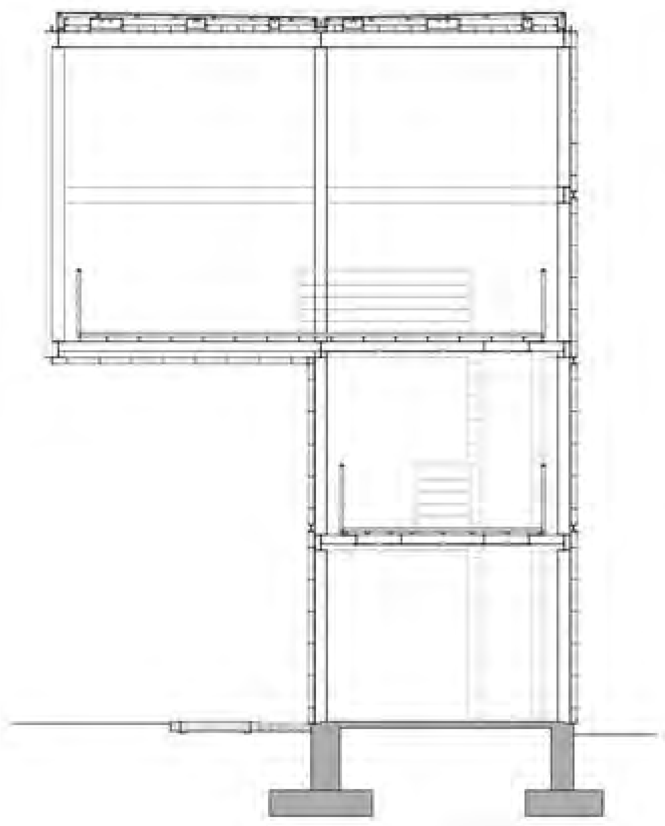
Figure 23. Polished gravel screed

Non-Load bearing Gabion Walls

Although used in landscaping as a means to retain and define slopes, gabion walls are however not suitable as primary load bearing structures due to their settlement over time. Instead, gabions/packed stone can be used as secondary structural infill for steel or concrete framing which additionally caters for more movement. In this method a particular aesthetic is achieved in which rather simplistic steel element frame the packed stone. This steel framing can either be exposed to highlight each structural member (as shown in the example), or alternatively concealed to give the effect that the gabion wall is in fact the load bearing structure. The use of steel as a framing structure, additionally maintains a rather simple and elegant material expression drawing emphasis on the more natural stone material, as apposed to concrete framing which would be seen to contest this equally 'weighty' material.

The use of stone as a walling material has another particular advantage in the climate of Namibia where summer cooling and winter heating is an important thermal comfort for a building. In this regard, stone walling, when positioned on the northern facade, acts as thermal massing, heating up during the day and radiating this stored heat out during the night. Although air is allowed to flow freely through this wall, it is kept at a relatively constant temperature by the stones that it passes. As shown below, an internal glass 'skin' can also be used to completely seal the internal space, only allowing light to pass into the building.

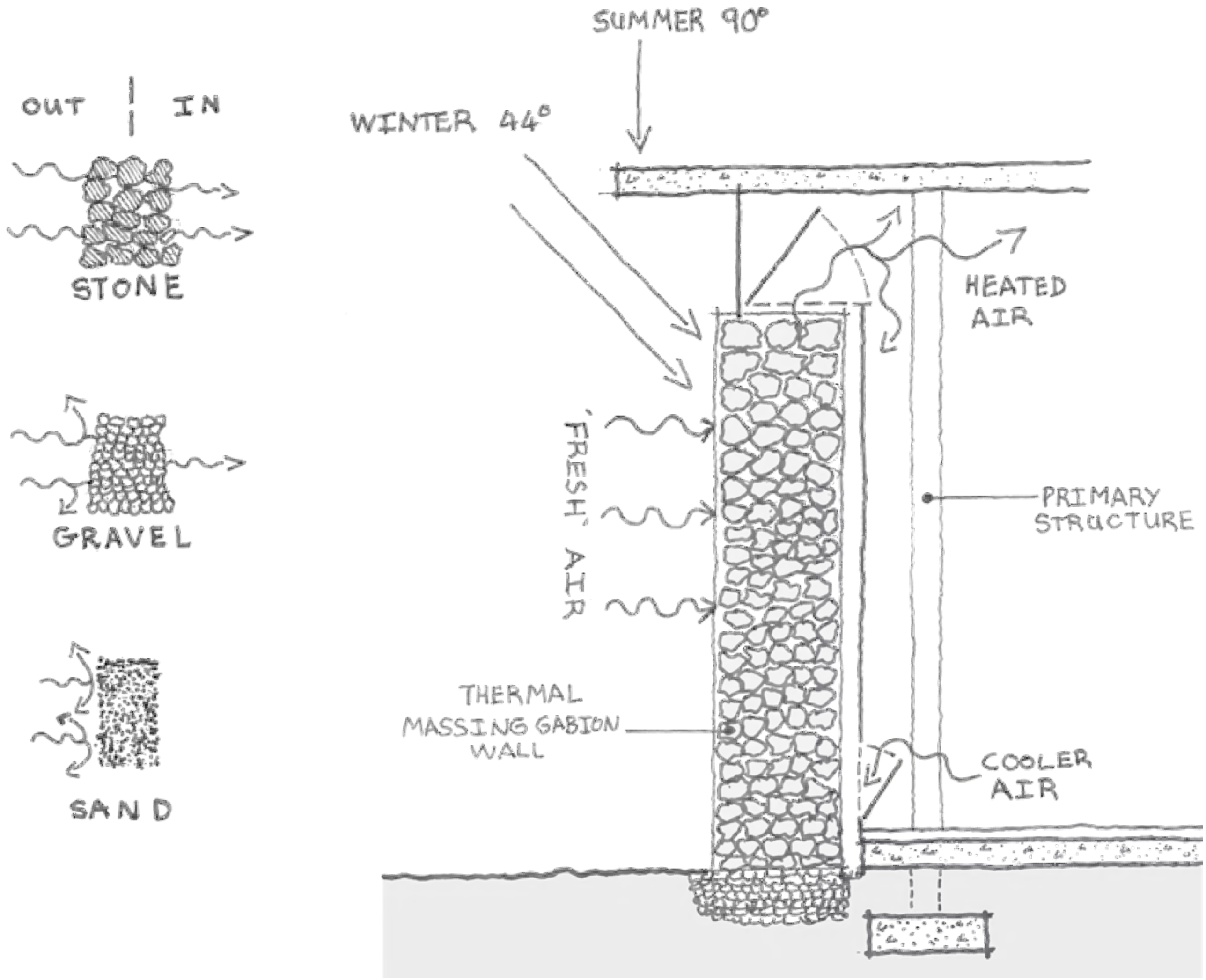
Figure 24. A cantilevered steel framed gabion wall structure that seems to effortlessly support to this heavy natural material.



Metropolitan Park South Access: Palidura Talhouk Architects

Figure 25. Slender steel framing emphasizing the gabion infill.

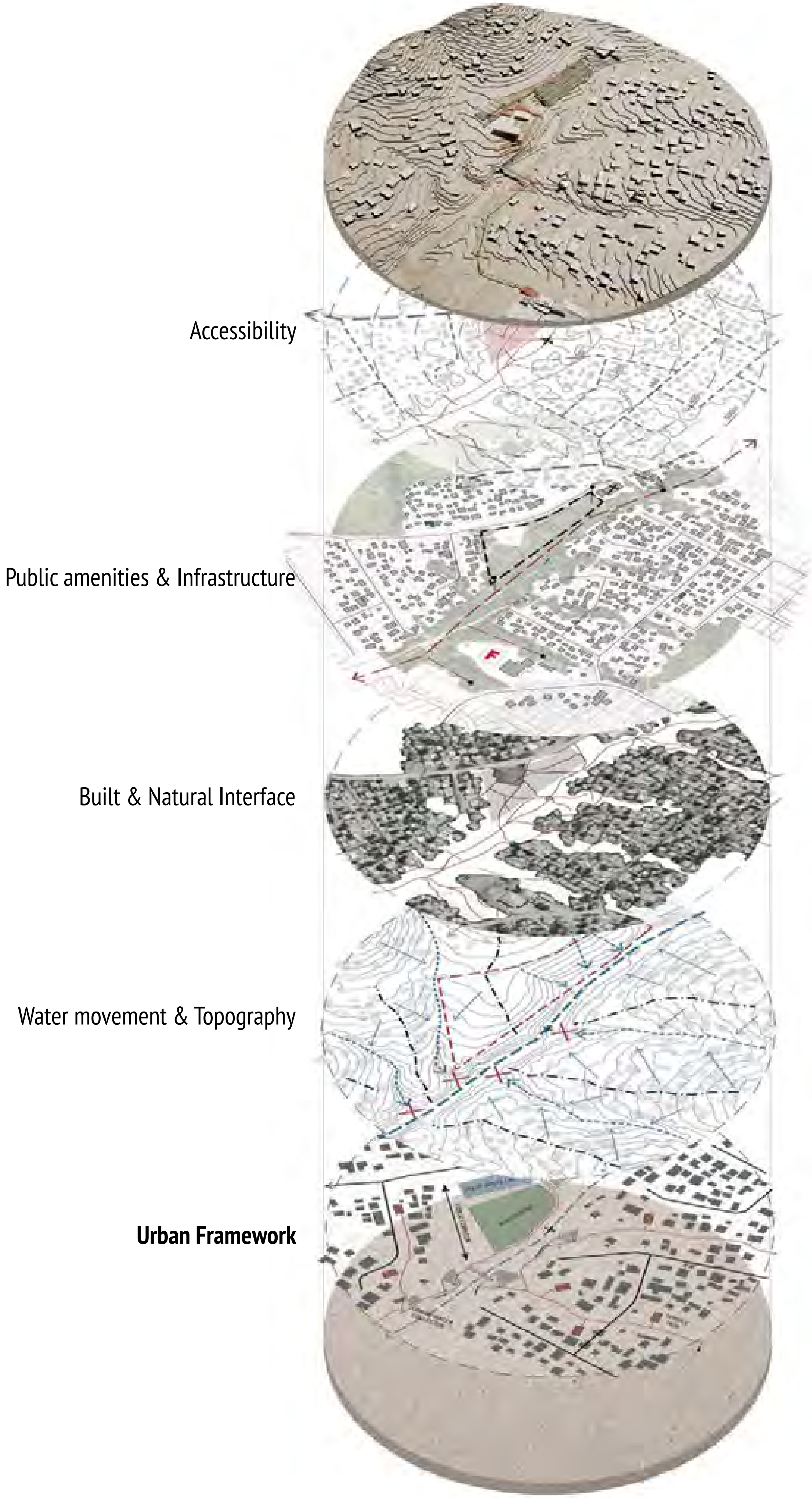
As shown below, the use of different grades of material in itself allows for varying degrees of natural ventilation. Due to its fine grade, sand, when compressed in rammed earth applications contributes to both good thermal massing and insulation. Insulation in this case is generally achieved through the creation of thick and large walls which are constructed by compressing sand into a shutter boarded cavity. In this process, different colours and types of local sand can be used to create 'banded' rammed earth walls. As with gabion walls, rammed earth walls are generally not used as primary or load bearing structures but are again instead used as infill or compressed around primary structures.



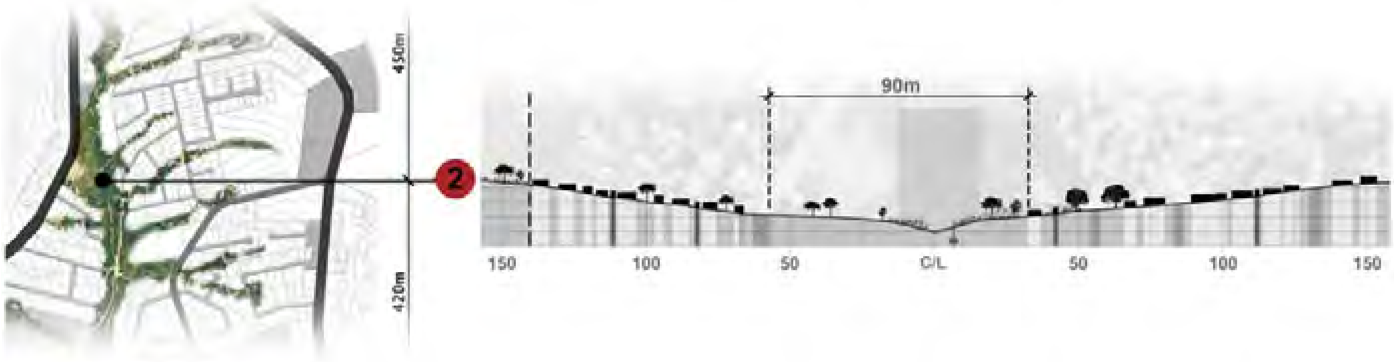
As shown above, using the thermal properties of the gabion structure, this wall has been adapted to act as a passive ventilation system. The way this system works is similar to that of a 'trombie' wall where cooler (denser) air is taken in at floor level, heated by the surroundings stones and escapes out an opening or vent at the top of the wall. This system can additionally be adversely controlled by closing either of the two vents.

In the design of both the land scape and built structural systems, the way in which this material can be used as thermally regulating walling and flooring material deems it fit for its application within the natural environments of KIS, and which will be shown in part 5.

End of Part 02


Accessibility
Public amenities & Infrastructure
Built & Natural Interface
Water movement & Topography
Urban Framework

PART 3
Creating an Urban Framework



Through technological analyses, spatial organization of sites (and their hypothetical programmes), the river's edge in its entirety can begin to form a narrative in which multiplicity of pedestrian choice encourages its establishment as a space of multiple values. To better understand and define site in its formal interaction with its context, one looks at the work of Stahn Allen who explores the concept of landscape urbanism and its potential in the urban environment.

The term 'Field Condition', as theorised by Allen refers to the "reassertion of architecture's contextual assignment" which seeks to work with the site and not against it. It is understood as any spatial matrix that is capable of unifying diverse elements while respecting the identity of each. These elements in themselves are fluid in interaction and form (Allen, 1997). A 'field condition' that is a river possesses the added component of landscape, adding vertical complexity to its spatial matrix which, as argued by Allen has the potential to activate space without the traditional weighty apparatus of space making.

The potential effectiveness that landscape has on urban environments advocates its efficiency for contemporary urban issues such as urban sprawl. In relation to Urban Acupuncture, this notion is reinforced in the context of decentralisation and decreasing density where traditional form based intervention proves slow, costly and inflexible in relation to the extent of informal development at the boundary of the city (Waldheim, 2006).The acknowledgment of landscape i.e. the river as a vital and effective means of tackling urban issues signifies the potential of the Kilimanjaro River and how it can in fact be the driver for urban rejuvenation as well as the creation of safe and healthy public environments.

As visualized by Allen, the potential in this landscape exists, however, can only be achieved through appropriate insertion of architecture and landscaping elements that unifies opposing edges. The issues that exist within the river stem directly from the interactions with these edge and the way in which inhabitants behave towards and utilize these natural spaces. The reassertion and re-establishment of these edges is, therefore, crucial in an architectural approach to dealing with biological waste pollution and water conservation.

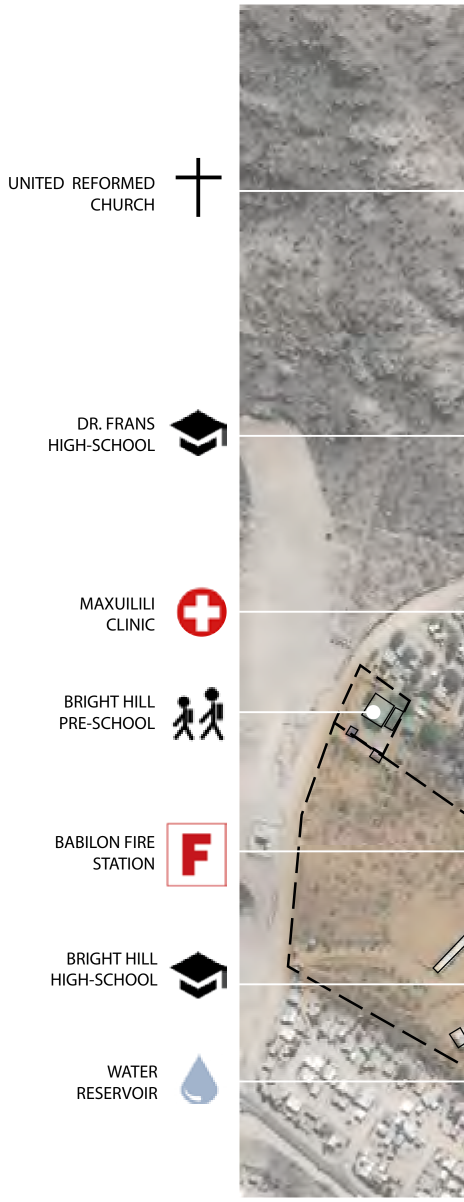
From the development of a conceptual approach which utilises multiple sites of insertion as a type of 'Urban Acupuncture', and which views the physical environment through an ecological lense, one site in particular will now be mapped, analysed and explored in greater detail in an attempt to develop an **urban framework** which addresses the issue of water and environmental conservation through the introduction of a new urban condition. One which aims to define and create qaulity public space. From this analysis programming of site in relation to these many interconnected informants can be defined for the insertion of architecture that responds to both its urban and immediate contextual informants.

To better understand this potential the following section will look at the site through a series of lenses that focus on four underlying principles which will act as useful tools in creating an urban framework. With reference to **Addendum A (site photos)**, the following analyses has been conducted.

Urban Connections

As a point of departure towards designing an urban framework reference is first made to the chosen site and its existing urban connections. Upon a closer examination it is clear to see that river and its tributaries are in many ways already an established circulation route that provides a certain level of accessibility to the people in the area. Thanks to Governmental initiative this area of KIS also provides its inhabitants with access to both schools and recently built clinic, maintaining a relatively high level of service delivery. Although these public amenities attribute to a higher quality of life there is, however, still little to no infrastructural system provided for and between these amenities which as previously outlined is the primary cause for the disposal of untreated wastewater and biological waste into the natural and public environments of KIS.

In relation to its proximity to these urban attributes an opportunity for its establishment as a more direct point of connection and 'missing piece' in the areas urban composition. Located within walking distance from two high schools, a pre-school, church, fire station and clinic, this site offers both a link and point of insertion into both the existing circulation networks and built environment of the area.



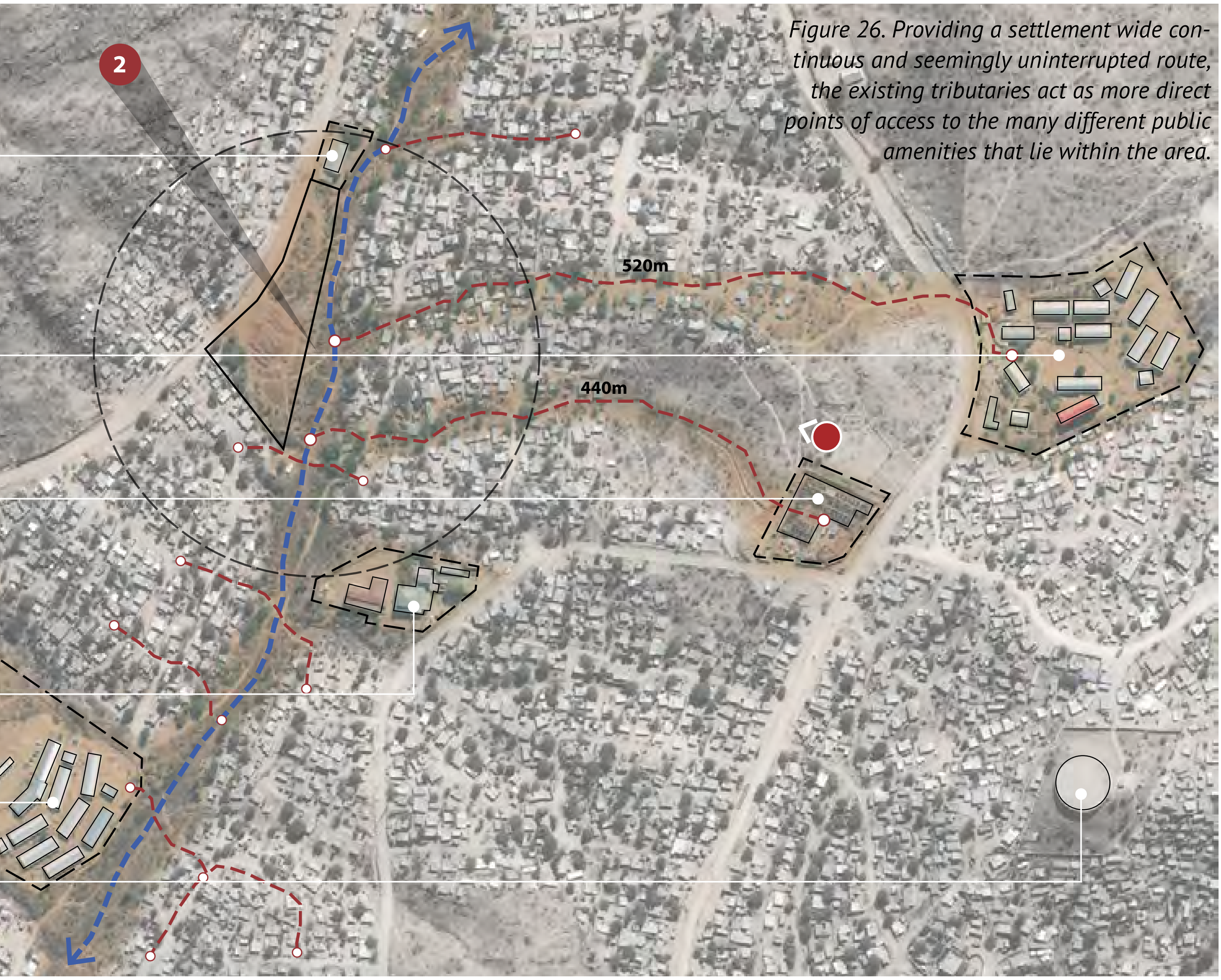
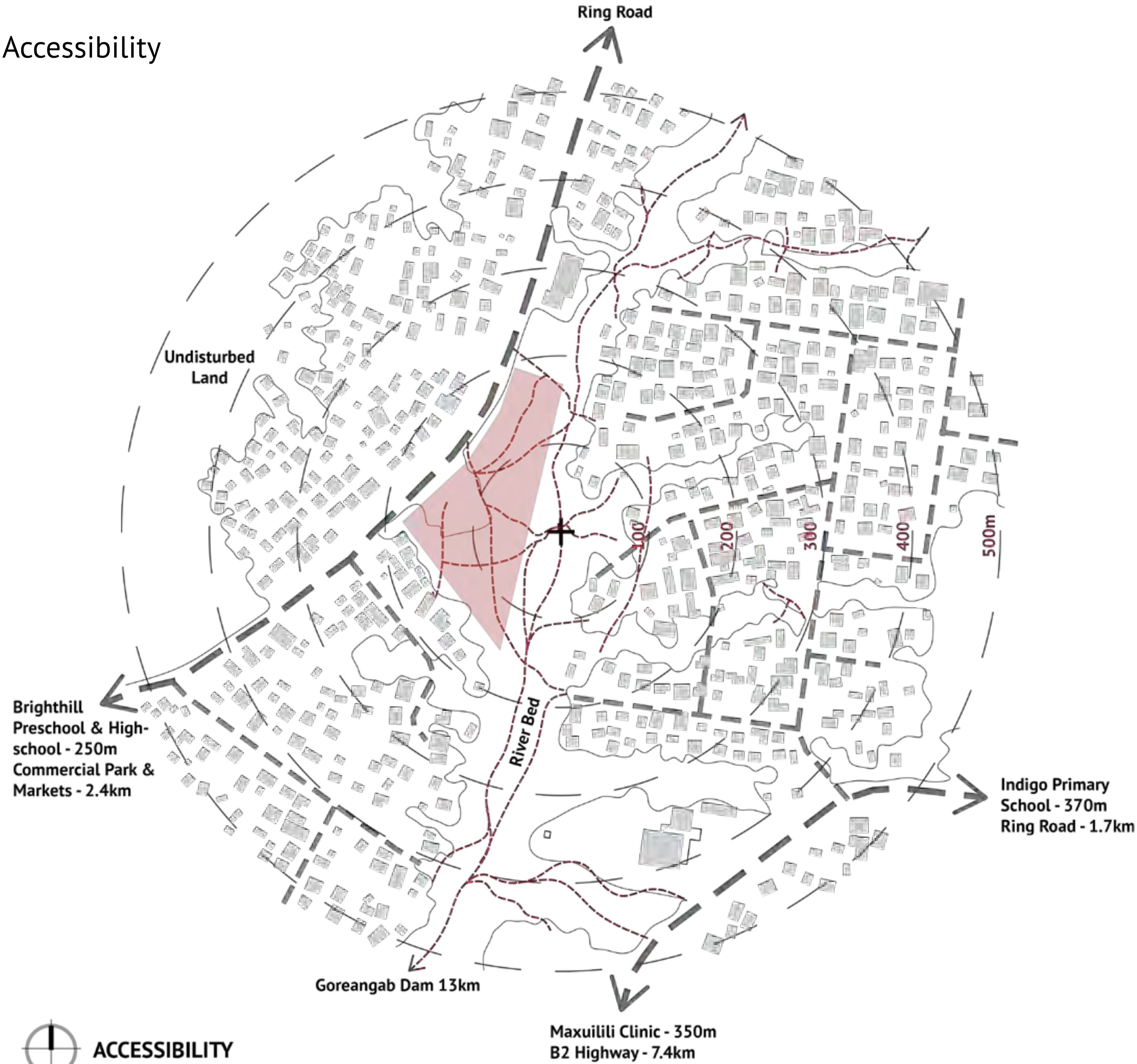


Figure 26. Providing a settlement wide continuous and seemingly uninterrupted route, the existing tributaries act as more direct points of access to the many different public amenities that lie within the area.

