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Resilient Design Strategy: Engaging Amphibious Structures to Combat Flood in the Development of an Internally Displaced Persons Settlement Scheme in Nigeria

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Resilient Design Strategy: Engaging Amphibious Structures to Combat Flood in the Development of an Internally Displaced Persons Settlement Scheme in Nigeria

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Abstract. Flooding is a natural disaster that has been on the increase in many parts of the world. In the last two decades, this unforeseen destructive occurrence has led to the loss of millions of lives and properties valued at millions of dollars in many countries, including Nigeria. Though several attempts have been advanced as possible solutions to help curb the devastating consequences of flooding in the past, many of the solutions have proven not to be as effective as expected. This paper, examined the potentials amphibious structures present as a resilient strategy to combat flood, to develop an architectural design proposal of a sustainable Internally Displaced Persons (IDPs) settlement, that can withstand the peculiar challenges caused by flooding in Nigeria. The study adopted qualitative research approaches. Data consulted to develop the design proposal were assembled through random search of the internet from archival documents related to the subject and the data were analysed by thematic textual analysis. The findings were presented with texts, architectural two-dimensional and 3-dimensional drawings, tables and plates. Useful information from the analysed data became the conceptual framework on which the scheme was developed. The outcome of the study is the development of an architectural design scheme that utilised a combination of amphibious structures strategy and simple sustainable innovative design measures to proffer solution to an environmental problem, as well as the peculiar social, cultural and religious issues associated with the study area. The conceptual base on which the model was developed is for the settlement to co-exist with flood, rather than the common concept of resisting flood. Though the design was developed for a location in Girei, Adamawa State in the Northern part of Nigeria, the scheme is a useful guide for designing settlements and addressing issues in flood-prone areas in other parts of the globe, as well as a valuable educational material on issues pertaining to the development of settlements in flood-prone areas.

Key words: Amphibious Structures, Resilient Design, Flood, Internally Displaced Persons Sustainable Settlement and Nigeria.

1. Introduction

Flooding is a natural disaster and it is one of the earth's most occurring, widespread and damaging natural hazard. It typically occurs when there is an overflow of water on land that is normally dry [1]. It can also be described as the inundation of a geographical region that is not usually covered with water [2]. Flood occurrence can be due to a rise in the volume or capacity of water within a body of water, causing the water to overflow and submerge land forcefully [3]. Flood is a very devastating phenomenon that not only leads to deaths, destruction of properties and infrastructure, but leaves an environmental menace in its wake, as well as aiding the spread of epidemic viruses that causes diseases like typhoid and diarrhoea [4].

A 2011, a United Nations (UN) report revealed that about 2.3 billion individuals were affected by flood in the last 20 years resulting in about 56% of people affected by natural weather related disaster worldwide. Floods are said to account for about 84% of deaths caused by natural disasters, globally [5]. It is therefore safe to conclude that flooding is a threat to various communities and human settlements across the globe. Globally, there has been an increase in floods by about 50% in the last 10 years and their occurring rate is faster than ever recorded [6]. Nigeria is not left out of this statistics as the impacts of flood in the country in the last two decades, has led to the loss of over 11 million lives and