Accessibility



ACCESSIBILITY

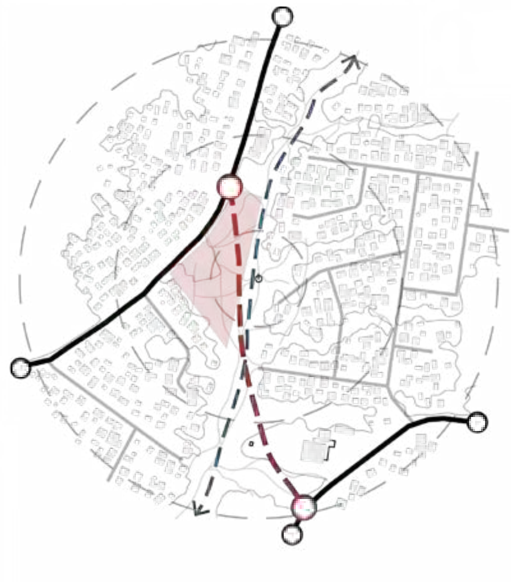
Primary Circulation, currently exists as graded gravel roads that do not yet possess kerbs or any formal storm water or surface run off collection systems. In times of heavy rain, this lack of surface water catchment contributes to irregularly occurring flash floods within the river beds which is exacerbated by the clearance of vegetation, causing the erosion of certain areas of the natural landscape.

Secondary Circulation
Undefined dirt paths that have been created through unplanned settlement expansion. Most of these paths are accessible via car and are fronted by unfenced informal house that typically consist of timber framed corrugated sheeting with generally no surface-bed structures of any kind.

Tertiary Circulation
Pedestrian Desire Lines serve as routes both across the secondary routes and river bed, providing direct access across the settlement and river.

Informal Residential
In the erection of individual households, availability of funds and building material have both guided and negated much of the built form, resulting in the formation of a particular typology. In this typology, that is reminisce of many informal settlements, residents utilises freely available and cheap materials to creatively and personally shape their built environment.

Primary Link



Establishing a link between these two primary circulation rotes may contribute to better accessibility in the future however this route is currently only defined by a series of footpaths and obstructions which make this link highly unfeasible, although increased pedestrian movement and spatial definition may prove effective in its establishment.

Secondary Link

When viewed from above the creation of the settlement and layout of roads seems to be cut or ends at the river. The continuation of these routes can increase cross-river connectivity. In relation to the chosen sites, two roads that end at the rivers edge can allow for the redirection and continuation of existing secondary routes.

Tertiary Link

Existing footpaths have been created through the movement of people across the natural environment. To preserve and define this element of the urban fabric, these desire lines, that already frame and define particular areas in themselves, can provide points of insertion upon which architecture can strengthen and promote particular routes.

Public Amenities & Infrastructure

Shebeen

Throughout KIS, home owners have set up informal trading along certain routes providing inhabitants with a necessary and valuable means to access goods, at a retrospectively low price. Surrounding this particular site however, Shebeens are amongst the only type of informal trade that exists. Perhaps a leisure place for some, these places can be viewed with caution. In providing value to the river and its edges, the absence of informal traders presents a rather obvious yet simple contributor towards creating valued public space.

United Reformed Church (Incomplete Project)

Located directly along side the selected site this half completed yet still inhabited church provides some of the only religious and roofed public space in the area. Seen as a valued communal space, the church and its immediate surroundings present the opportunity for its involvement in the defining of these spaces.

Babilon Fire Station

Located diagonally across the river, the Babilon Fire Station stands out in its context and is seen as a visual point of reference in the immediate context Although fenced off and inaccessible from the rivers edge, it provides the area and its people with an emergency service. In relation to water conservation, the fire station poses an opportunity for an alternative means of water use, to be described in part 3.

Cadastral

Although informally developed, site boundary lines have been allocated via Governmental planning in which small sites are individually owned providing some definition of the public - private interface. These boundaries are however only physically defined by the odd boundary fence or road edge and in many ways do not represent the physical manifestation of the settlement.

Estimated Route of Existing Sewer line

At capacity and over flowing, there is an existing sewer line that runs along both the river bed and its tributaries. As seen to the left, there is little being done to rectify the infiltration of this sewage into the natural environment,

Selected Site

Built & Natural Interface

A footpath leading down into the riverbed where it joins a river long pedestrian path

In the growth and occupancy of the settlement, the interface between informal development and nature has resulted in the riverbed and its natural interfaces being, in most parts porous in interaction with the (shack dwelling typology) which in themselves appear to possess limited private outdoor space. This porosity has allowed the river and its river's edge to become part of everyday living, bluring the boundaries between private and public space. In the definition of these territories and insertion of an urban framework, it is believed that these spaces must therefore impart a sense of belonging towards individual residents and their personal and private spaces. This can be achieved through publicly inclusive architecture that maintains a sustainable functional assignment. It can therefore be argued that the creation of architecture should encompass a "functionally open and visually transparent" (Dovey & Dickson, 2002: 6). appearance, along the programmes that necessitate this, which in the context of these private-public spaces, can allow for maximum 'chance encounters' and thus insert itself into the multiple social (living) and formal (non-living) contexts KIS.

As seen to the left, the natural environment of KIS is not confined by boundaries and exists as an interconnected layer that is ingrained in both the private and public areas of the settlement. In the climate of Namibia, vegetation, such as trees are more often than not the only driver/informant of informal public space making due to the shade they provide from the harsh summer and winter sun. In many parts of the world, trees have been used to define outdoor classrooms were any number of children can gather below this naturally defining element of space making. In this rather obvious observation it is important to note that the relationship between the inhabitants of KIS and their natural environment is not entirely disconnected, but rather in need of reprogramming, where a greater respect towards nature and all it has to offer is adapted in everyday living.

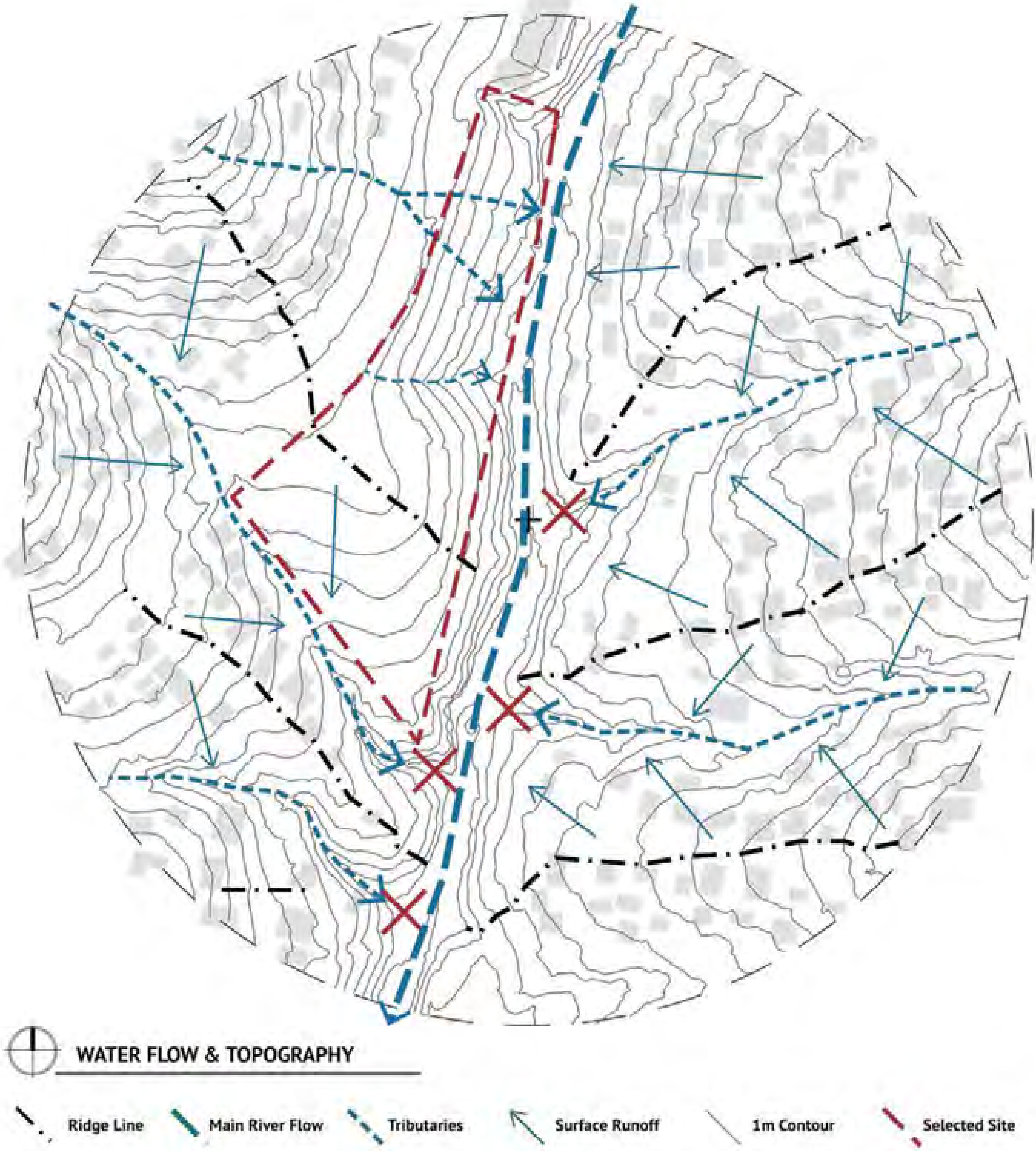
Although a strategy driven approach which inserts itself into the social and formal contexts of the river shows evidence of effectiveness, public acceptance and ownership can determine the true success of this integrated framework. In achieving this, one needs to focus on the complex notion of human agency and the associated social and cultural values implicit in how we behave and act in our daily life. A phenomenological approach to architectural agency provides an opportunity to manipulate and adjust behavioural habits of society, minimising the negative impact that KIS and inhabitants have on the river. This approach locates itself more at the 'messy' realities of daily life and less at the built-form of the city and rather than only being adapted at an urban scale, finds itself at the micro-scale allowing larger influences to occur with lesser action. An approach such as this "can allow us to rediscover sustainable micro-ecologies of daily life that can seed the ground-up ecology of the city" (Charlesworth & Adams, 2011: 8), and act as a catalyst for both environmental and social upliftment.

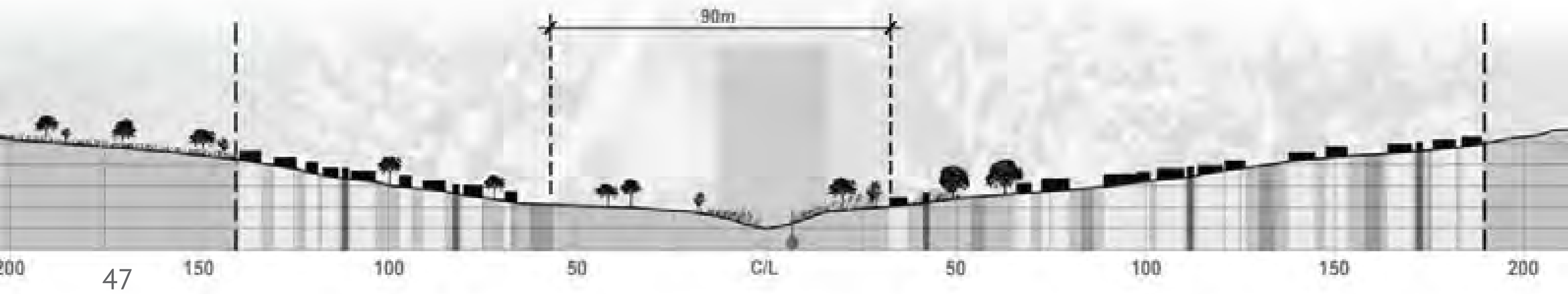
In an area such as KIS, where socio-political and apartheid formed demographic disadvantages highly influence the general public's agendas, sustainable considerations and attitudes towards natural spaces are low on the list of priorities. For this reason, it can be argued that notions of sustainability should not be instigated through a top-down policy driven approach but rather through socially guided development that focuses on creating a new urban condition: one "in which difference, fragmentation and plurality prevail and are inevitable outcomes of our multicultural and transitory city lives" (Charlesworth & Adams, 2011:37). Planning with multiple publics requires a new type of process, a more participatory, fragmented and more agonostic processes that can acknowledge conflict and dissension. Coupled with an ecological approach to design and strategy driven approach of implementation, the river's edge can in fact become a fragmented but inclusive public space.

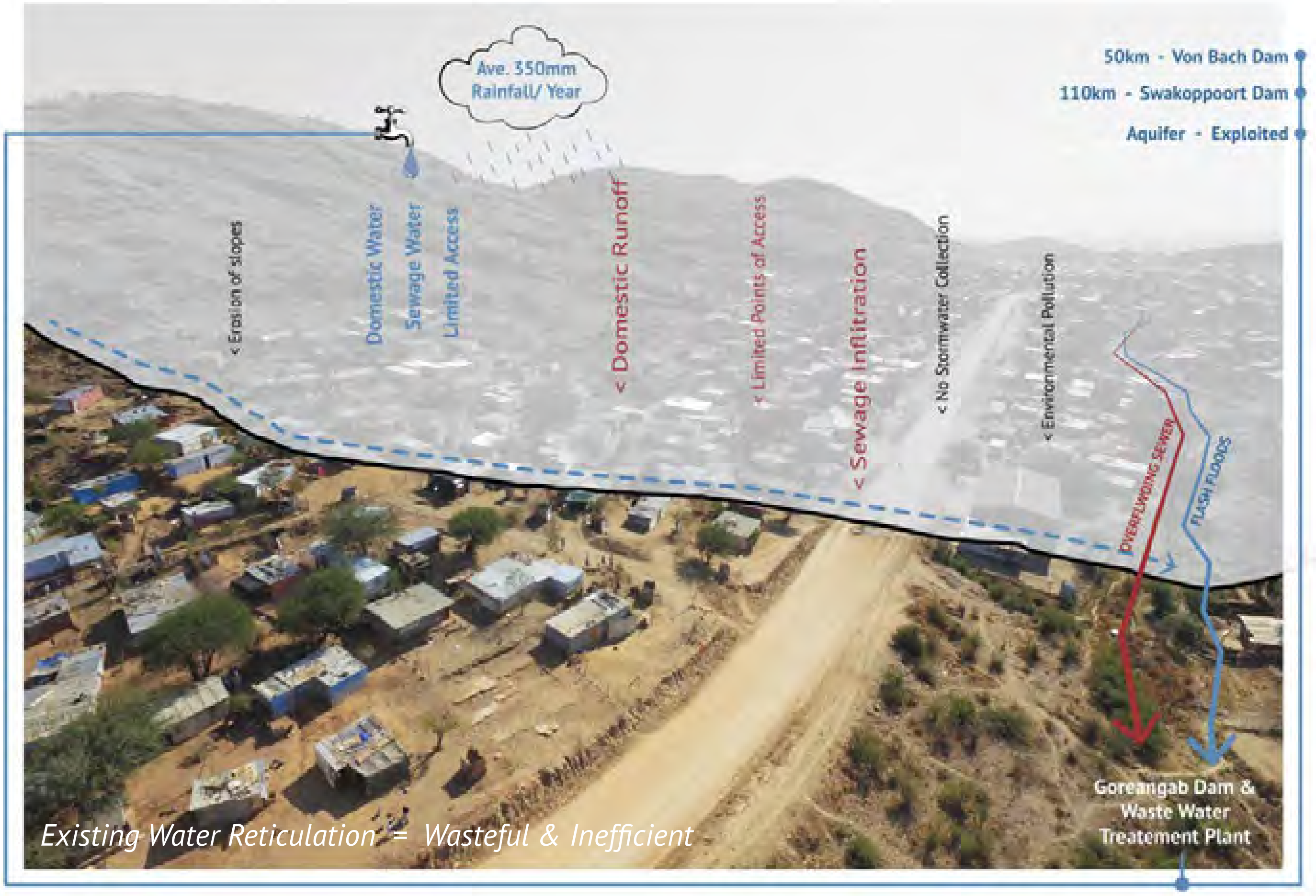
"... the ability to recognize objects in our environment is critical to our ability to act and function in places effectively" (Lynch, 1960: 5)

Through this understanding that human behaviour plays a fundamental role in the creation of public environments, it can be concluded that effectiveness can be achieved through the establishment of value based interventions that are recognised by the people of KIS as a means to better their environment through communal participation. Public space is used when it serves a function Providing value for its people and through public involvement reinforces power over and respect towards these spaces. It is this social insertion and value based intervention which equips architecture with the means to effectively re-establish a respectful relationship between man and the natural environment.

Topography & Water Flow

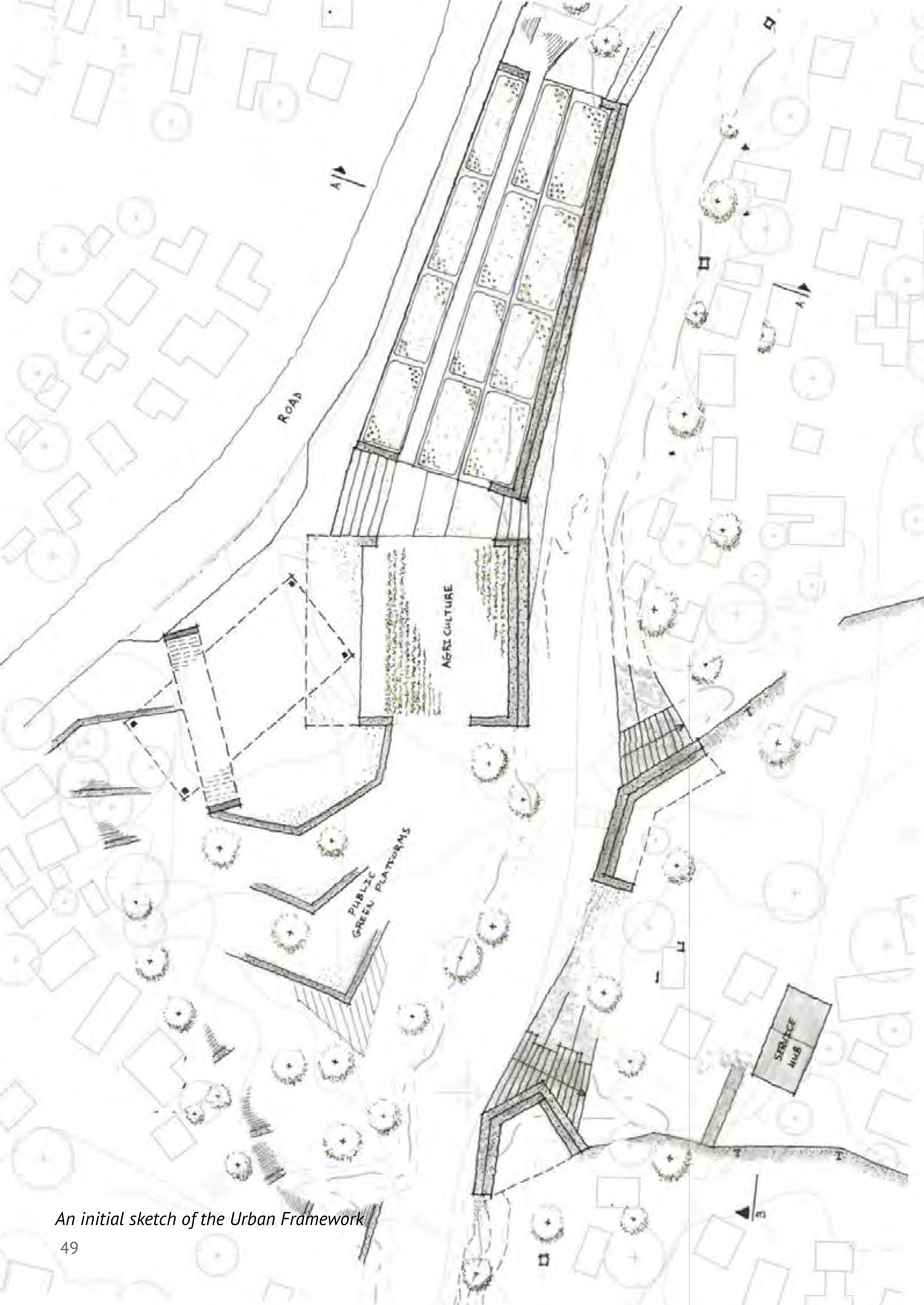






In the physical context of KIS, its topography is perhaps the best example of how undefined this landscape really is. Between these 'rolling' hills the river beds and their tributaries provide a continuous and directional route for both the flow of annual rain water as well as for any waste water and domestic surface water run off. Upon examining this layer it is clear that these tributaries are perhaps the most beneficial and strategic sites of insertion as they provide a point of interception where all forms of domestic waste water can in-fact be collected, specifically at their junction with the river. A strong driver in the formation of an urban framework the natural network of riverbeds acts as an existing platform to which this collection system can be integrated.

In the analyses of site through these specific lenses, an urban framework can now take shape. In this framework, improved accessibility and definition of these both pedestrianized and natural routes provides an opportunity for the integration of an alternative and somewhat non-conventional form of infrastructure that aims at minimizing wastewater and sewage infiltration by intercepting its disposal. As apposed to the conventional 19th century standard of centralized waste treatment facilities, this infrastructural system aims to not only collect and store this waste, but also treat and recycle it into potable (drinkable) water and fertiliser. This in turn not only minimizes its infiltration into the natural environment but creates a continuous and sustainable method of decentralized wastewater treatment.



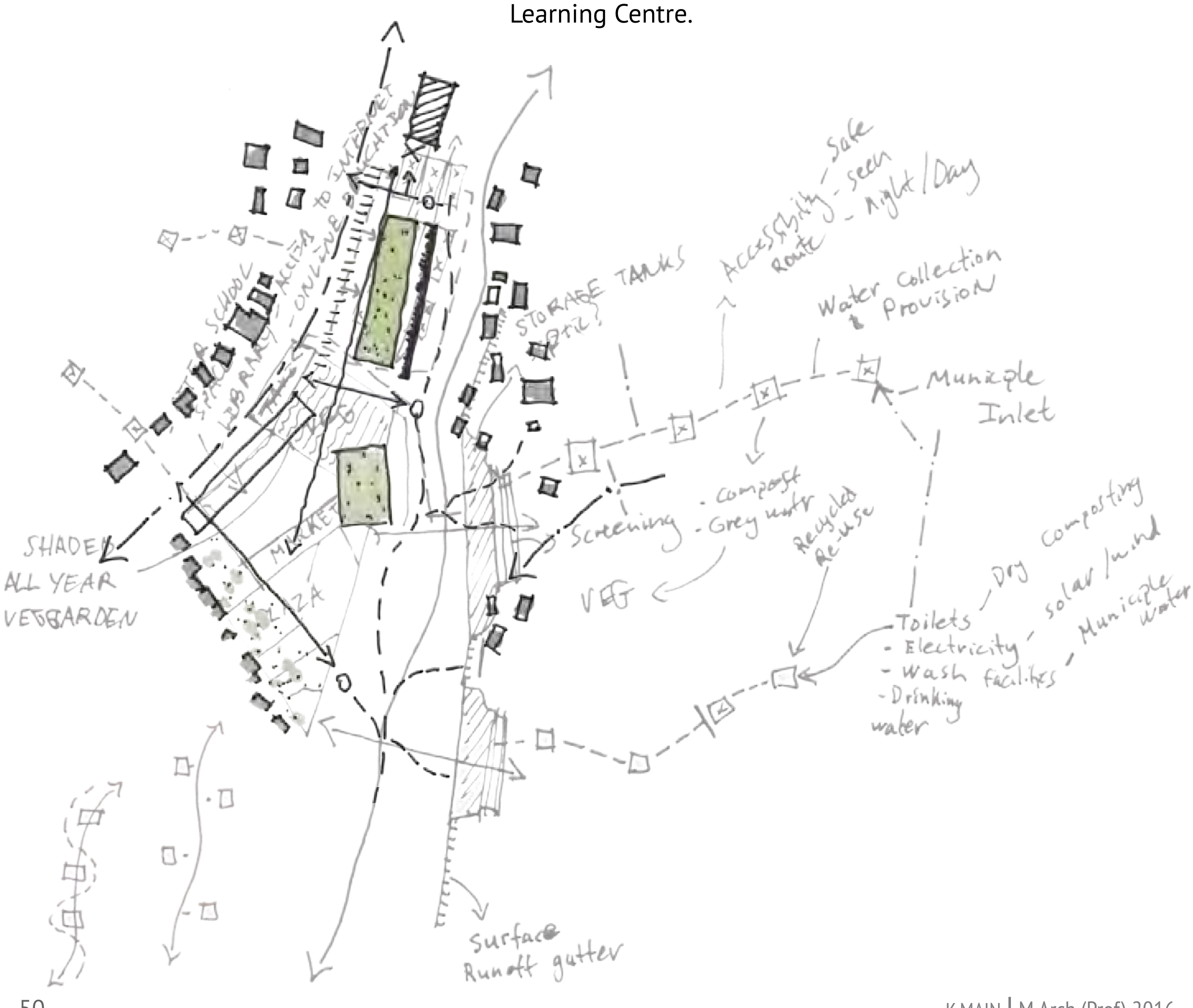
An initial sketch of the Urban Framework

Part 4

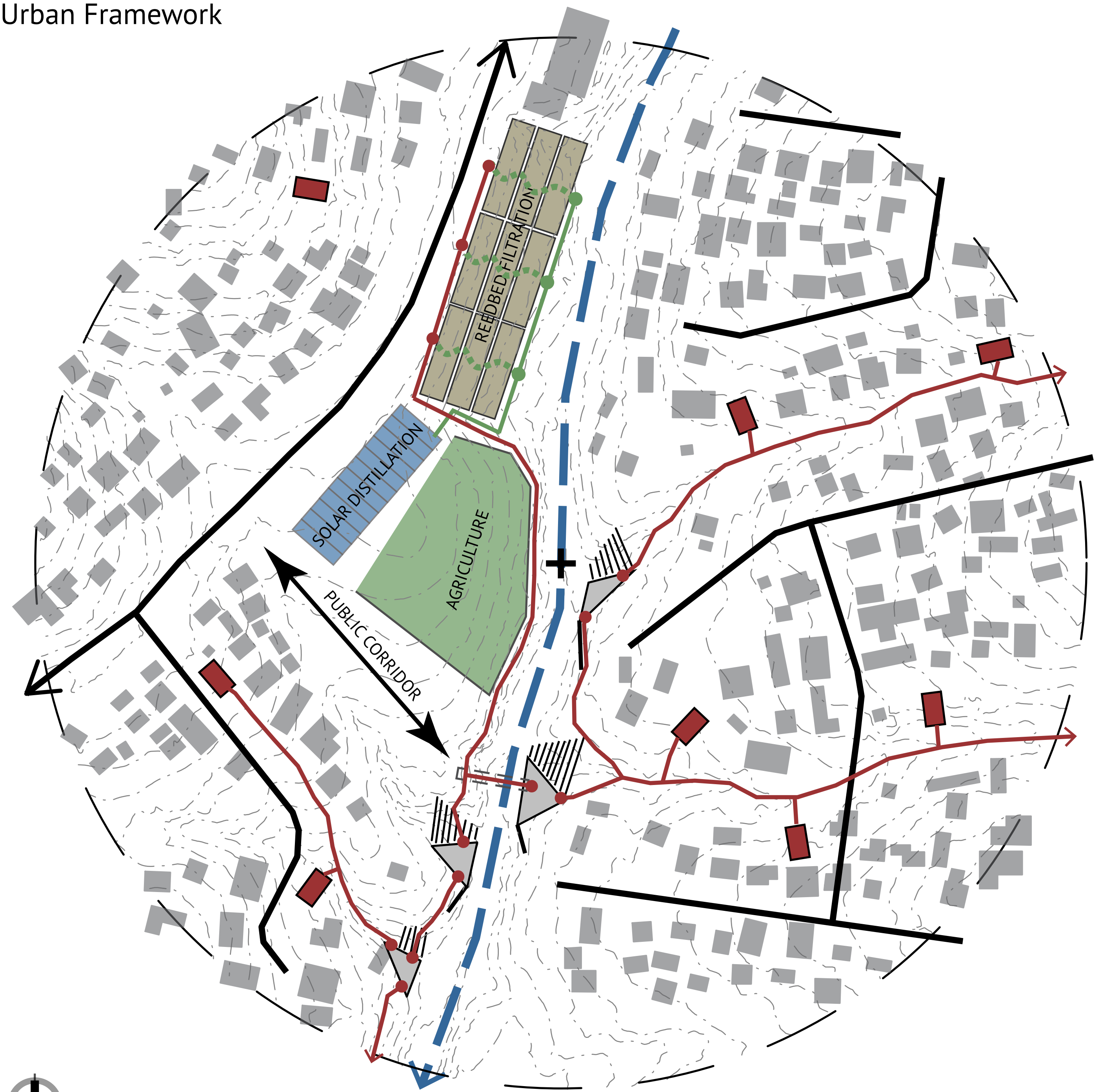
Urban Framework

"Thinking ecologically about design is a way of strengthening the weave that links nature and culture…It is simply the effective adaptation to and integration with nature's processes." (Van Der Ryn & Cowan, 1996: 18). Ecological design [or Eco-Logic Design] is seen as an integrative, ecologically responsible design discipline which is defined as "any form of design that minimizes environmentally destructive impacts by integrating itself with living processes." (Van Der Ryn & Cowan, 1996:x). This design discipline connects and integrates the notion of sustainability and 'green' architecture by placing ecology at the forefront in the decision making process, providing an ethical and ecologically orientated basis from which to work . Holistically, it provides a new way of approaching design (Van Der Ryn & Cowan, 1996).

Following a critical and optimistic analyses of site the following framework has been developed. Using analogies from the technological exploration, an ecological approach to design, and the notions of urban acupuncture as a type of landscape urbanism, this framework seeks to address the issues of wastewater and sewage infiltration into the natural and public environments of the area. In the further development of this thesis, certain elements of this framework will however remain hypothetical, namely the Service Hub & Urban Water Collector. These two prototypical devices do however still play a fundamental role in the development of the main architectural element: the Urban Agricultural Learning Centre.



Urban Framework



ELEMENT ORGANISATION

Library & Computer Facilities
Market Space & Trade
After School Space
Agricultural Space

Job Creation
Food Generation
Sustainable Income
Communal Farming
Agricultural Education
Economic Upliftment

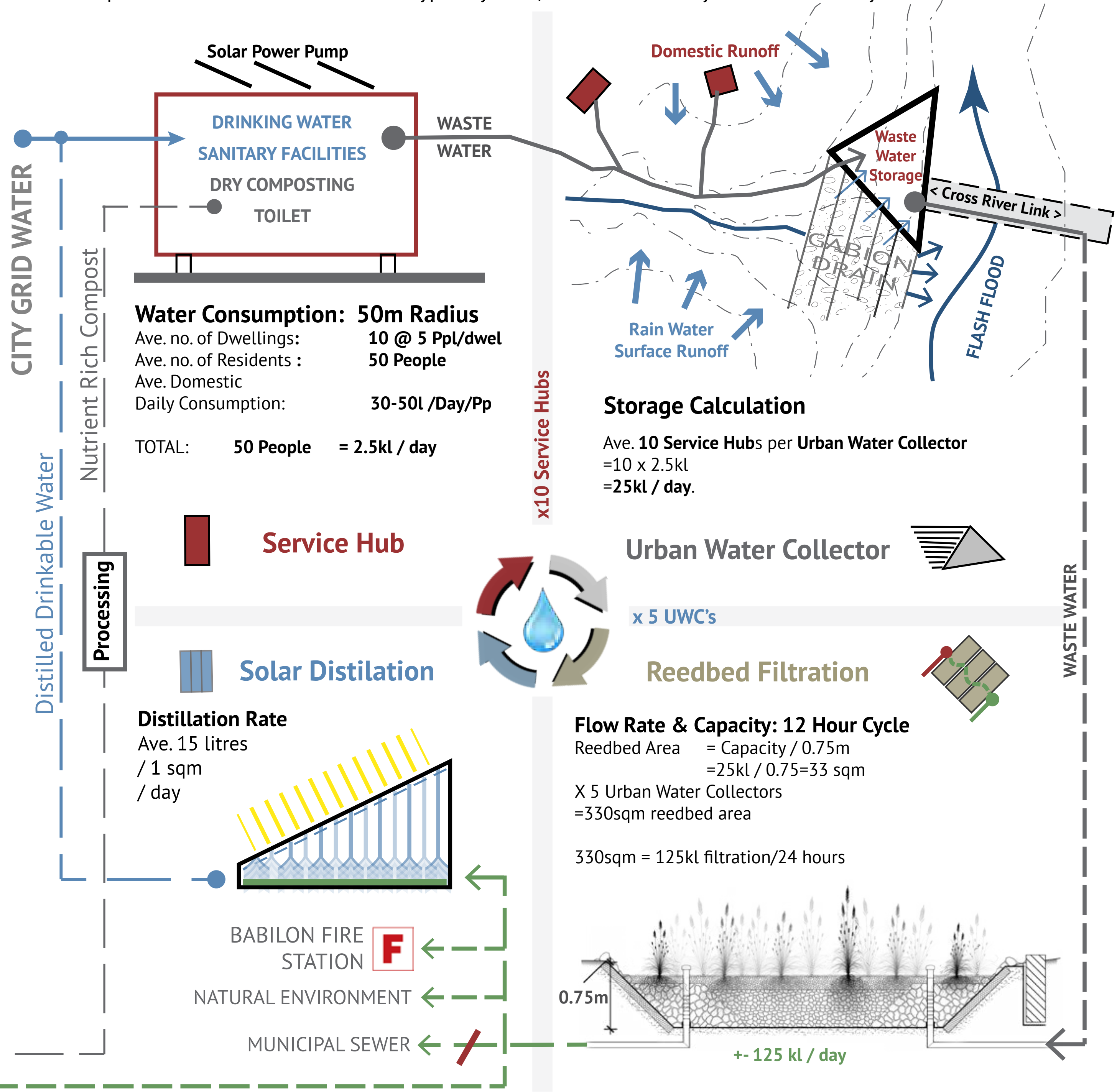
In an effort to facilitate the efficient and environmentally responsible disposal and management of water, as well as to better define and create healthy public environments, the following urban framework has been proposed. Most simply, this urban framework consists of an interconnected system that exchanges water in a series of 4 different contextually assigned architectural 'devices' that act to collect, store, pump, filter, distill and reuse wastewater. As shown to the left, this system has in itself acted as a platform for more defined architectural programming, which is able to utilize the 'bi-products' of this system and which will be introduced following the introduction of this framework.

PROGRAMMING | PERENNIAL AGRICULTURE

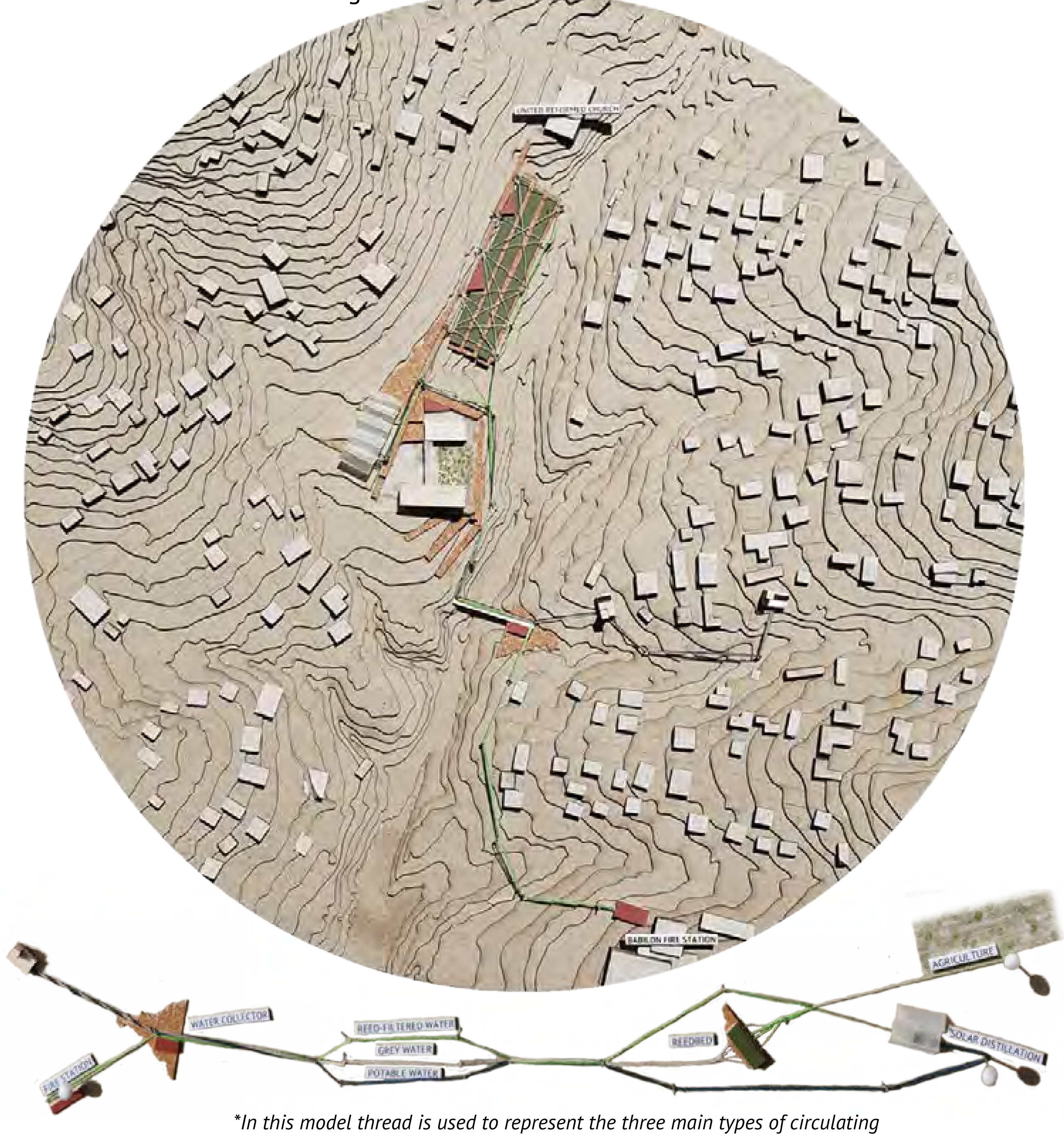
Recyled Waste water & Compost

It is hypothesized that these rather small but strategically placed elements have a number of potential 'knock on' effects towards the public, private, built and natural environments. Based on a ecological approach to design, this system inserts itself along the network of riverbeds where it utilises this waste as a resource, turning pollutant water and biological waste into reusable reedbed filtered water, potable water and nutrient rich compost. In their retrospective contexts each of these architectural devices serve a particular purpose while maintaining a particular hierarchical order in the framework.

In the initial stages of development a more calculated and somewhat engineered approach was adopted in order to better understand the number of services and the typical sizes of these elements in relation to their contexts. In this approach, and due to lack of site specific demographic data, population densities have been calculated based on an estimated number of inhabitants per house hold. This number is then multiplied by the number of households within a variable radius. In relation to these prototypical devices these varying densities enabled a level of parametricism to inform this framework. In this parametric equation, the minimum number of facilities is informed directly by the number of inhabitants and households within a specific radius of these elements. Overall this equation assists in the adequate provision of sanitary services for a particular area surrounding an individual element. This has in itself guided the general quantity and distribution of these elements across the landscape and which has since negated an estimation of the quantities of water that would be typically used, collected and recycled within this system.



Water Reticulation & Massing



**In this model thread is used to represent the three main types of circulating water at their different stages of filtration while the colours red and green are used to retrospectively present waste water storage and reedbed filtration.*

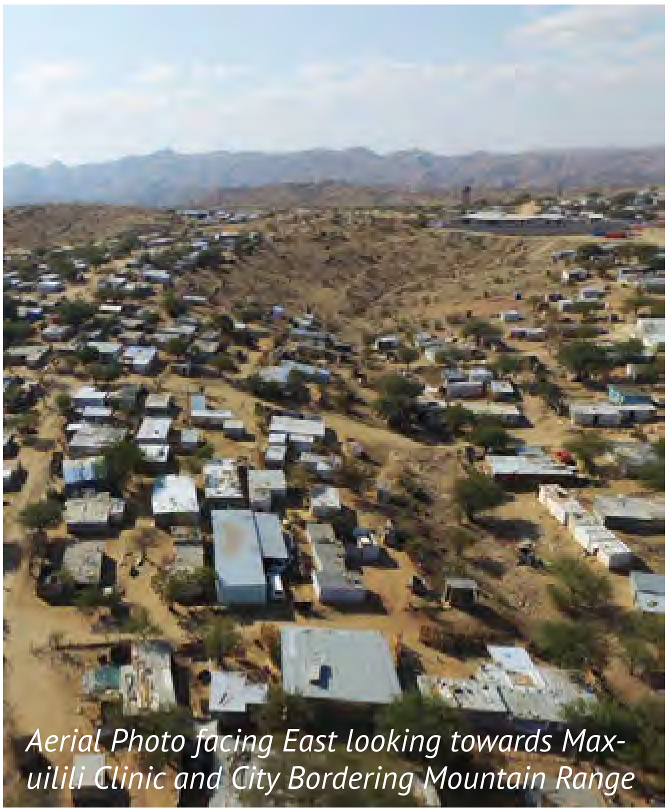
Following the diagrammatic conceptualization of this urban framework a more tangible 1:1000 model acted as a useful tool for exploring the physical and three dimensional aspects of the site and how it would be both functionally and visually shaped by these individual elements. As mentioned, up to this point, focus was given to the functional design and placement of the service hubs and water collectors, as without these contexturally informed parameters the next phase of design and programming would not be truly effective or adequate. As such the following section will look at how each of these elements architecturally contribute to their surroundings and the role they play in the overall system.

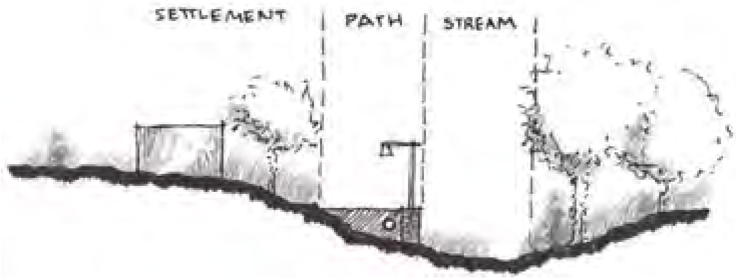
Service Hub

An element that is inserted into both the tributaries, and more private and personal spaces of the area, the service hub provides a facility which can either replace existing informal long drop toilets, or form and define new spaces. It is believed that these somewhat prototypical devices enable a functionally driven interruption of the existing water cycle, redirecting the typical use and disposal of domestic water. As apposed to conventional methods of combining and circulating sewage and greywater these 'service hubs' separately collects each for recycling in dry composting toilets, or reedbeds. Typically, compost would only need to be collected and processed every six months after which this waste can too become a source of income when sold.

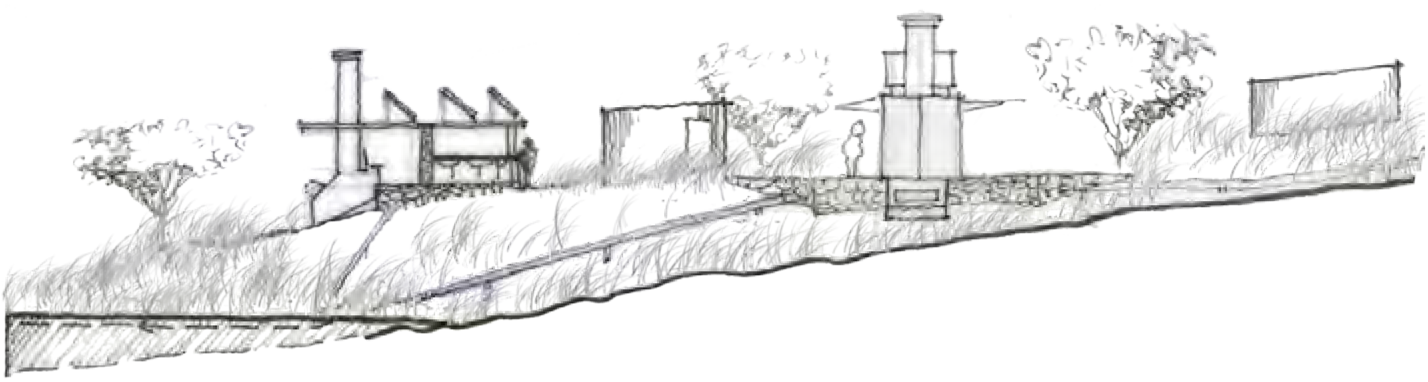

A model view up a tributary

Together these service hubs form 'runs' that make their way up the surrounding tributaries providing both formalized and informal points of infrastructural connection along existing and new pedestrianized paths. These points of connection that form physical links between the hubs consist of two crucial water pipes that are either surface mounted or subterranean. They act to transport either drinkable water to or grey/waste water from the service hubs and urban water collectors. Entirely dependent on their context, these 'pipelines' that stretch between these new insertions provide the opportunity for more defined routes upon which other infrastructural systems and public amenities can be added, such as electrical supply which can be taken further to provide a well lit and safe route between these elements at night.

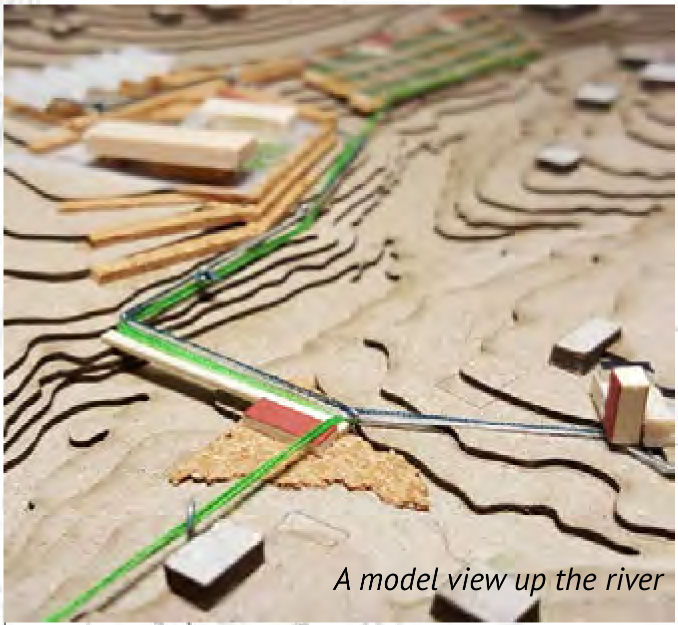

Aerial Photo facing East looking towards Maxuilili Clinic and City Bordering Mountain Range



As a means to create visual and informative points of reference within this landscape, the 'Service Hubs' would ideally be visible above the soft tree line, providing a continuous and somewhat informative directional flow of movement along these paths.

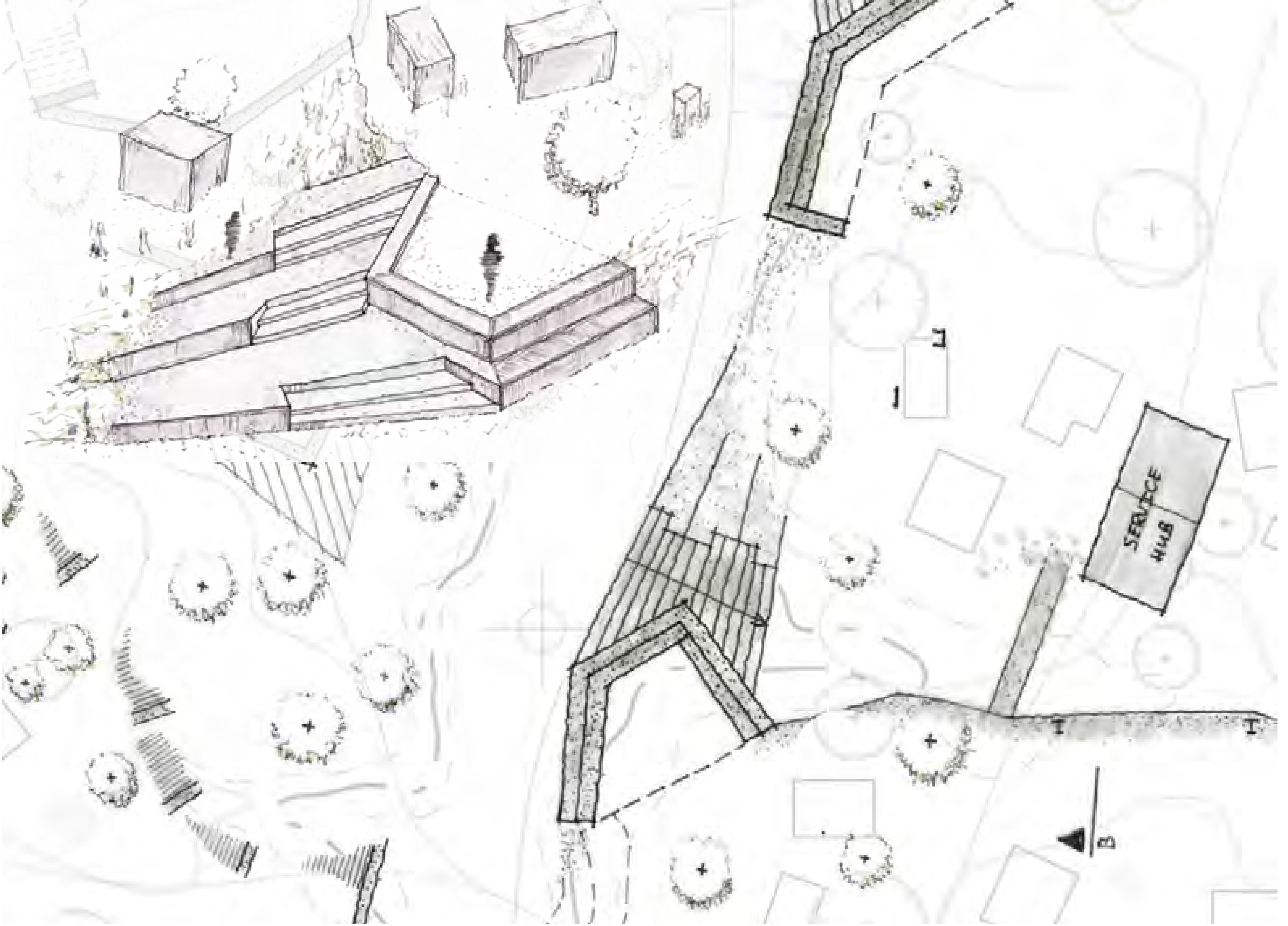


Urban Water Collector


A model view up the river

Situated at base of the tributaries, the urban water collector, as its name suggests, provides the lowest point of grey/waste water collection from the gravity fed Service Hub runs. These urban water collectors are vital in this non-conventional wastewater treatment process as they provide both the first point of waste water screening as well as temporary water storage in which primary sedimentation can take place, as discussed in part 2. Positioned at the junction with the river the urban water collectors have additionally been designed to serve a number of other functions. Firstly they are used to define and direct infrequent flash floods that flow along the main river bed. Secondly, they provide an opportunity for rain water collection during times of heavy rain, in effect turning these elements into temporary dams after which this dammed water can be absorbed into this ecologically orientated system for later reuse. Included in this catchment is any and all forms of general pollution that has manifested during the year, minimizing the further contamination of the near by Dam by providing a point of collection of this inorganic waste.

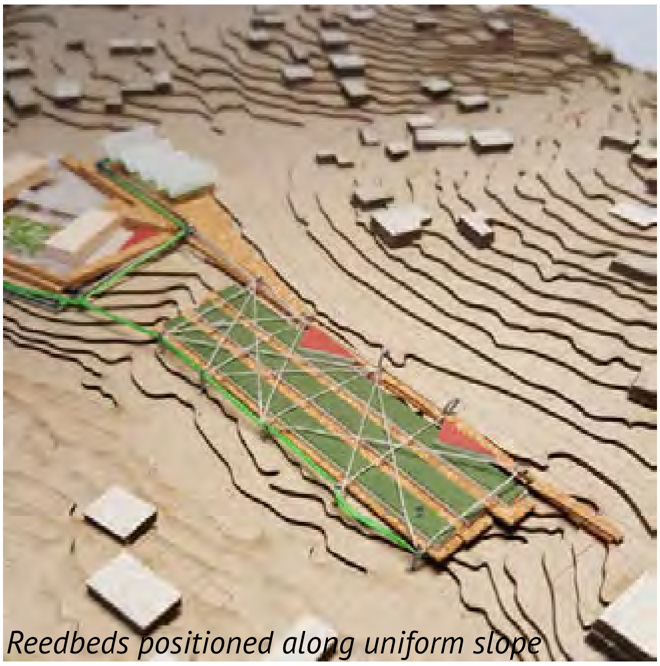
As seen in the model, these elements also provide a point of cross river water exchange that allows this system to function along both edges of the river.



Reedbed Filtration

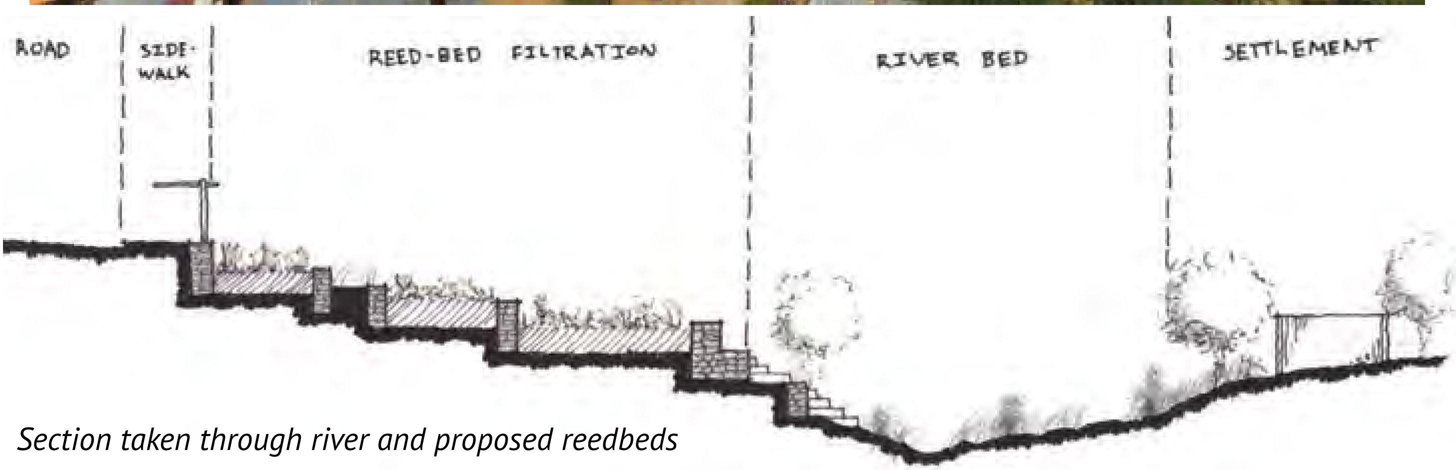
This next phase of water reticulation involves the filtration of these large quantities of water that is collected and temporarily stored via the potentially numerous urban water collectors. When determining the location and type of reedbed system, a particular area of site proved to be the most ideal location in the fact that it is both large enough (including future reedbed extension) and more or less uniformly sloped for the use of large scale gravity fed vertical flow reedbed system.

In this phase water is pumped directly into gravity fed vertical flow reedbeds. As explored in part 2, these reedbeds provide for the sufficient filtration of wastewater so that it may be safely disposed of into the natural environment which includes the safe dispersement over agriculture. In this case however, this reedbed filtered water is again collected and re-used in a number of ways (as shown in the urban framework diagram on page 52), and one of which will be described in the following section.



Reedbeds positioned along uniform slope

Aerial Photo looking South towards the city and Goreangab Dam



Section taken through river and proposed reedbeds

Solar Distillation

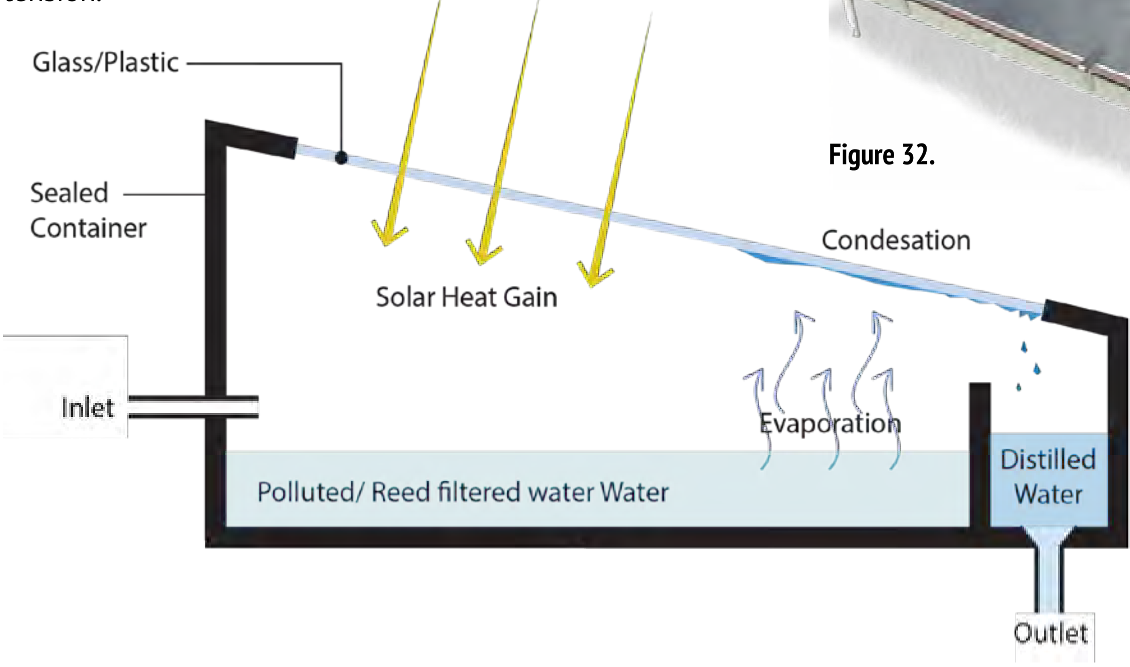
Model View of Distillation Panels and Market space looking towards North East

From the previous rough calculations of general water use and quantities it became clear that if this water reticulation system were to be (hypothetically) ever fully integrated it would need to not only collect and filter large quantities of water in a continuous manner but appropriately use and dispose of all this filtered water. In the ideal situation this water would be pumped into the existing sewer system (currently at capacity and over flowing) where it would make its way to the Goreangab Wastewater Treatment Plant and thus contribute the existing city wide water reticulation system. This is however not a reality and something which cannot be relied on. Instead the further use of this water prompted the exploration of Solar Distillation technology that allows the entire system to work in a continuous cycle of use and reuse, essentially creating a truly sustainable system.

Most simply this technology uses only natural processes to create clean drinking water from pollutant water. This process is usually contained inside a flat sealed box which has a slanted glass covering which allows solar radiation to enter and heat the air and water that is contained within the box. After sufficient heating, the water starts to evaporate into water vapor increasing the humidity with inside the box. Upon contact with the cooler glass surface, the water vapor condenses forming pure water droplets that run down the slope and into a gutter where it dams, after which it is collected. This entire process utilizes nothing more than the sun as a means evaporate wastewater and collect drinkable water. Although this system, as roughly calculated, only creates around 1500 litres of distilled drinkable water (using roughly 90sqm of distill surface area) from a potential maximum of 250 000 litres of wastewater per day it is still a start and may prove adequate in times of emergency or severe drought. As Windhoek receives around 300 days of full sunshine a year, this technology provides a relatively reliable method of drinking water attenuation.

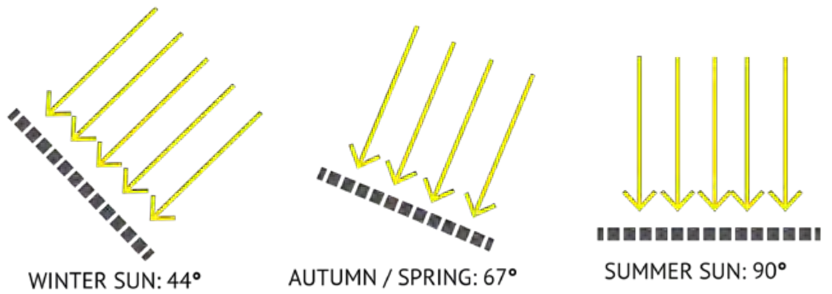
Shown in figure 32 shows an example how this system typically looks and how a modular form of design can be most beneficial in the integration of this technology and its possible future extension.

Figure 32.



As shown below, this somewhat simple method of water purification has been adapted into a system that is believed to be more efficient. As apposed to the conventional system that contains one basin of water, this adapted system instead suspends water in a number of half round 'gutters' that would ideally be painted black. This allows for increased heat exchange between this 'suspended' water and the heated surrounding air, therefore increasing the rate at which the water is heated and thus increasing the rate of evaporation and condensation. In addition to this, this adapted panel can be rotated and orientated to allow maximum solar gain through out the year as apposed the conventional system that can not be adjusted. As is, this idea remains theoretical, and will be shown and tested in the following section where this space and technology is viewed together with the Learning Centre.

Related to its location and design this technology has manifested in a series of distillation panels that provide shade for a proposed informal market. This shaded market space not only acts as a point of production and distribution of 'self' purified 'free' drinking water but as a necessary point of exchange of healthy and self produced vegetable and fruits which would be grown at this Centre. With regard to its contextual assignment, this market space runs parallel to the bordering primary circulation route. In an area with a generally low population density, and little to no informal trade, it is believed this location provides the most ideal point of social and economic insertion while at the same time acting as a transitory zone between this envisaged busy public street edge and a more semi-public educational space.

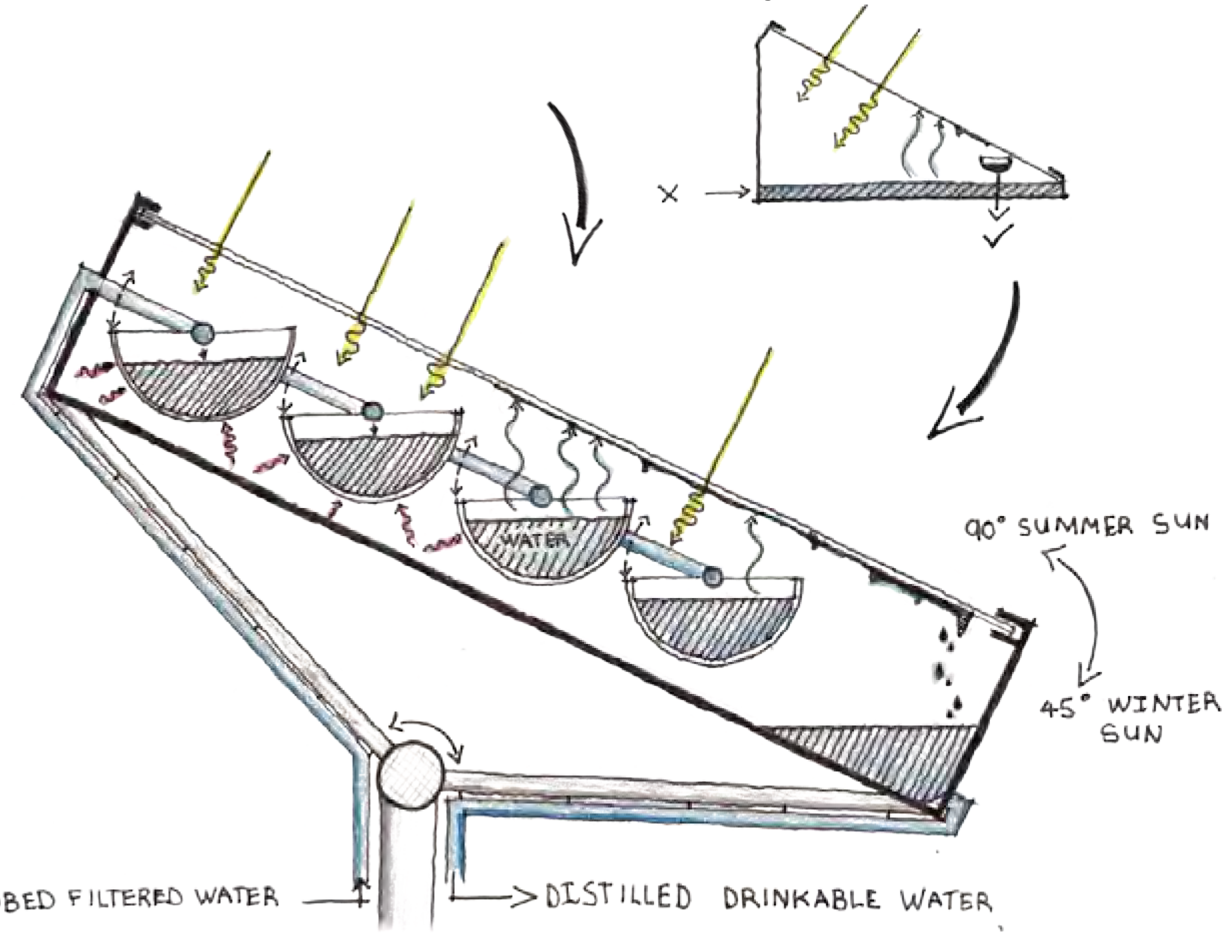


Windhoek
Optimum Tilt of Solar Panels by Month

Figures shown in degrees from vertical

Jan	Feb	Mar	Apr	May	Jun
83°	75°	67°	59°	51°	44°
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
51°	59°	67°	75°	83°	90°

Figure 33.



Initial Design of Rotateable Distillation Panel

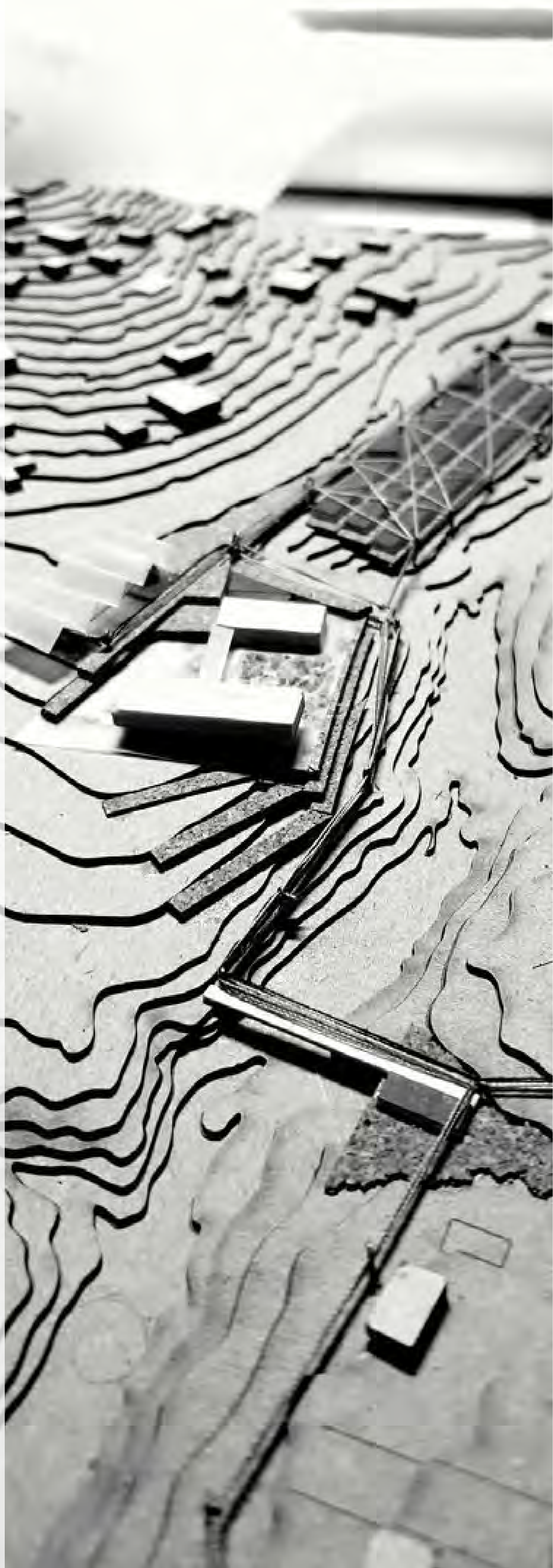
Part 5

The KIS Agricultural Learning Centre

It is at this point in the development of this thesis where focus is shifted to the design and development of the main architectural element/building. With reference to part one, and the settlement wide scheme, this building is to hypothetically form one of many along the 'rivers edge' and is there for seen as both a separate and functionally independent element within the urban framework. As previously mentioned, this establishment utilizes both the reedbed filtered water and contextually acquired nutrient rich compost as a free and sustainable means to both fertilise and water an area of agriculture throughout the year, turning the existing pattern of annual communal farming that relies on yearly periods of rain, into an extended perennial form of agriculture.

In relation to this, this establishment acts to not only serve as an educational facility but incorporates additional forms of solar and distillation technology as a hybrid form of infrastructure and public architecture. Programmed around this agricultural learning space is a mixed-use and multi-functional facility that provides the surrounding populations, both young and old with an opportunity to learn and practice this somewhat basic but highly effective means of food attenuation. Included in this development are a number of facilities that include classrooms, a computer Centre (allowing for research), a library, (which additionally functions as after school space), storage (for the market and Agri Centre) and administrative space (for managing the Centre)

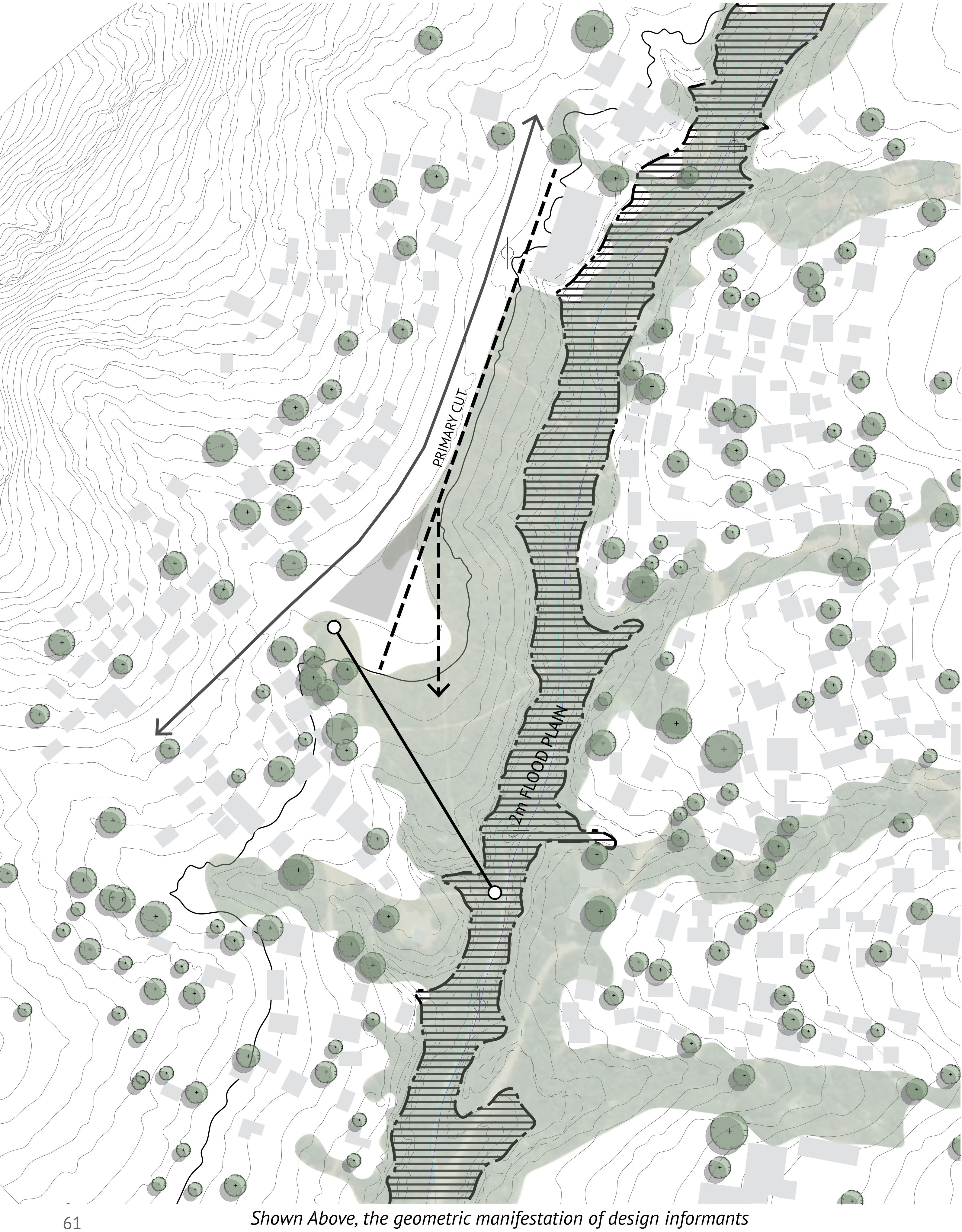
Although only mentioned at this point in the thesis, the design and programming of this space and building has been developed in conjunction with the 'off site' urban framework elements and which will be explored in the following section.



Form vs Function

As shown to the right the initial stages of design and organization of the **reedbeds, agricultural land** and **agricultural facility** reflected a somewhat abstractual form of spatial organization. In this, an attempt was made to draw on the existing 'informal' arrangement of the immediate context, perhaps embedding a more aesthetically coherent and recognizable spatial organization within this site. In this design approach, reference was made to previous conclusions which outlined the idea that fixed (non living) systems within any environment act as platforms for static (living systems) to exist. As seen in this more abstractual form, this was understood and tested as an array of fixed and informally or 'naturally' established spaces upon which the public (through building programme) would occupy and 'naturally' complete this symbiotic relationship. In the insertion of this functionally living yet formally non-living facility, the abstractual notion of 'replicating' existing settlement patterns of organization was ruled out and instead focused on a more finite and technologically considerate design approach which seeked to work with this elongated site, in another way.

In relation to part 3, section 03 (Gabion Technology), further design development was directed to a more geometric approach to defining the landscape. Working with gabion walls and level changes, this resulted in a terraced, and rather jagged array of leveled platforms upon which either of these three elements could be located. Although functional, this array of platforms created an unnecessary and harsh obscurement of the existing 'gentler' landscape, revealing how formally sensitive the overall composition of this landscape really is. In relation to the directional movement of the incoming water pipes, this array too proved to be highly technologically insensitive. Although 'uneventful' this design approach did however establish an understanding of how one might transform this landscape in relation to gabion technology and the slope of the site.



Shown Above, the geometric manifestation of design informants

Keeping it Simple

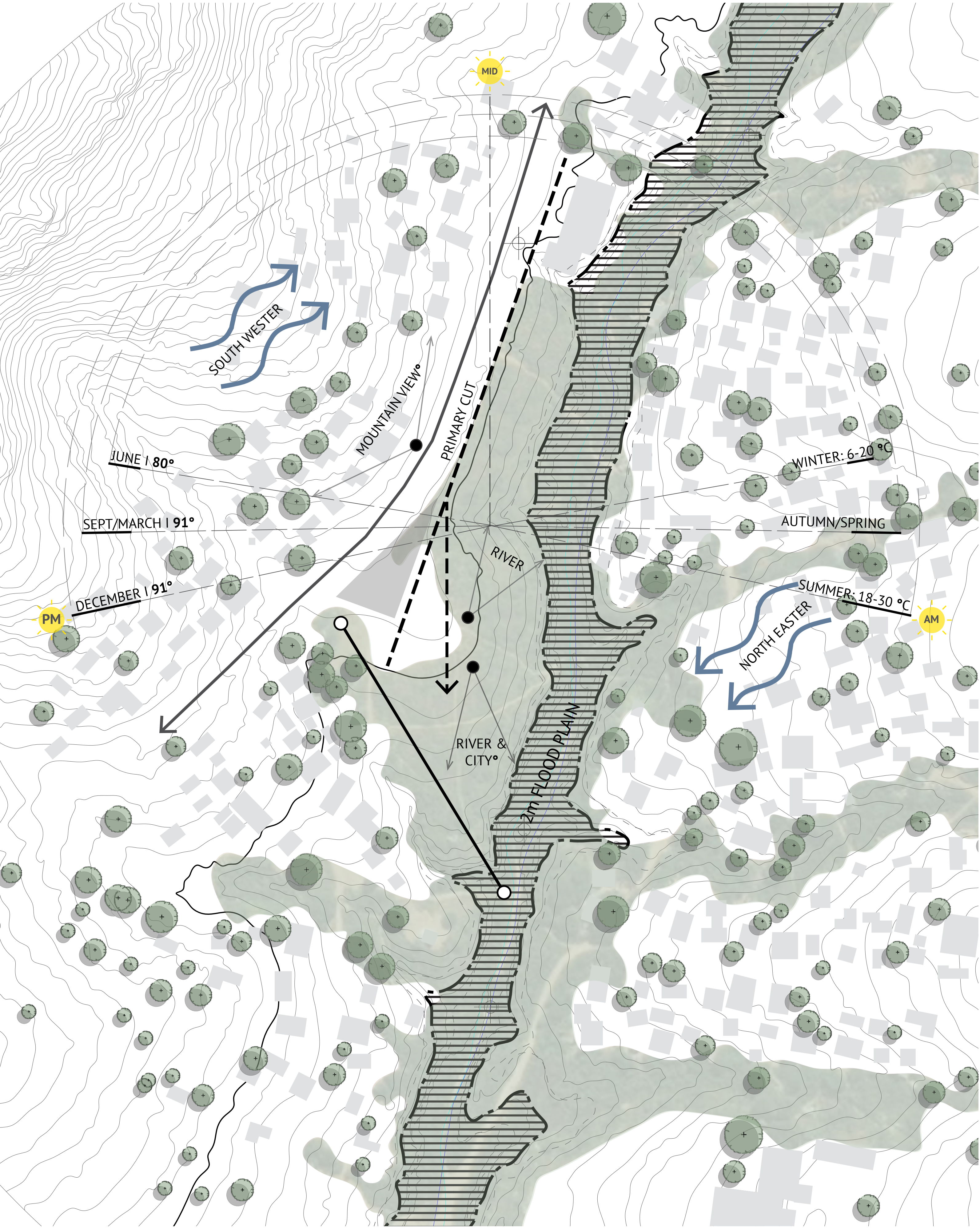
As such, a more simplistic approach was taken. In this approach, great attention was paid to the theory of landscape Urbanism, where instead of developing and 'formalizing' such large areas of the site, these areas could in fact be 'activated' by simple incision. As previously mentioned, this notion seeks to work with the site and not against it. In this more simplistic approach, focus was given to both the linear geometry of the site and existing contour lines.

Here, a single and full length incision is made into the site that runs more or less parallel to both an existing contour line and road, (as shown to the left.)This line, constructed from gabions acts to both retain and cut into the landscape and is made deep enough to provide a sufficient change in height which was determined at around three meters (although varies longitudinally). As mentioned in part 3, section 4 (utilizing site) this single cut allows for not only the definition of two flat platforms, but for a substantial amount of 'earth' material to be used in-situ in the building process. In addition, this cut provides a single and uninterrupted route for the varying water pipes that run between these elements, in essence creating both a spatially defining and infrastructural 'spine' that acts as the backbone for water reticulation and overall site definition.

On the south end of the site, this 'cut' is what first defined the separation between the street level market space, and 'mid' level Agri Centre space. Drawing off the sites geometries, namely the road edge, this cut provides a visual point of reference in this landscape drawing the eye from the street into the market space that increases in width as the road draws away from this 'cut'. At this point the cut perpendicularly steps down and 'dissipates' into the landscape where it is met by a proposed pedestrianized corridor that links the road and river/urban water collector.

On the North end, at its most shallowest depth, this cut is additionally used to define an area between the reedbeds and road edge, allowing for the potential establishment of informal trade which would additionally formalise this route between the neighbouring church and proposed market space. Through this conceptually simple method of space making, an indefinite extension of and consideration for future growth can be achieved, which draws off this then 'existing method' of spatial definition.

Contextually drawing on little more than the existing topography this desirably more sensitive and simple approach continued to guide the design of the Agricultural Centre. Through this and the above mentioned processes of design development it became clear that this 'green field' site requires a more simplistic approach to enable a more gentler visual introduction of these elements into the existing river, road edge and informal setting.

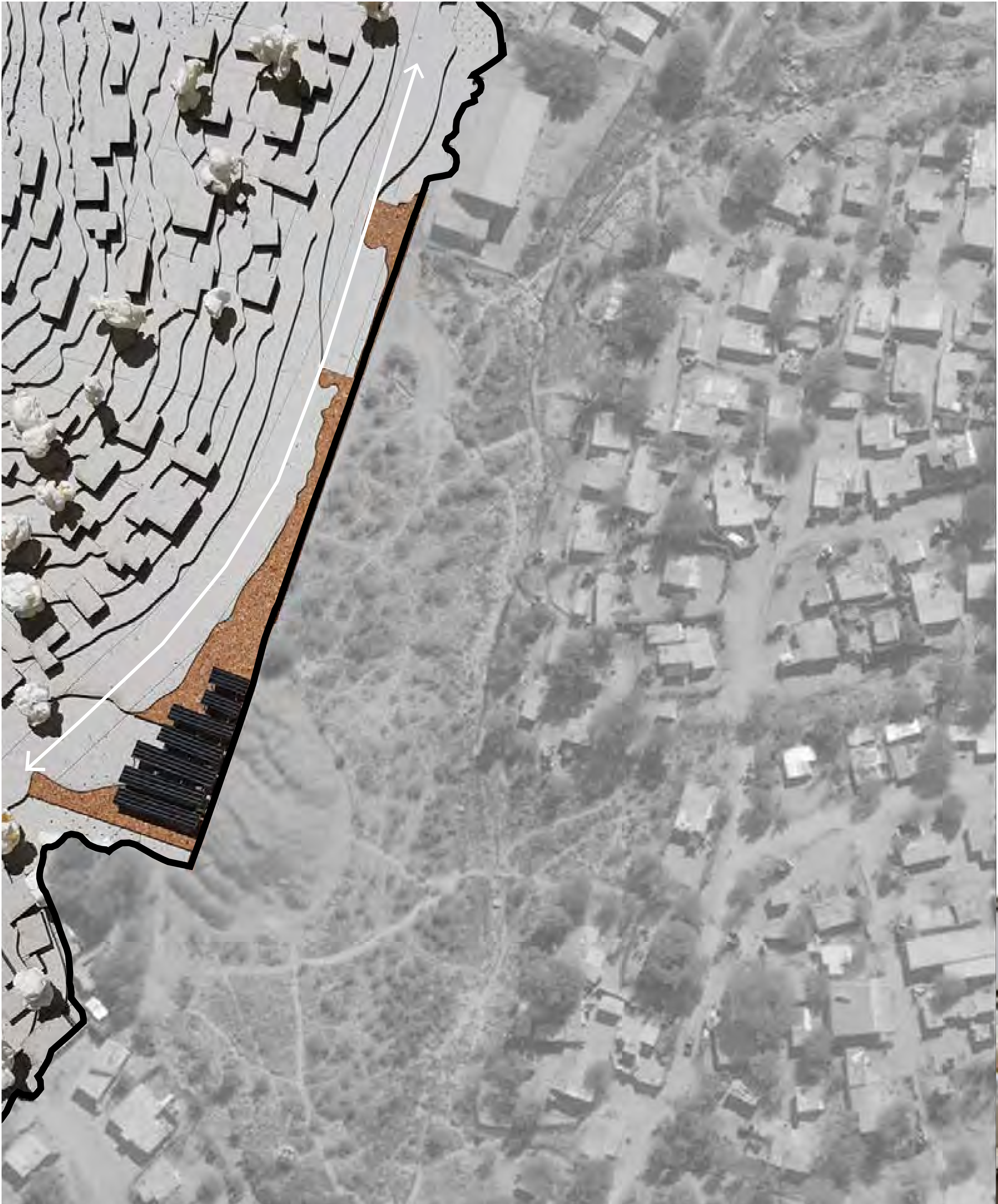


Shown Above, the sun and surrounding views in relation to the conceptual site geometries

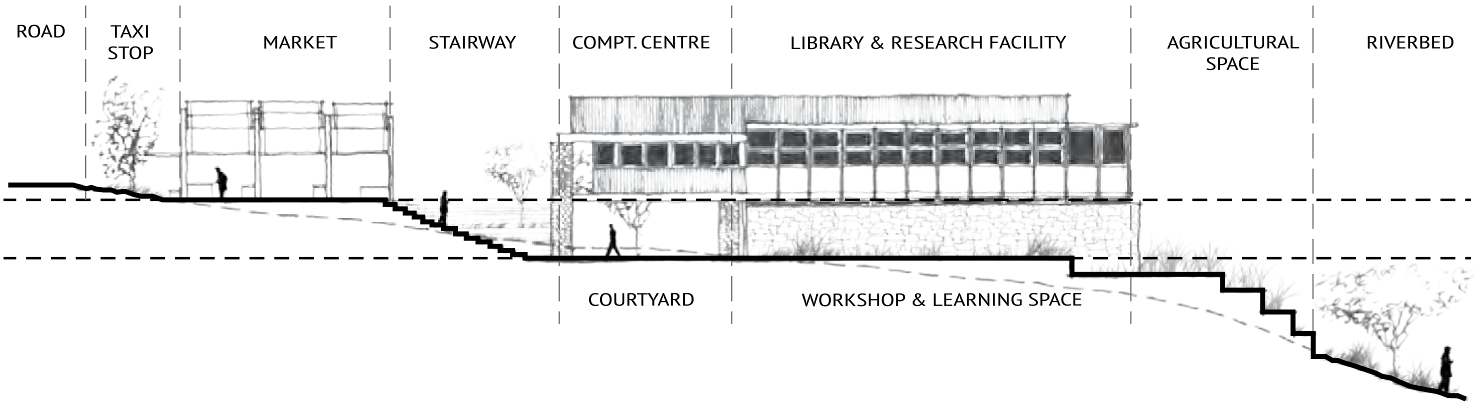
Following the conceptualization of this spatially defining, water bearing 'spine' , the next stage of design looked at the location and orientation of the Agricultural Centre in relation to the sun and wind, as well as to the different surrounding panoramic views. At this stage and as seen in **Addendum B,** a 1: 500 model (paper scale 1: 2000) was used, where physically working with the site and its topography enabled this conceptual line to be tested and further used to inform the arrangement and massing of building elements. Considering the relationship between massing and solar orientation at this stage of design was considered vital, specifically in this context and climate where both winter and summer day time temperatures rise above 20 degrees Celsius. Establishing a true north orientation at this stage ensured for a more easily manageable passive design solution within these massed elements at a later stage.

Orientating one to direct north, as well as to the view down the river , a secondary line of cut (and fill) is made which runs from an axial intersection with the primary cut towards the view of the river, as well as towards the closest landmark, the Babilon fire station.

As previously mentioned, landmarks, such as the babilon fire station provide some of the only large visual points of reference along side the rivers edge. In improving accessibility and most importantly readability, this Agri Centre not only orientates towards north and the river view, but establishes a visual link between itself and the nearest land mark, fostering an improved sense of security through a visually 'guarded' pedestrianized river route that relies on the watchful and clearly visible eye of the Centre, its market space as well as surrounding residents.

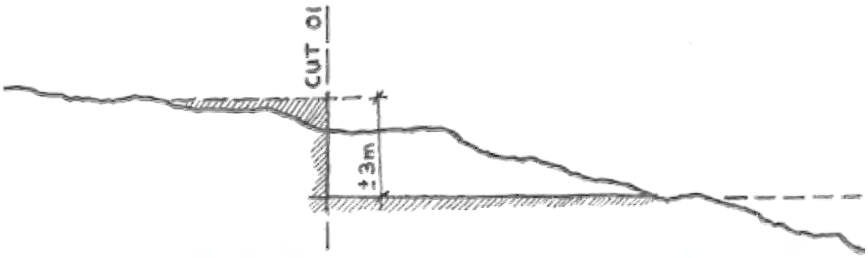


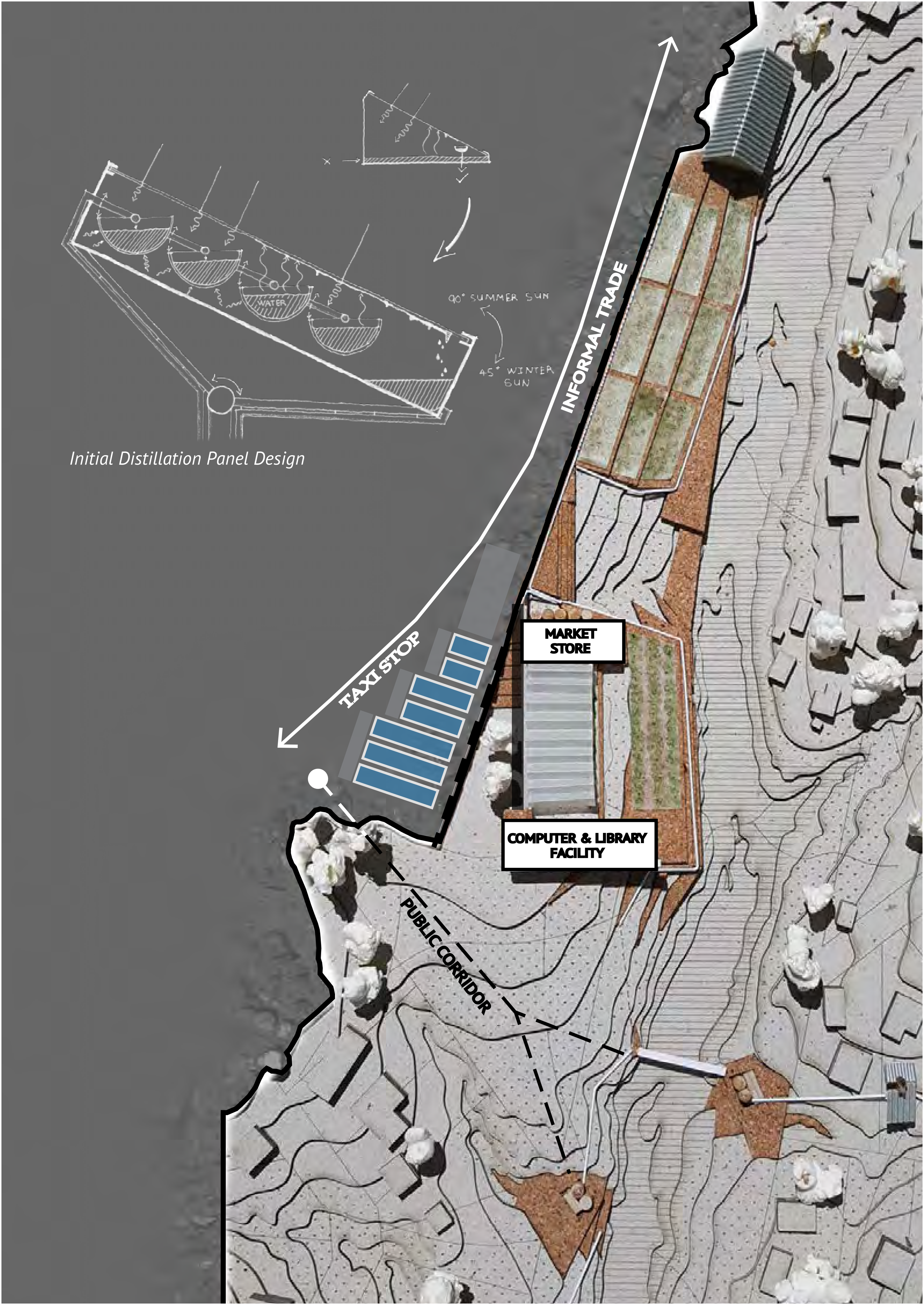
As shown above, the length and position of this 'conceptual line' enabled a more defined level change between not only the market and Centre & reedbeds, but between the river and higher informal residential area that over looks the site and riverbed. In any future spatial definition, this 'line' may provide a useful reference point and thus guide and perhaps encourage further growth, were a terraced landscape facilitates a more efficient use of this still very 'natural' environment.



As shown in section A, working with this change in level prompted the vertical definition of the Centre itself, where the street level becomes the first floor level of the Centre. This vertical definition and 'separation' was further used to inform the materiality of the individual programmes. In the 'continuation' of the ground floor plain, an upper level is created which is both partly connected, yet disconnected from both the street/market and lower agricultural space. Lying level with the street and overlooking both the river and agricultural space below, the 'first' floor level provided a secure and somewhat appropriate location for the proposed computer and library/ research facility, located on the South Side.

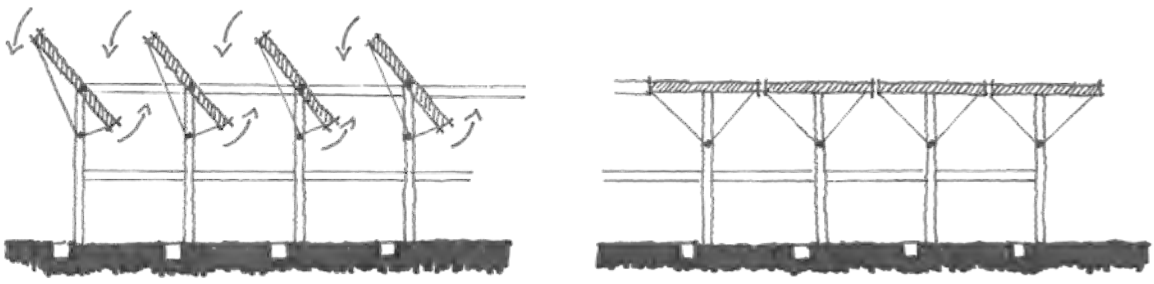
Although this facility is to be fully publicly accessible, there is still however a degree of reservation and privacy maintained within the design of this facility and space. This reservation can not only impart a sense of ownership and responsibility towards which ever community member(s) runs the Centre, but ensure that the library and other learning spaces are appropriately designed and managed towards quieter, safer and quality spaces of learning.





Initial Distillation Panel Design

As previously introduced, solar distillation technology has been integrated into the design of the market space. Drawing reference to the partially designed rotatable distillation panel, this area and type of technology not only serve as a market space during the day, but as a mixed-use space at night, where the distillation panels can be manually rotated to the horizontal position, thus fully roofing the space below. Creating at mixed use space has a number of other benefits such as providing both day and night time occupancy and thus maintaining a form of 'visual security' into the night time. A particularly advantageous benefit to this is the way in which this 'shared' space can create a daily routine of packing out and packing up each day. Although time consuming, yet generally practice, this routine can ensure that this space is cleared and made 'clean' after each day. In this, a certain level of respect can be gained towards both this space and others who might use it.



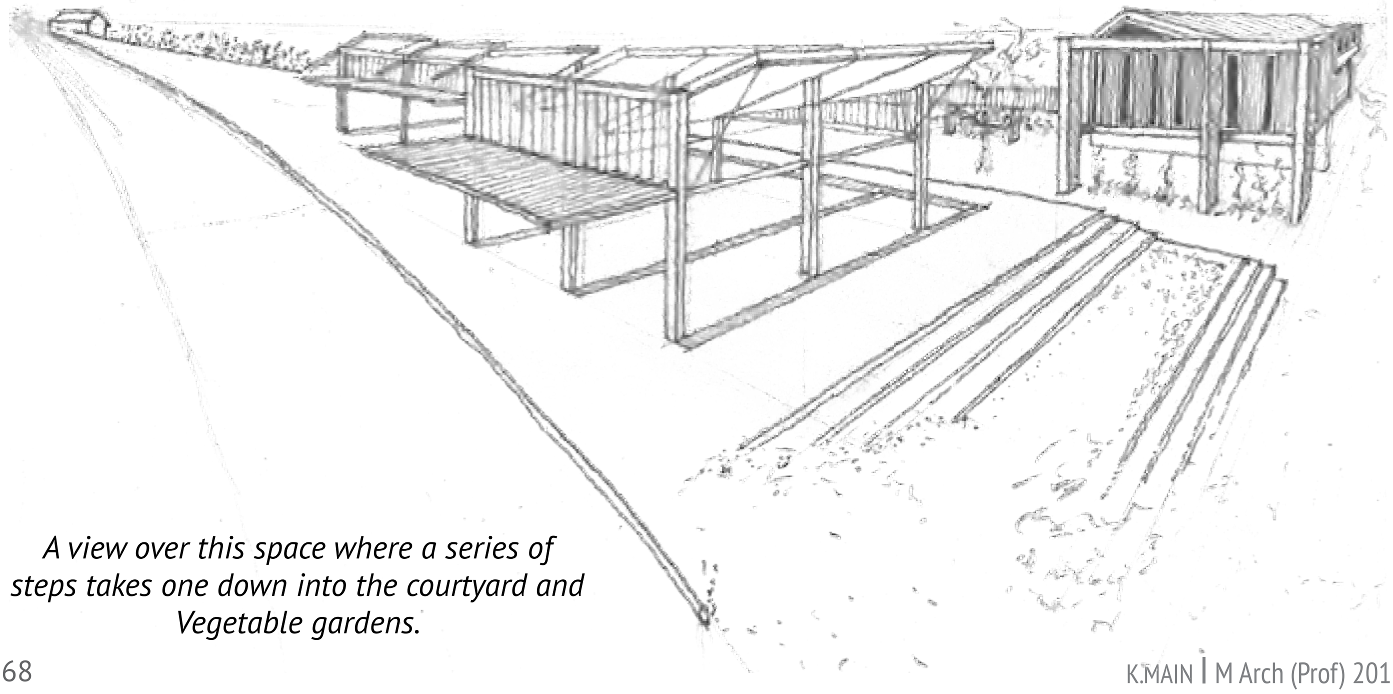
Day-Time optimum solar orientation and shading

Night-Time Roofed Enclosure

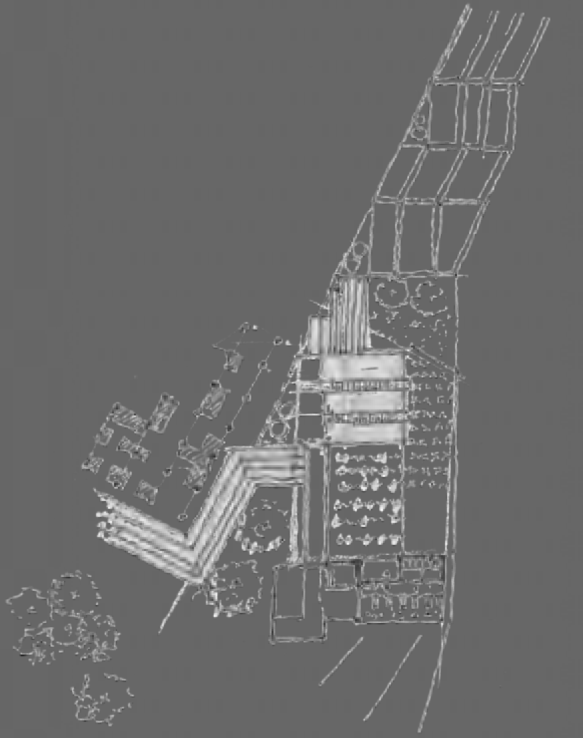
In the placement and functionality of this structure, provision for incoming reedbed filtered water pipes and distilled water storage manifested as a linear network of sub-surface concrete channels that house these pipe. As seen below, these channels run parallel to the primary steel column structure and are covered with a suitable steel grid. These channels not only house these water pipes but also act as storm-water channels for the collection of any surface water runoff, including that of the water that may be used and acquired in-situ from these panels.

As shown in the sketch below, this structure goes on to provide shaded seating for the proposed taxi stop that borders the market and street. In the context of KIS, shade, as simple as it is, is an important aspect of space making, providing shelter from the harsh summer and winter Namibian sun. In this regard, the mere fact that this area is shaded can perhaps increase its public mixed-usability. Currently absent, trees and other natural forms of space making will be additionally located in and around the Centre.

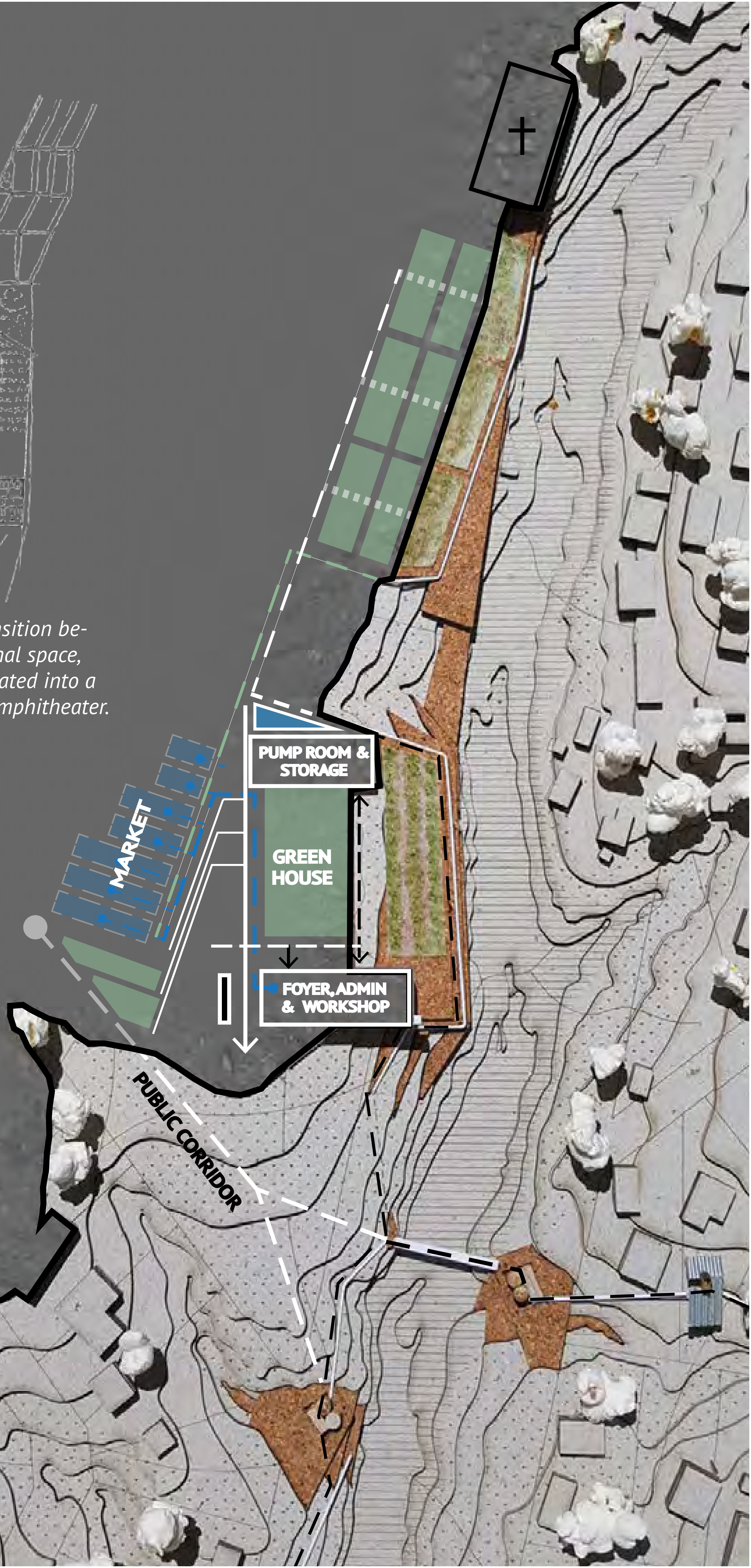
Although labeled as a market, this space might in fact require no label, as in the context of KIS, the creation of shaded and usable space such as this may take on a variety of activities, drawing reference to Tschumi's "eruption of events" (Dovey & Dickson, 2002).



A view over this space where a series of steps takes one down into the courtyard and Vegetable gardens.



Initial sketch of defining the transition between the market and educational space, where the primary site line dissipated into a series of steps that resembles an amphitheater.



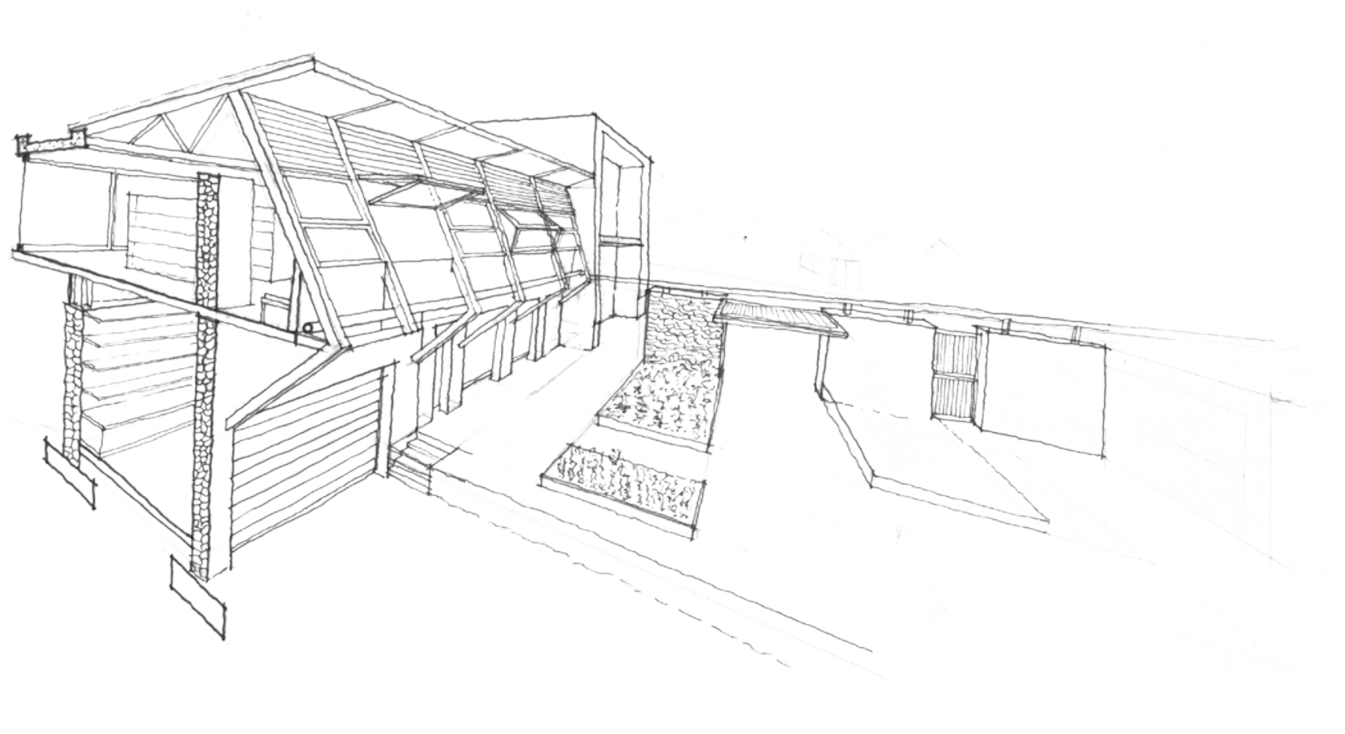
Located below the library and computer facility (shown in Section A), lies the proposed agricultural learning space. Viewed from above, this space is located below the street and market level where both noise pollution and visual distraction are minimized by level change and vegetation that is to exist within the courtyard/ green house.

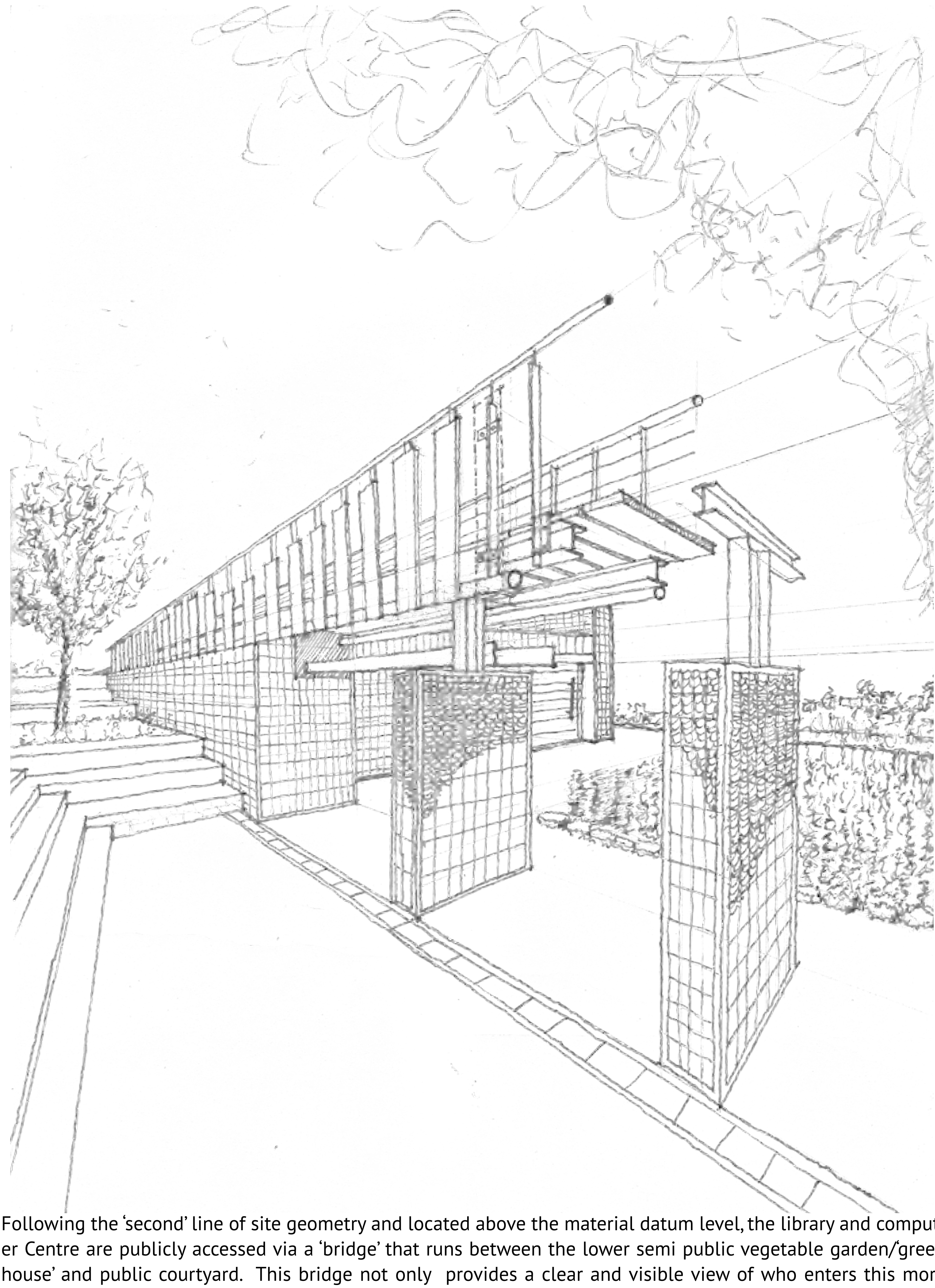
In terms of the buildings materiality and as previously mentioned, excavated site material is to be used as much as possible in the building process. Here, at the top line of the excavated area there is a vertical separation of the Centre and programmes which has been reflected in the vertical material composition of the lower and higher lying spaces, which were treated as follows.

On the lower level, where the earth has been excavated and larger gabion walls are used for retainment, the lower walls of the building itself is used to represent the first and larger grade of material, creating a ' stone' datum level. In the initial stages, this 'datum' level represented the highest point to which the courser stone walling would be built, however through design development, this visible line is only evident in the South Facade and columns of the bridge where gabion walling ends, and steel framing continues.

On the upper level above this stone datum level, the 'stone' materiality of the Centre is seen to end and 'break' free of the larger on site material composition, exposing a more slender steel framed primary structure. As mentioned, this primary steel structure provides the necessary support and framing for stone and gabion technology as an infill.

In the vertical separation and 'hierarchy' of graded material, it is believe that the conceptualization of this datum level provided for a separate definition of spaces through materiality. For instance, in the spaces of learning, located below the datum level, a more natural and somewhat familiar setting is created, ideally encouraging relaxed and focused learning. Above the datum level on the other hand, a less weighty and more modern material composition encloses the computer Centre and library space. Through this more advanced construction, it is intended to convey the importance and perhaps security of these upper spaces.





Following the 'second' line of site geometry and located above the material datum level, the library and computer Centre are publicly accessed via a 'bridge' that runs between the lower semi public vegetable garden/'green house' and public courtyard. This bridge not only provides a clear and visible view of who enters this more secured space but additionally acts to carry the incoming distilled water and waste pipes. Together this bridge and service route create a 'physical boundary' between these two spaces which has in itself been designed to incorporate a series of panels that slide along this line, allowing day time 'permeability' and night time securement.

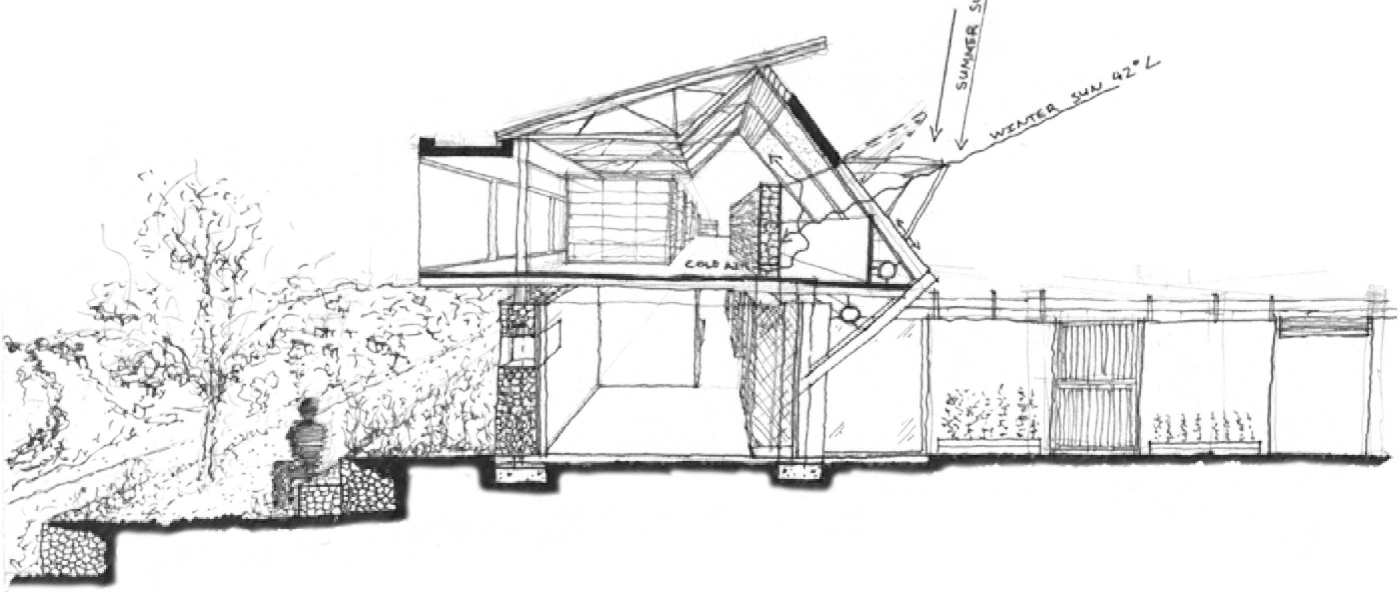
Technical Design Approach and Material Use

Having established suitable locations for the varying programmes, using thus far, largely massed elements to represent built forms, the architectural and passive solar design of these forms themselves was undertaken. From previous considerations for solar orientation as well as the establishment of these two different levels and material 'datum', the typical way in which these built elements would be designed was further explored. In relation to the different solar angles during the year, the building has been designed to passively cool and heat itself. In this approach careful consideration was given to the roof and walls of these spaces which were designed as follows:

Roof In the initial stages, when determining the angle and type of roof, it was decided to orientate the north facing side at 45 degrees, perpendicular to the winter sun. Facing the roof (which thermally contributes most of a buildings solar heat gain) in this direction and angle theoretically allows for increased solar heat gain during winter and minimal solar hear gain in summer allowing the roof plain to remain a relatively constant temperature throughout the year. Although strategically orientated the roof itself needs to be of a suitable insulating and watertight material. Although not thermally insulating, it was decided to use corrugated sheeting due to its ease of access, functionality, comparatively low price and contextual material similarity. In this case, a cheap and local product known as 'craftlok' is used. In order to achieve the desired insulation of the roof plain, solar panels were integrated as a means to not only absorb solar heat gain and insulate the roof but convert this energy into electricity, giving 'free' power to the Centre and possibly this entire alternative infrastructural system.

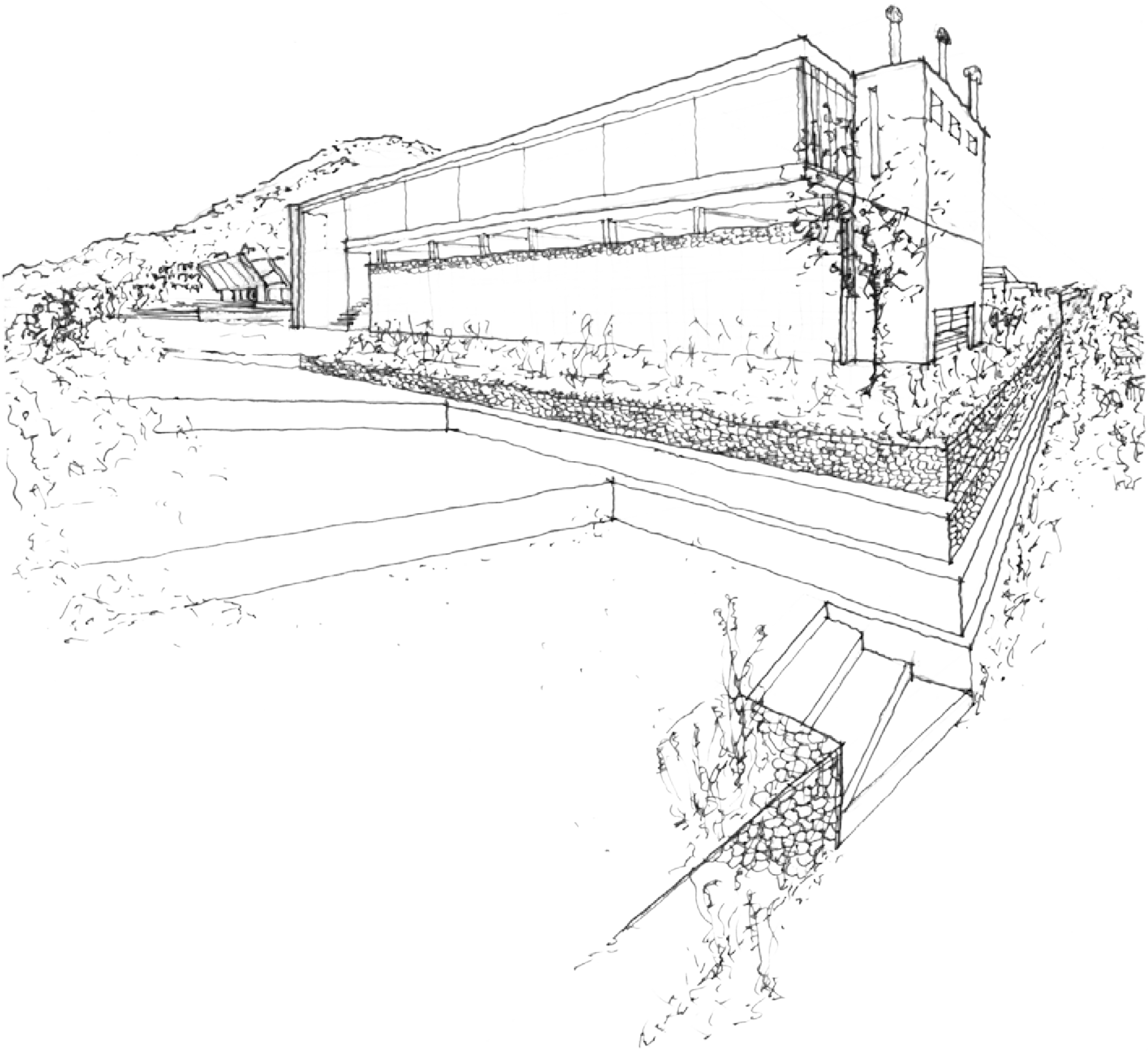
As shown in the initial sketches, the north side of the roof inadvertently formed the upper north facade. With this it was decided to locate the incoming water pipes at the base of this roof where they can be accessed from both the upper and lower floor. With this a perpendicular return was made back to the building which provided support for these pipes. It was however soon realized that this is an in efficient use of this northern facade and instead this 45 degree return was turned into a window, where reflected light and an over looking view of the vegetable garden was gained, in essence providing the library space with a framed downward facing and rather intimate view of the vegetable garden. (As shown below).

On the South side, a lower pitch of 15 degrees enabled this high ceiling space to slowly lead down to this 'framed' view. In the development of this upper South facade both the view and indirect south light went hand in hand, creating well lit space with a river view further promoting this location as a library and space of learning. Largely insulated and better regulated , the roof plain is believed to provide an important thermal regulation of this now roofed library space.

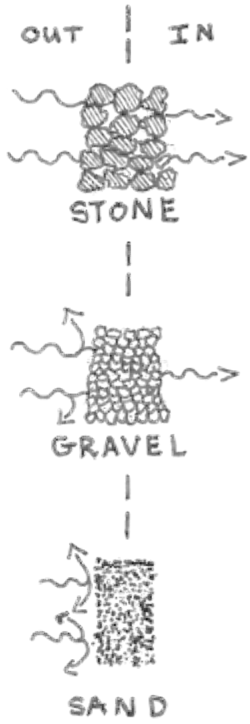


Having selected an appropriate roofing material(s) that assists with internal temperature regulation, the next step involved the selection of the secondary structure that would hold the sheeting and solar panels. In order to further minimize heat gain through the roof, a more insulating and comparatively less thermally conductive material was chosen. In contrast to steel, timber was chosen as this secondary structural material. Aside from its comparatively low carbon foot print, timber is one of the few widely used building materials that is able to store carbon dioxide. In more recent years, in places such as Switzerland, the use of timber as a building material has been highly encouraged due to this fact and where buildings receive certificates for the amount of carbon that they store within their built timber structure.

*Carbon store refers to the amount of carbon dioxide that a tree typically photosynthesizes within its life cycle, where it uses and stores this environmentally harmful gas.



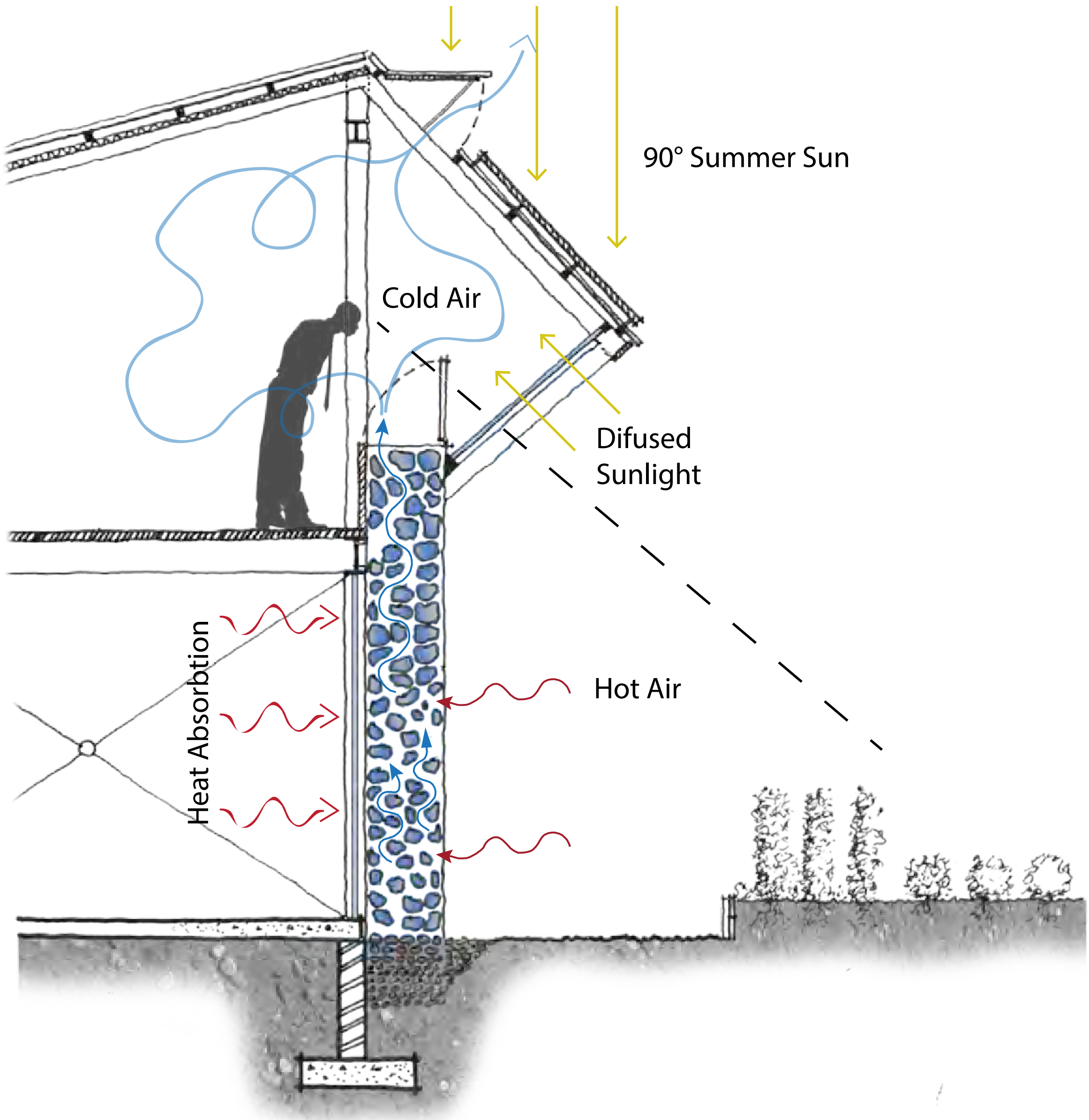
Walls As previously mentioned, stone/ gabion walls, that would typically be constructed from in-situ materials have been designed in such a way as to use these materials thermal properties to strategically locate either of these grades of material across the north-south axis. As will now be explained, larger gabion walls were located on the northern facade where rammed earth walls are located on the South Facade.



North Walls

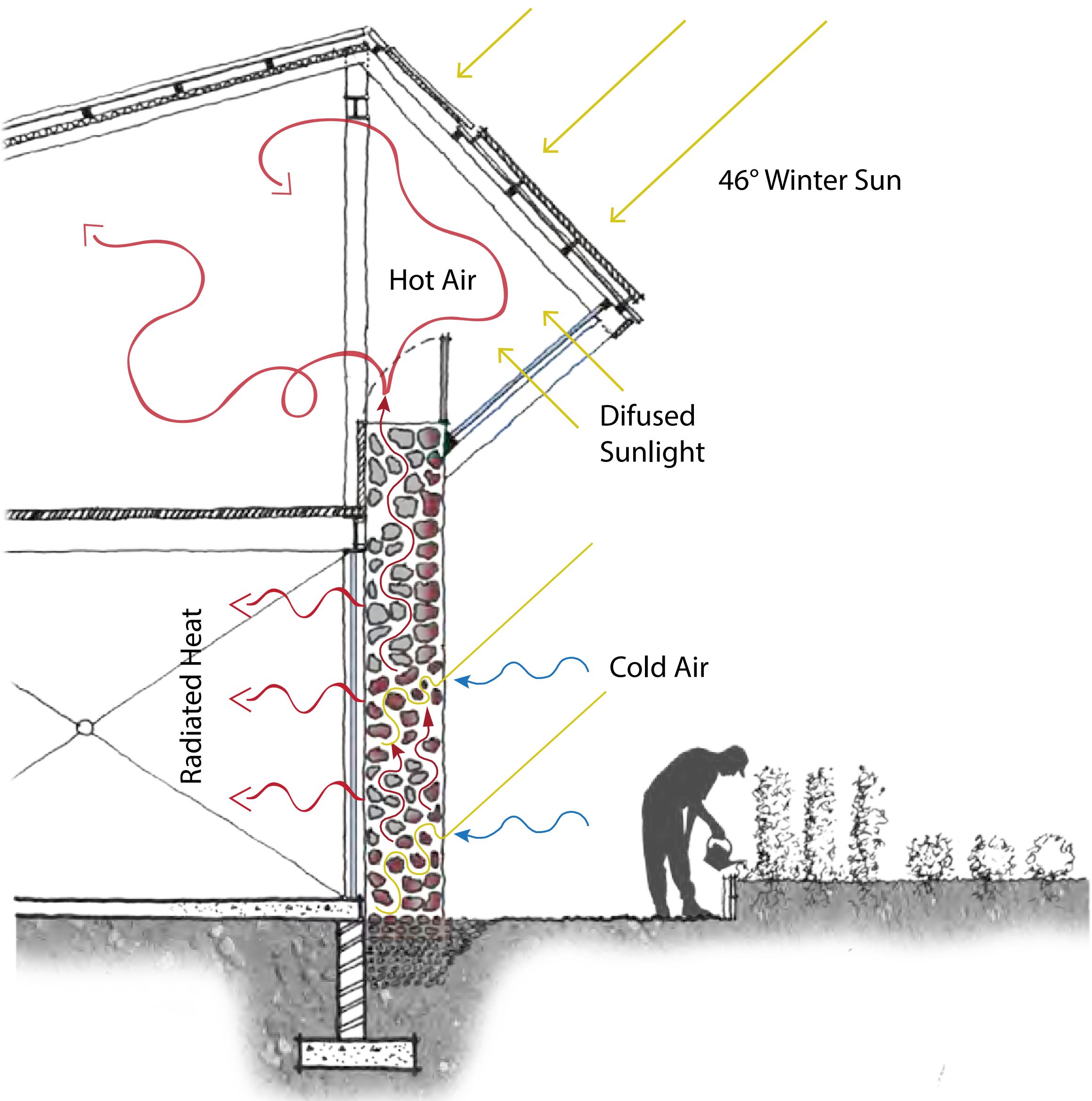
Rising above the stone 'datum' level these thick larger stone gabion walls are constructed on the northern outer edge of the primary steel frame where they are used as natural ventilation shafts for both the ground floor classrooms and upstairs library space. The way in which this passive ventilation and cooling system works is as follows:

In summer, when the mid day sun rises to a 90 degree angle, the large northern overhangs provide shading for these stone elements. Receiving no direct solar heating, these stones maintain a cool and stable day and night temperature. Acting as a large air conditioning box, these cool stone elements cool any passing air that makes its way up these natural ventilation shafts. It is important to note the flue effect that is created is only effective when sufficient air is allowed to flow out at a higher point. In this case, as shown below, air is allowed to exit and induce this vertical air cooling and movement through an openable vent located near the apex of the roof.



SUMMER

On the other hand, in winter, when the mid-day sun is at a 46 degree angle, these stone elements are exposed to full solar heat gain where through the day they heat up. In this heating, a natural flue effect is created by the rising convection currents created between the stones and within the gabion wall. This air theoretically continues to rise through the wall into the library space where it heats the internal air, increasing the temperature within the space. This not only acts to thermally regulate the internal air temperature but allow for natural ventilation without the need to open a window, something that may prove useful in winter when night time temperatures fall to as low as -5 degrees Celsius. When winter temperatures such as this are experienced, the opening at the top of these shafts can simply be closed. This prevents any cold night air from passing over the heated stones into the building. In addition, this closeable and controlled method of temperature regulation minimizes the rate at which this thermally massed heat dissipates at night. Although larger stones, that can potentially retain more heat are seen to be the most effective grade of site material, sufficient thermal testing with smaller stones of even gravel may prove otherwise.



WINTER

South Walls

As shown in the design of the upper level south facing roof, focused was given to the view down the river and to the incoming south light. Although generally the colder side of a building, it is believed that this roof space is sufficiently thermally regulated by both a well insulated roof and natural ventilation system, thus substantiating why in fact this upper south side is merely 'insulated' by glass and why it has been treated differently to the ground floor which will now be explained.

With reference to using these materials thermal massing properties, this lower south facade is the sight of a large rammed earth wall. Ending at the stone 'datum' level, this wall plane continues as a high level window where it allows south light into the space. This space is to form a workshop and administrative area, both of which work out onto the vegetable garden and away from the colder, yet well insulated south facade. As previously mentioned, rammed earth walling can provide the necessary insulation that this colder side needs while using nothing more than on site material. Although a rammed earth wall is desired, earth, as shown in Addendum D can encompass many forms of construction including that of Adobe bricks. Although not mentioned or analyzed, the information within this addendum has been inserted due to its simplistic and well illustrated methods of working with earth material. This addendum and book in particular draws reference to a more simple and somewhat rural method of construction which may prove useful when teaching or demonstrating these methods to members of this community who may be involved in constructing the Agricultural learning Centre. Information such as this would ideally be accessible from the library once it is built, where this information and methods of simple and natural construction may start to influence the existing typology.

It is at this point were reference is made to Addendum C which displays the latest design work of this establishment in the form of a computer aided three dimensional model. This model has acted as a useful tool in the design of this Centre, specifically when working with the sites irregular topography and scale. Drawing reference to each aspect of part 5, addendum C displays a more resolved and perhaps clearer understanding of the design of both the upper and lower floors of the Centre which can be viewed following the conclusion of this dissertation.

Conclusion

In comparison to the millennia that we have existed on this earth, mankind is only just beginning to realise his impact on the natural environments in which a transition from conventional forms of design to ecologically sound forms of designing has begun to occur.

Upon an analysis of KIS through an ecological lens and an understanding of ecological design it is clear that the issue of biological waste and the relationship between man and his environment cannot be resolved or re-established through mere architectural intervention alone, nor through a top-down policy driven approach but perhaps through a fully integrated and alternative infrastructural system that blurs the boundary between architecture and infrastructure.

Although the issue of biological waste contamination within the natural environment of KIS has occurred partly through the lack of infrastructural provision and poor spatial organization, it is in fact rooted in the way modern society has developed in which nature has been excluded, forgotten and as a result polluted. In order to mend this relationship and to re-establish the importance of the natural environment within the city this Agriculcural Centre has been designed to not only serve the river and its edges but be designed in such a way as to celebrate the river for its existance as nature. Through this celebration, society can begin to reconnect with nature and all that it has to offer which in the case of this agricultural Centre includes the on site natural materials.

Through this connection, the river and its edges can begin to create a new type of urban condition, one in which culture, individuality and community are acknowledged as important aspects of the human condition and one where multiple programmes exist while maintaining their contextual assignment. Through a socially based form of intervention, communal participation and governance can establish ownership which as seen in VPUU can path the way to better livelihoods and sustainable ways of living, in which poverty is minimized and where nature and natural materials become ingrained as a valuable and respected element of KIS's physical make-up.

Through the exploration and understanding of how on site building materials can be thermally advantageous, and passively designed into a building, it can be concluded that although this method may be time consuming, it is a method that encompasses both a low embodied energy and simplistic construction deeming this technology suitable for KIS and its contexts. Through the exploration of the natural processes of wastewater and human waste treatment as well as through gabion structure earth retaining and 'natural' walling systems, it is evident that these technologies are more complex and require more attention to design and detailing than one might think, and which will be taken through into the final stages of design of this Centre. For this reason it can be concluded that although there is a great potential for their integration along the river's edge, they are prone to failure if not properly located, designed, engineered and maintained. As with any naturally functioning system, technologies such as wastewater and human waste treatment must be integrated not only into the physical landscape, but into the social and communal aspects of this context which can ensure the sustainment and effectiveness of this technology in minimizing the negative impacts that society has on the natural environments of the city. Through the effective establishment of this alternative infrastructural system, this method of processing waste and managing landscapes has the potential to become the next step in Windhoek's management of its natural ecosystems and water which can see the future city as one which symbiotically exists with nature.

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- **Addendum C**: All information contained within Addendum C has been photocopied from the Book 'The Barefoot Architect' by Johann Van Lengen, and adapted in photoshop to display four pages per A4 page. (Van Lengen, J. 2008. The Barefoot Architect. California: Shelter Publications Inc.)

List of Figures

Please Note: Images and diagrams that are not labeled are self-drawn and photo shopped using information and data acquired from both the City of Windhoek: Planning Department and Google Maps. 2016. Available: https://www.google.co.za/maps/@-22.5101326,17.0452043,13314m/data=!3m1!1e3?hl=en [2016].

ADDENDUM A: Aerial Photographs**:** Credit to Kelt Elves from 'Drone Photography Namibia'. 2016.

This Addendum is attached in support of part 3 where an analysis of site is conducted through multiple layers.

Upon a site visit to Namibia in both April and July, it was decided that an aerial view of the site may prove usefull in getting to know the site better. As primary research and public engagement does not form part of this thesis, this aerial view provided a better understanding and view of the conditions of the landscape and more private spaces, something that Google earth could not provide.

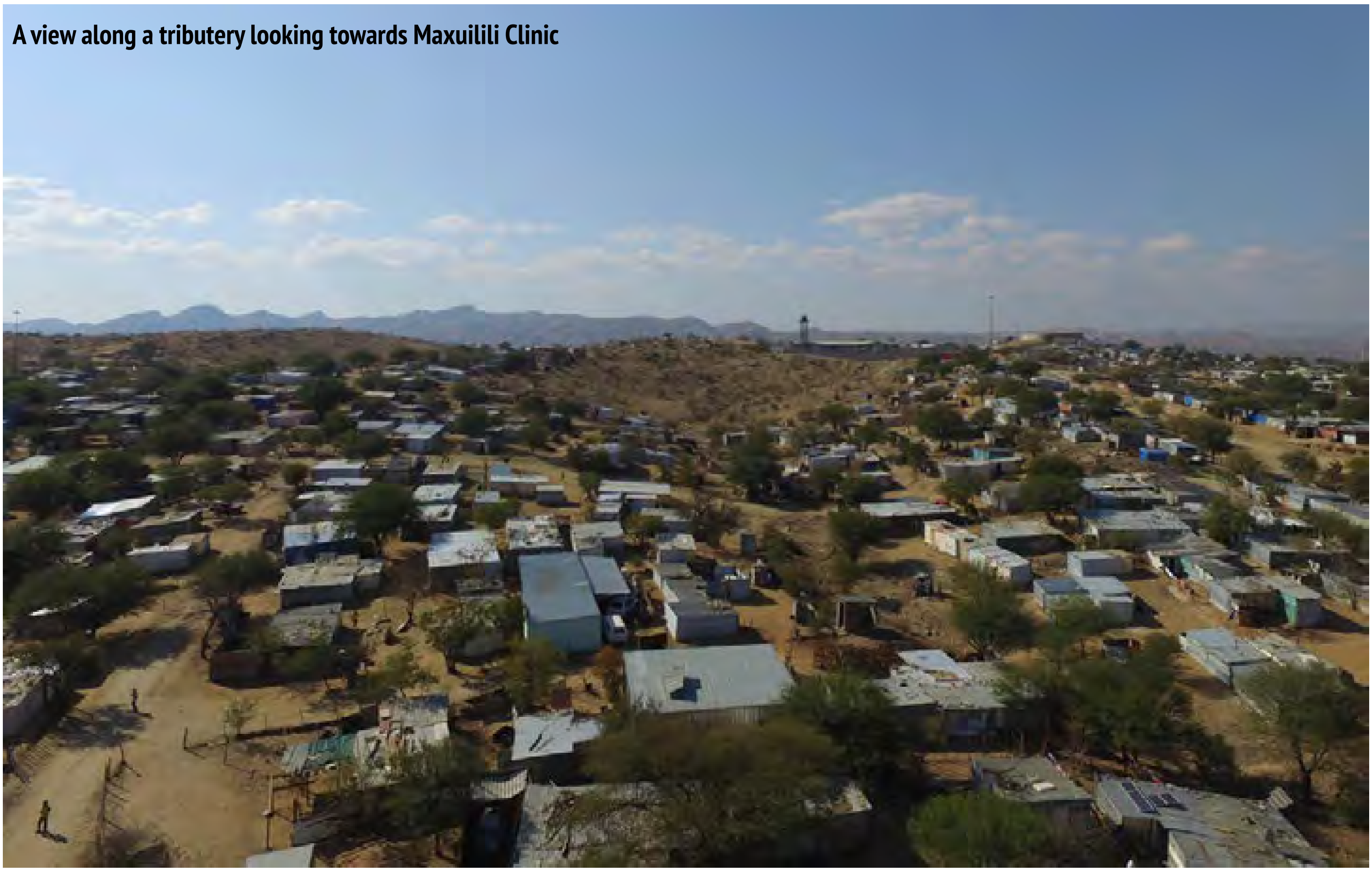
South West View down the main road

South West View down a tributary. In this photo one can notice the extent of informal toilets along this route. Although it is believed some are connected to the current over flowing sewer.

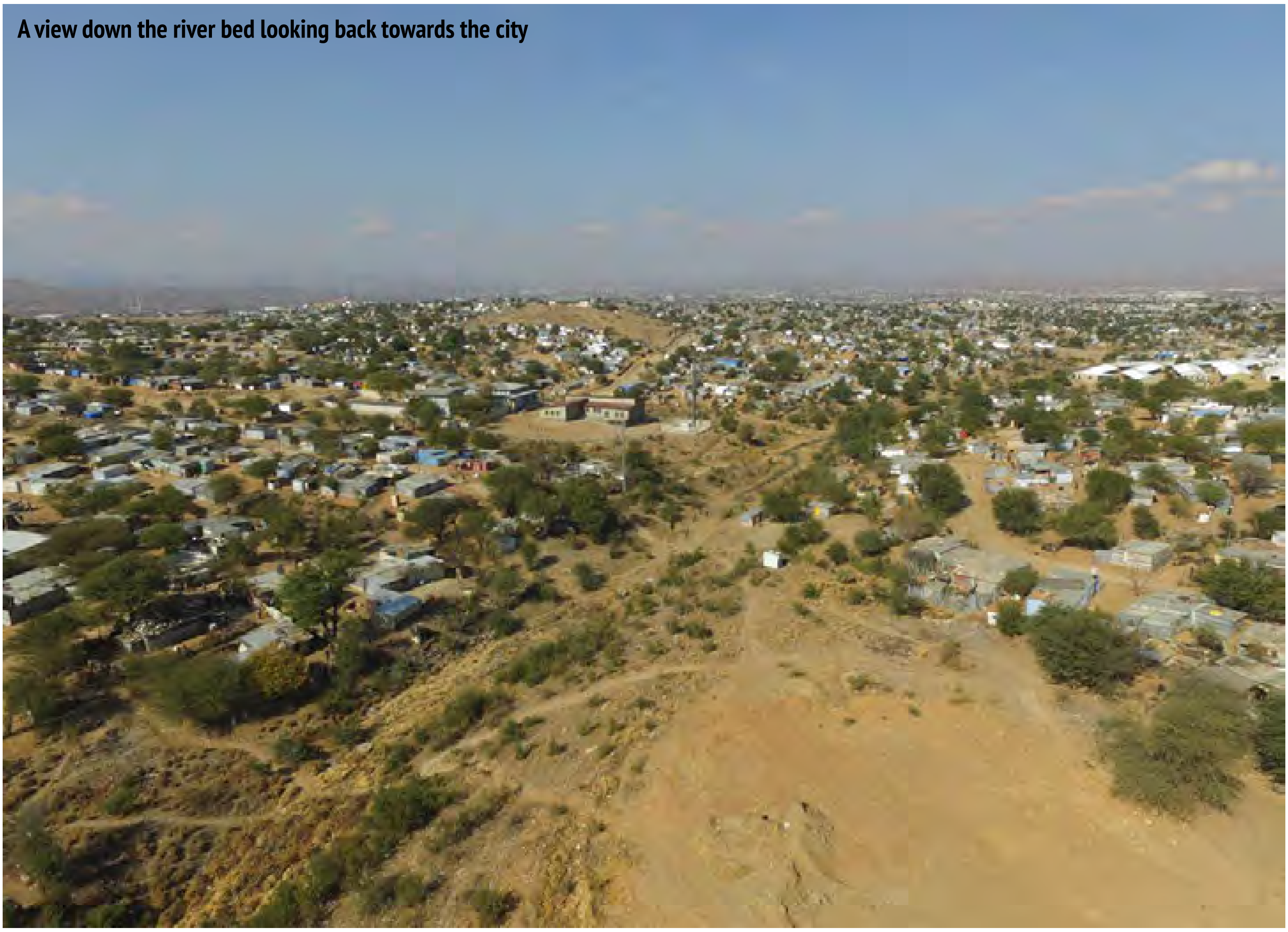
North West View down the main road

Westerly view of site and bordering mountain. As was later discovered, this mountain is in fact the 'Kilimanjaro' of this settlement and name.

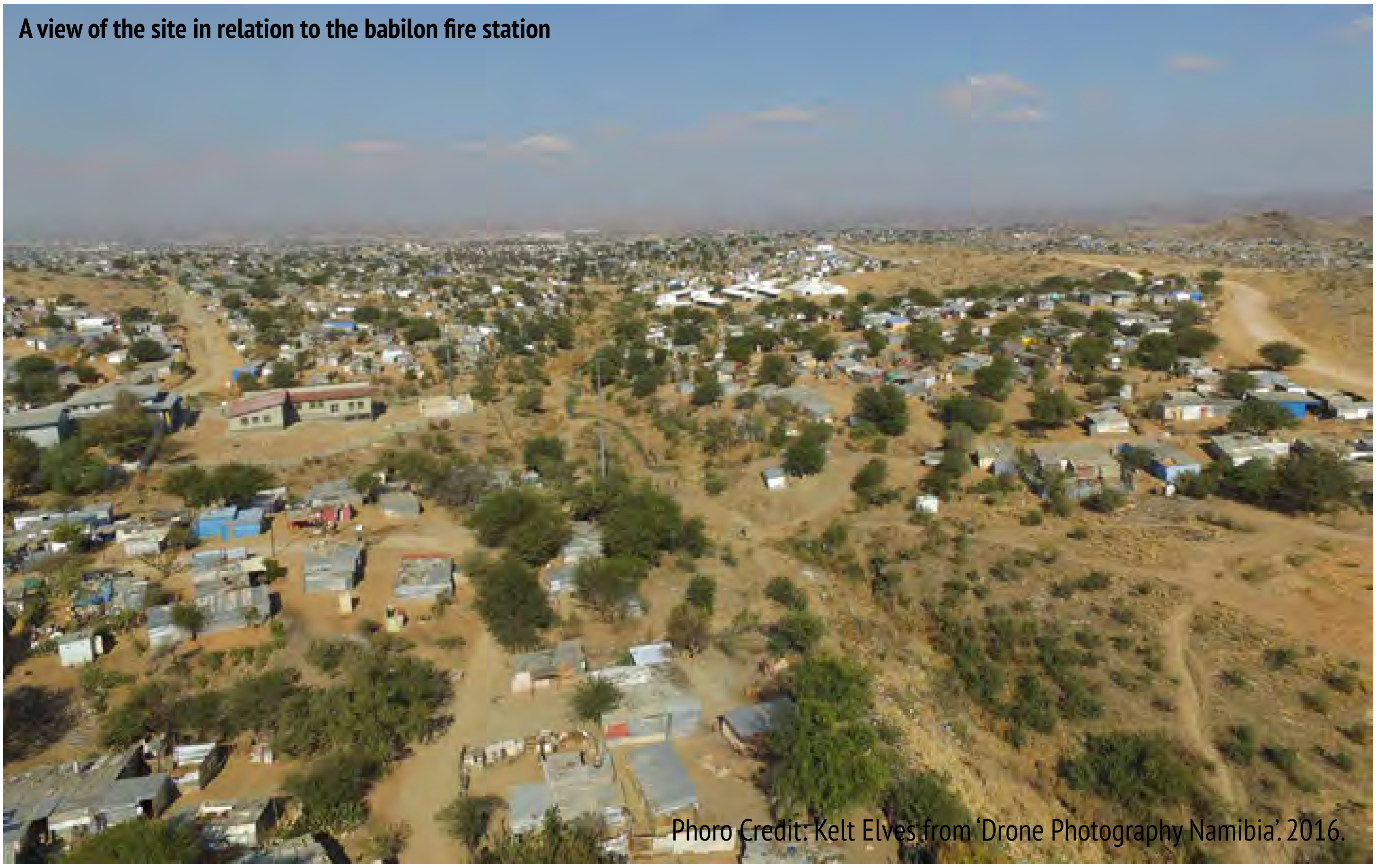
A view of the nearby church in relation to the selected site



A view along a tributery looking towards Maxuilili Clinic



A view down the river bed looking back towards the city



A view of the site in relation to the babilon fire station

Phoro Credit: Kelt Elves from 'Drone Photography Namibia'. 2016.

Site Photos: July 2016

Approaching Site View

Leaving Site View


The top end view of the proposed pedestrian corridor


Litter within the riverbed


Bottom end view of the proposed pedestrian corridor


View looking towards the nearby Church


One of the locations for the proposed ‘Urban Water Collectors’.


Inside the nearby Church

ADDENDUM B: Photographs of both the 1: 500 contour model.

This addendum is attached in support of part 5, where the tangibility of this model enabled a more sensitive and realistic approach to design and site development.

A Southern end view of the conceptual cut

A rivers view of the church, reedbeds and Agri Centre. Seen in this image, the water reticulation pipes from the reedbeds


‘Urban Water Collectors’ situated at the base of the tributaries. where they collect wastewater from the ‘many’ service hubs’.


Northward view up the River taken from the ‘Babilon Fire Station’.

ADDENDUM C: Extract from '*The barefoot Architect*' by Johan Van Lengen. Pages 298 -313.

This addendum is attached in support of part 5, where earth material is exacted on site. The information and illustrations contained within show the many other methods in which earth can be used as a building material.

EARTH

MATERIAL TESTS

Almost all types of earth can be used to build walls, such as adobe brick, and wattle and daub walls. The quality of the earth is determined by the proportion of clay to sand. There are many types of earth in the composition of an earth sample. It is often necessary to combine earth from one area with some from another part of the site, even when the lot is small. A rich earth which has a lot of clay needs to be balanced out with sand, and a poor earth needs to be enriched with clay.

To know if a soil is adequate for adobe bricks try the tests below:

Several points on a site need to excavated to perform these tests. First remove the upper layer of earth that contains organic material and vegetation. Then remove samples of earth from different depths.

TESTS

COLOR	dark (oily) white (sandy)	not good for adobe bricks
	red brown	can be used for adobe bricks
	light yellow	best for adobe bricks
ODOR	do not use earth that smells moldy since it has vegetal matter	
TEXTURE	if it does not grind, it has a lot of clay if it grinds a bit, it has a lot of mud if it grinds a lot, it has a lot of sand	

SEDIMENTATION

1. Fill ⅔ of a cylinder glass cup with earth. Add water to the top and 2 teaspoons of salt. The salt helps to separate the parts of clay and sand.

2. Stir the contents vigorously for a few minutes.

3. Watch the parts separate.

4. If the separation is not very clear, stir it again and let it sit for a few hours.

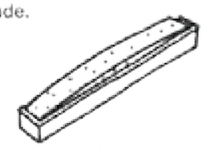
5. If the separation is clear, measure the proportion of clay to sand (for example, here the proportion is 2 to 1).

SHRINKAGE

The next step is to make a malleable mixture to pour into a test mold of 4cm x 4cm x 40cm.

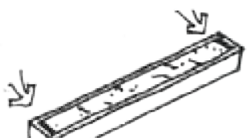
Leave the filled box to dry in the shade.

If the mixture curves in the center like a rising cake, it is not to be used and another type of earth should be found.



Normally the earth should shrink and crack. Push the whole block to one side and measure the size of the shrinkage.

The mixture should shrink more than 1/10 of the whole length, so in this case, 4cm.



TEST STRIP

Knead the earth with water and make a 20cm-long, 5cm-wide and 2.50cm-thick strip. Push down on the end of the strip, pushing it forward out of your hand with the thumb to see when it breaks.

If it breaks before reaching 5cm of length, it is too sandy.

If it breaks after 15cm, it has a lot of clay.

If the strip breaks between 5 and 15cm, it is good for making adobe bricks.

Now make some adobe bricks to test their strength:

To make an adobe brick which is resistant to humidity, you can cover it with tar or apply burnt oil instead, using only half the quantity of tar. The best solution is to use small quantities of manure. Straw, grass or pine needles can also be added to the adobe mixture.

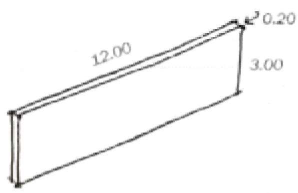
If the quantity of sand is equal to or up to two times greater than the amount of clay, the earth is good for adobe construction without adding sand or clay.

When the earth is not adequate, follow the table below to adjust proportions:

MATERIAL	PROPORTION
sand	4-8 parts
clay	4 parts
water	4 parts

The recipe of this mixture must be adjusted for each type of earth, but the basic recipe remains the same.

The proportions for a wall that is 20cm thick, 3m high and 12m long using a 20-liter bucket, for example, are the following:



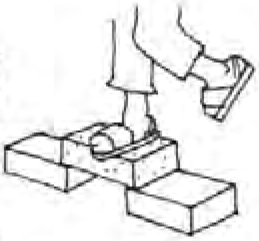
After the mixture has been stirred, it should have a uniform texture and color without marble-like streaks of different colors.

302 MATERIALS

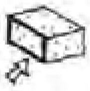
TESTING THE ADOBE BRICKS

To test the adobe bricks to know if they are strong enough to use for construction, do the following test:

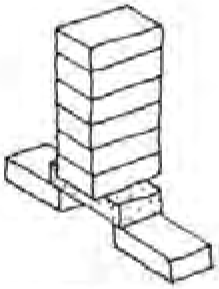
1 Place an adobe brick on top of two others spaced apart and step on it heavily. It should bear the weight without breaking.



2 Soak a whole adobe brick in water for 4 hours. Then break it in half and measure the thickness of the dampened surface. It should not be greater than 1cm.



3 Soak another whole adobe brick in water for 4 hours and place it on top of two other ones spaced apart. Pile up 6 other adobe bricks on top of it. The adobe brick being tested should withstand the weight for at least 1 minute before breaking.



When adobe bricks do not pass the test, the recipe mixture should be adjusted or be used for interior, non-structural brick walls.

MATERIALS 303

PREPARING THE EARTH

Horse or mule manure, when available, should be mixed with cut straw and added to the adobe mixture. The manure increases the durability of the adobe, since it is resistant to humidity and erosion over time. Also the manure deters termites and assassin bugs from penetrating earth walls.

Find the place where the best earth is found, then:

1 Excavate the earth.

2 Cover the approximately 30cms high earth mound with straw.

3 Put on a 10cm layer of sand and 5cm of dry manure.

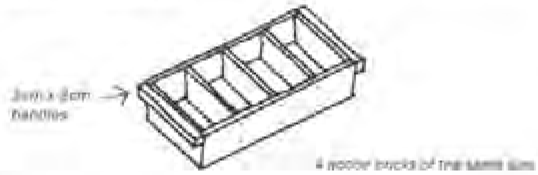
4 Remove one or two wheelbarrows, add water and mix.

5 Mix all the materials together by treading with the bare feet.

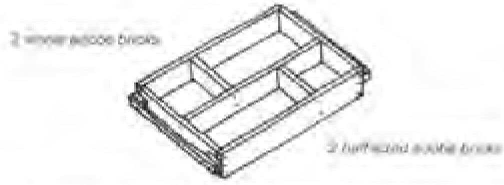
304 MATERIALS

MOLDS

Adobe bricks can have many dimensions. The most common sizes are: 5cm x 10cm x 20cm, 8cm x 10cm x 40cm, and 10cm x 15cm x 30cm. The molds can be made with wood or metal. At the ends, add handles to facilitate carrying.



The wood used for the molds should be clean and smooth. Make the mold impermeable by applying a layer of burnt oil or a mixture of tar and oil or kerosene.



When the adobe bricks are thinner, a mold can be made for 2 whole bricks and 2 half-sized bricks.

THE MIXTURE

Let the mixture settle with a little bit of water for 3 days to cure. Then add more water until it is malleable enough to place into the molds.

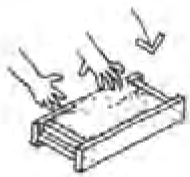
MATERIALS 305

- The adobe bricks should maintain the shape of the mold. If they bulge, there is too much water in the mixture.
- If one part of the brick sticks to the side of the mold, there is not enough water in the mixture.

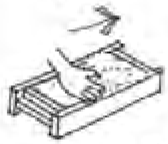
MOLDING THE ADOBE BRICKS

1 Wet the molds with water.

2 Shovel the mixture, throwing it well into the corners.

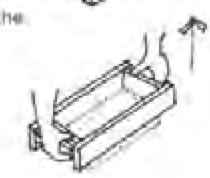


3 Add more of the mixture, and level out the top.



4 Wet your hands, and smooth out the top surface.

5 Remove the mold carefully.



6 Let the brick dry for 1 or 2 days, depending on the weather.

7 Let the bricks harden for 20 days before using them.

The Barefoot Architect. (Van Lengen, 2008 :298-305)

DRYING THE ADOBE BRICKS

The adobe bricks should not be left out in the sun to dry. If there is not a shaded place to dry them, cover them with leaves and wet them every once in a while.

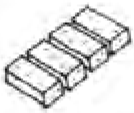
When they have dried, line them up in rows that are spaced to aerate. Leave them in this position for some days, depending on the local humidity.

It is always better to dry out the bricks slowly to prevent splitting or deformations.

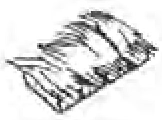
with splitting the brick breaks

with deformations the brick curves

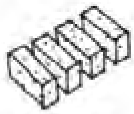
In dry climates, the bricks must be watered in the afternoon so that they dry overnight. Also sprinkle them with water every once in a while or cover them with straw. Two days after they are removed from their molds, they should be turned to the side as illustrated below.



drying position



covered with straw

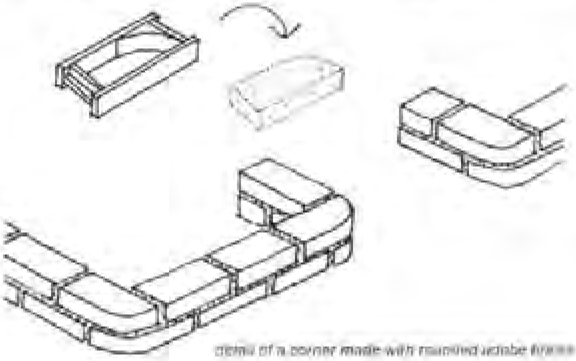


turned to the side

Round adobe bricks can be made for the corners of walls, including those around the doors and windows. These curves create a beautifully shaped house.

MOLDS FOR ROUNDED ADOBE BRICKS

Corners of walls made with adobe bricks are especially susceptible to breaking from impacts or the effects of the climate. Consider making the corners round to diminish the fragility of exposed corners. To make rounded bricks that fit together well, the proportion between the length and the width of the other bricks should be 2:1.

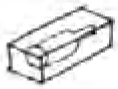


detail of a corner made with rounded adobe bricks

ADDING DISCARDED MATERIALS

Lighter-weight adobe bricks can be made by adding discarded materials inside the bricks, such as cans, bottles, milk cartons, and corncobs.

cans



bottles

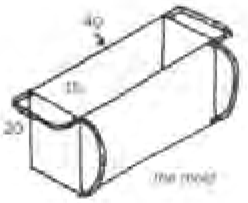
cartons

corncobs

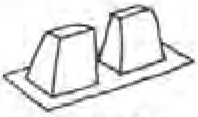
EARTH-CEMENT BRICKS

Stronger as well as hollow bricks can be made with an earth-cement mixture and metal molds.

The mold is made with sheet metal with rods welded to the sides as handles.



the mold



the internal mold

Use a heavy hardwood stick to press the mixture into the mold.

the wood stick

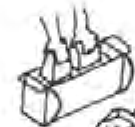
FABRICATION

area to mix and fill the molds

area to remove and dry the bricks

See chapter 10 for the proportions of the mixture.

1 Bring the molds to the area where the mixture is prepared. Place the internal mold inside the other one.

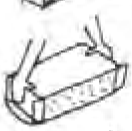


2 Fill the mold with the mixture using the stick and a shovel.

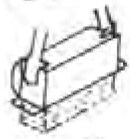
3 Hit firmly with the wood stick to make sure all the corners and spaces of the mold are filled.

4 Move the filled mold to the drying area.

5 Place the mold down. Turn the bricks that are already dry on their sides.



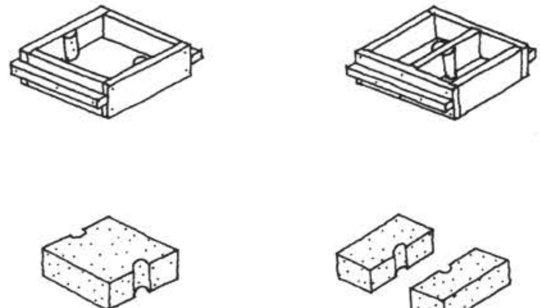
6 Turn over and remove the mold carefully.



7 Pull out the internal mold carefully.

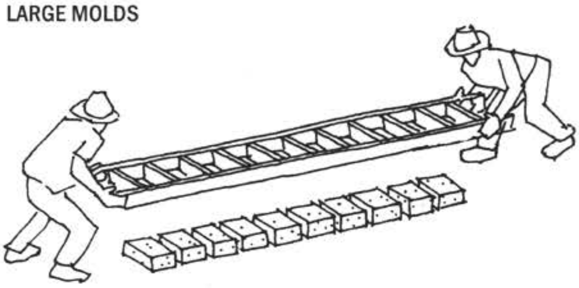
REINFORCED MOLDS

To make molds that are more resistant to the weight of the mixture, reinforce them with steel or wood rods. As shown below, the holes in the bricks are for the placement of the reinforcing.



The brick above is square since the four sides are the same dimension. Half-sized bricks can also be made.

LARGE MOLDS

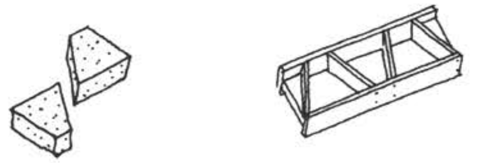


Large molds can make many bricks at once.

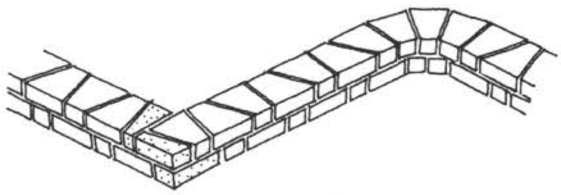
OTHER TYPES OF MOLDS

There are many other shapes of molds that can be made:

You can build a mold for trapezoid-shaped bricks where one side is longer than the other. The mold should have 3 or 4 brick spaces.



Adobe bricks shaped like this can be used to build walls with round corners.



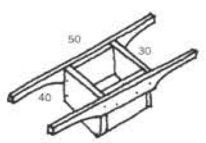
Square corners require half-sized bricks.

walls with rounded corners

To improve the quality of an earth, add cement by increasing proportions to 1 part cement for 12 parts earth. Lime can also be added to make a mixture of 1 part cement, 2 parts lime and 24 parts earth.

cement	lime	earth
1		12
1	2	24

When the earth is very sandy, the mixture can be improved using 1 part cement for 10 parts earth. Since cement irritates the skin, it should not be mixed with bare feet but with mechanical mixers.



inside dimensions of the measuring box

To the left is a measuring box with dimensions that facilitate making a proportional mixture. Ten of these boxes produce one cubic meter.

LIME AND CEMENT MIXTURE

6	boxes of sifted earth (8mm sieve)
1	bag of cement
2	bags of lime

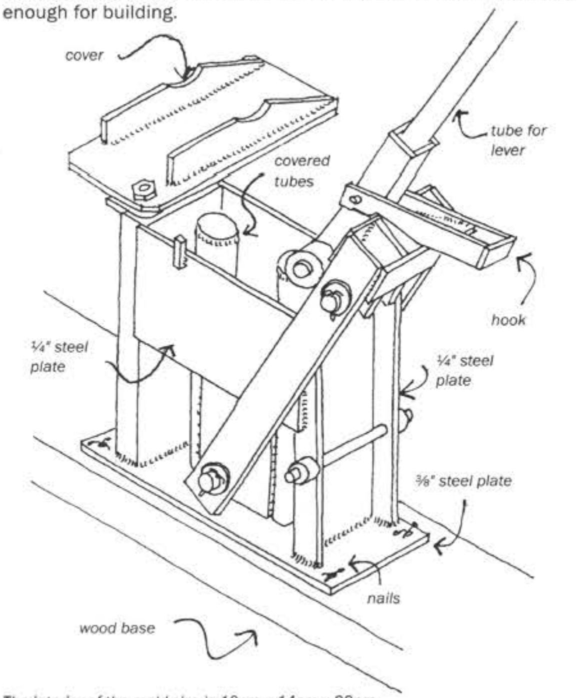
1 Prepare the dry earth and cement mixture.

2 Mix the lime with water.

3 With a watering can, add the water and lime to the earth-cement mixture.

BRICK PRESS

Build a brick press machine to make sandy earth into bricks strong enough for building.



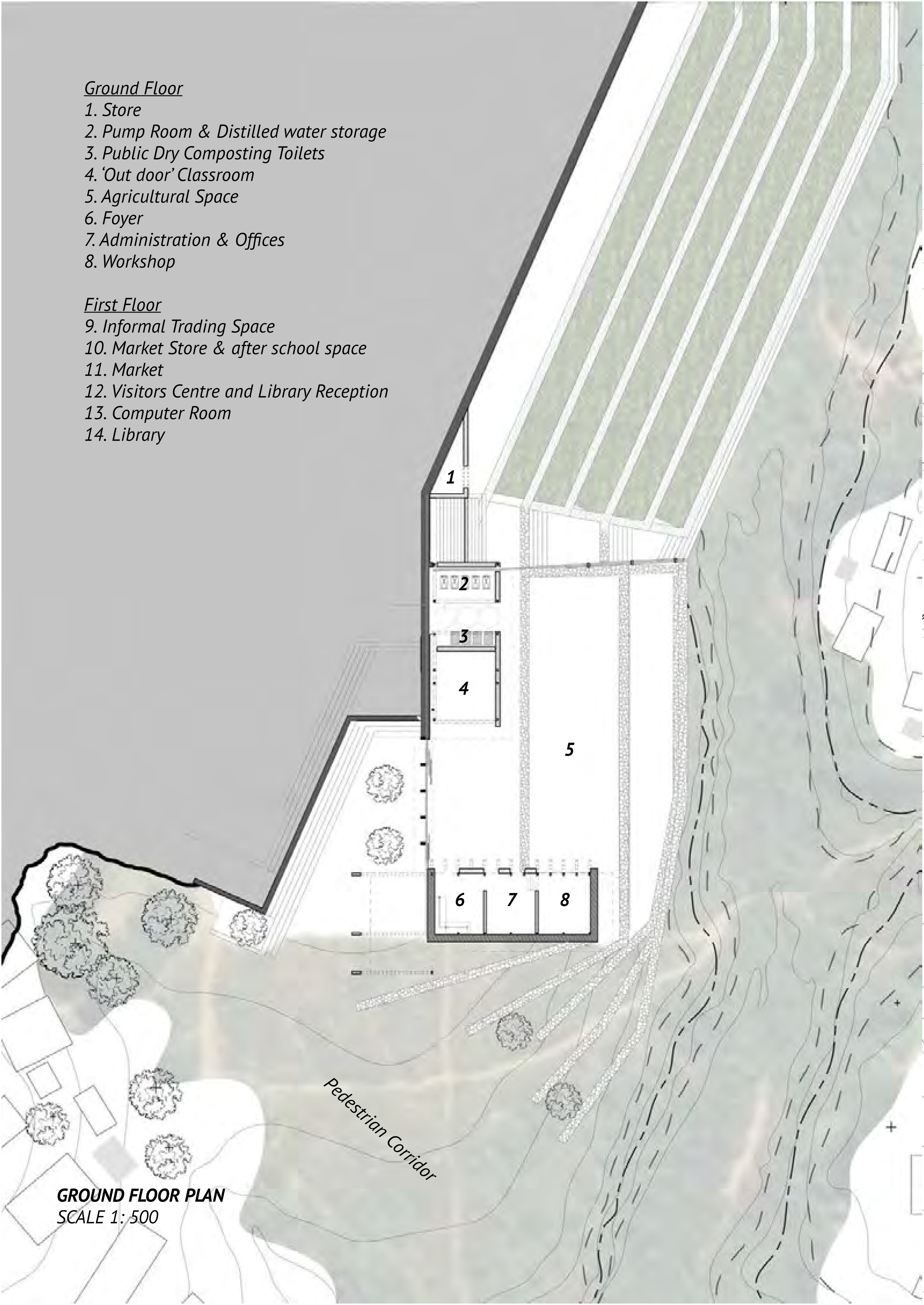
The interior of the mold size is 10cm x 14cm x 29cm.
The galvanized tubes have a 5cm diameter and are spaced 15cm center to center.

There are several types of machines available. The original and most well-known model is Inva-ram.

The Barefoot Architect. (Van Lengen, 2008 :306-313)

Ground Floor
1. Store
2. Pump Room & Distilled water storage
3. Public Dry Composting Toilets
4. 'Out door' Classroom
5. Agricultural Space
6. Foyer
7. Administration & Offices
8. Workshop

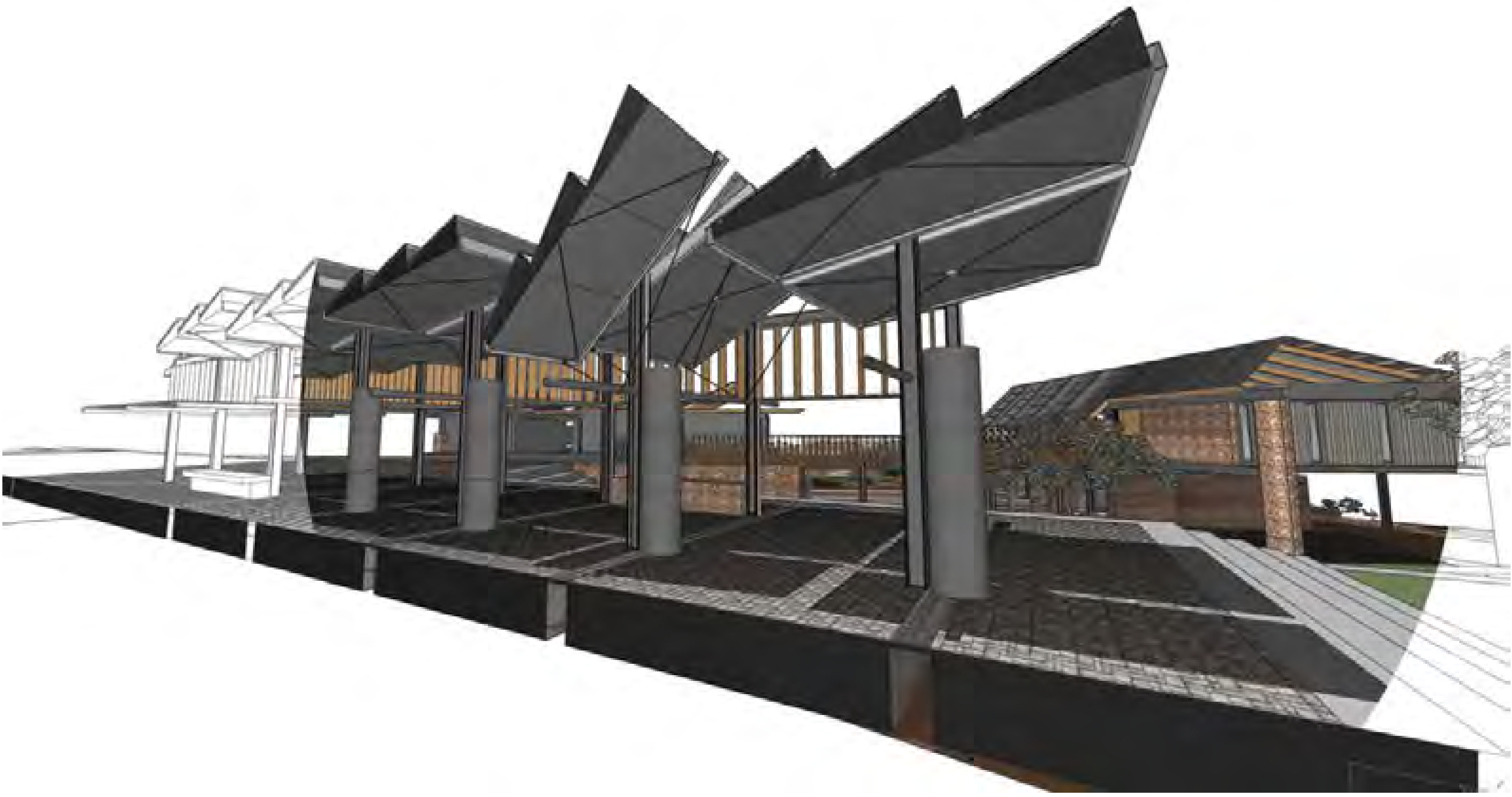
First Floor
9. Informal Trading Space
10. Market Store & after school space
11. Market
12. Visitors Centre and Library Reception
13. Computer Room
14. Library



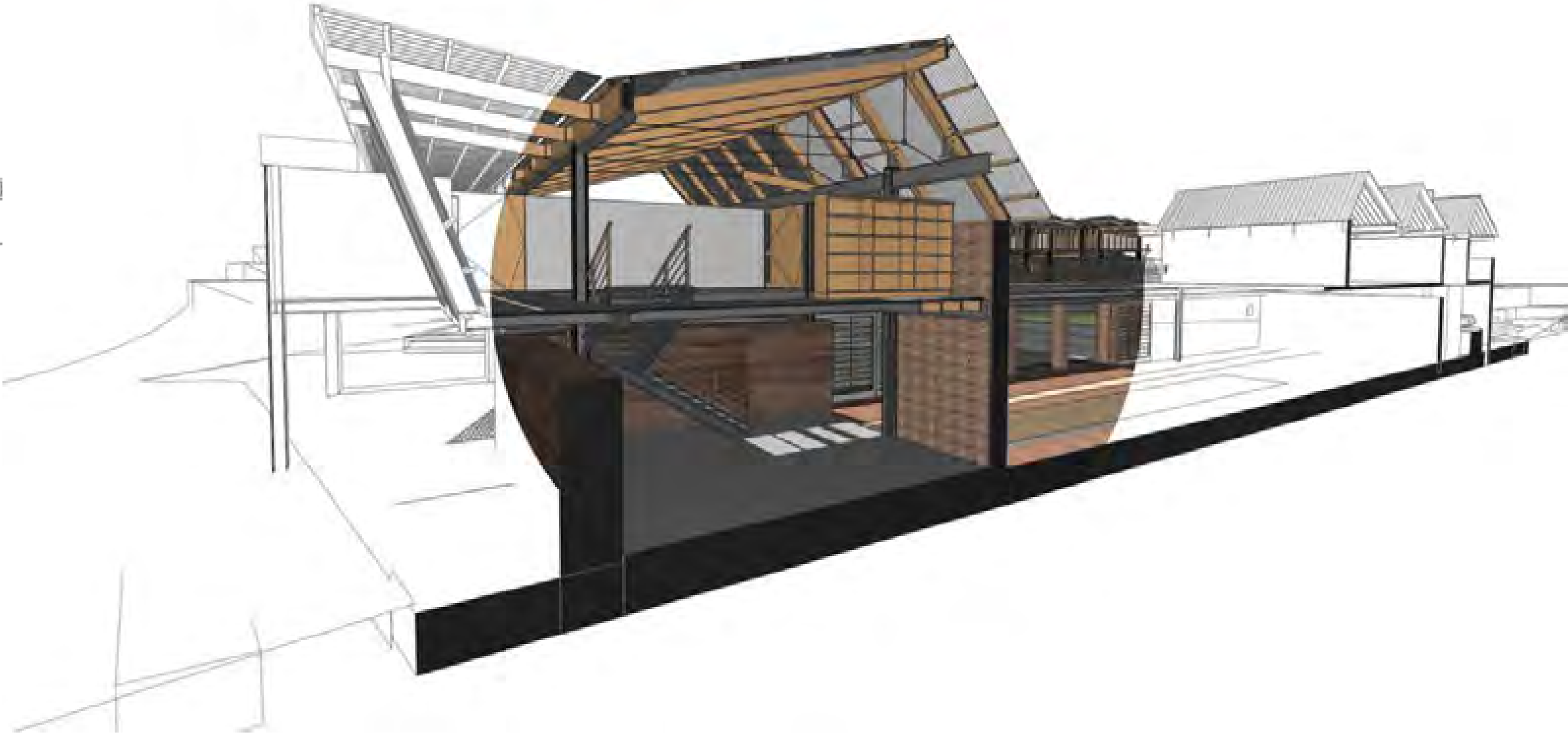
GROUND FLOOR PLAN
SCALE 1: 500

FIRST / STREET LEVEL FLOOR PLAN
SCALE 1: 500

South Facing Approach from Main Road

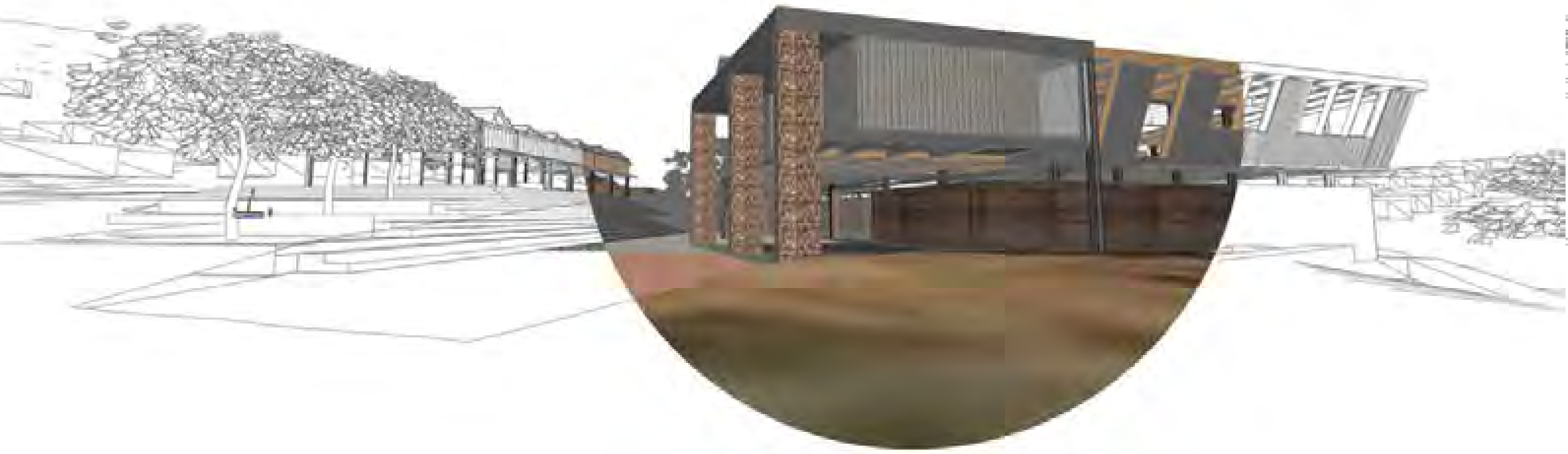


Sectional Perspective Through Market Space and Distillation Panels



Sectional Perspective Through Foyer and Library Space

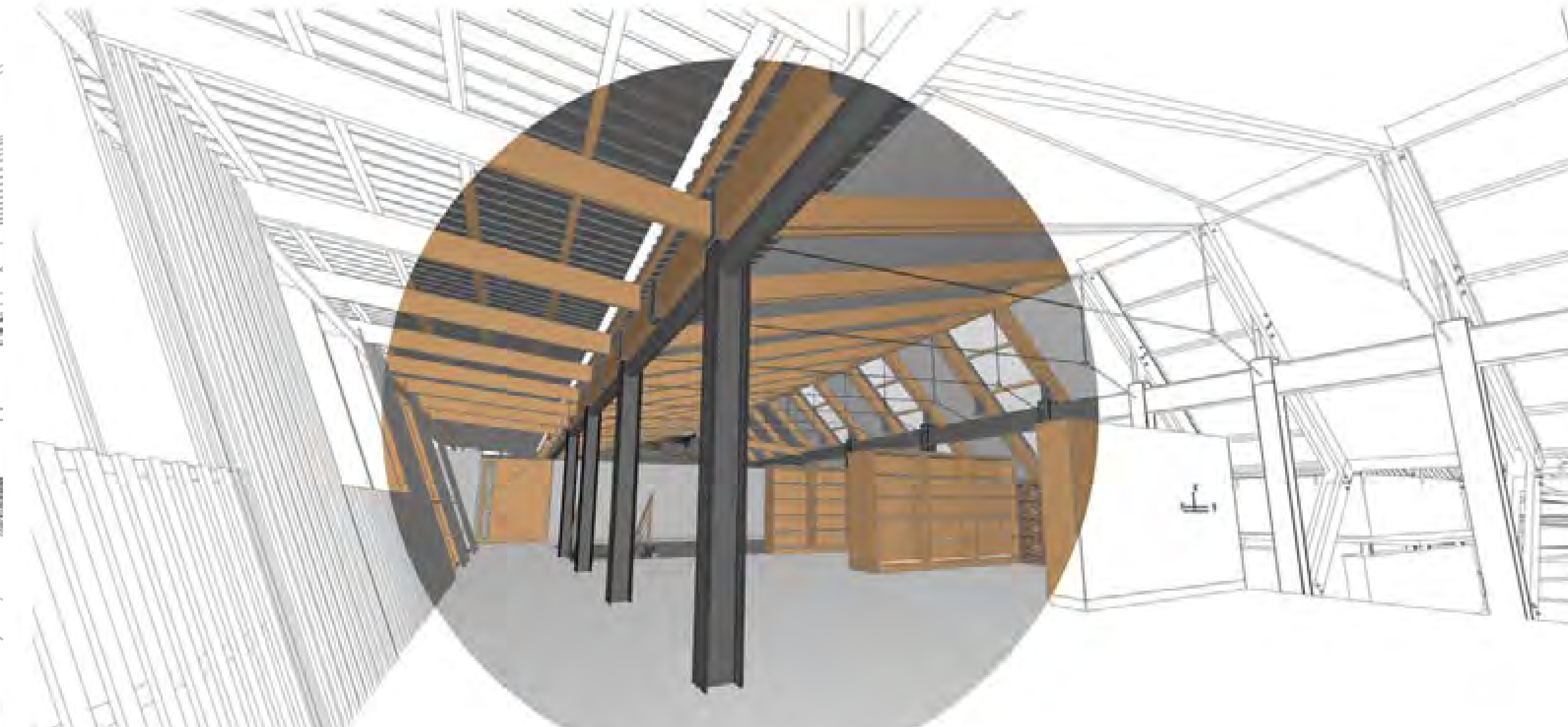
Sectional Perspective Through Amphitheatre and bridge



A view looking towards the Centre from the pedestrian corridor

A view standing below the adjustable solar distilation panels looking towards the Centre

View of vegetable garden and courtyard



View of Upper floor Library Space

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data.The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook**(available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/usr/ebe/research/ethics.pdf

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Kenneth Spencer Philip Main
Department		Architecture and Planning and Geomatics
Preferred email address of applicant:		kspmainis@gmail.com
If a Student	Your Degree: e.g., MSc, PhD, etc.,	M. Arch (Prof)
	Name of Supervisor (if supervised):	Dr. Matteo Fraschini
If this is a researchcontract, indicate the source of funding/sponsorship		N/A
Project Title		The River Edge: Architecture as a catalyst for Urban Rejuvenation

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Kenneth Main	signature removed	**15 Apr 2016**

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Click here to enter text. MATTEO FRASCHINI	signature removed	**15 Apr 2016**
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduateresearch (Including Honours).	TINA BERLANDA Click here to enter text.	signature removed	**15 Apr 2016**
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	Click here to enter text.		Click here to enter a date.

END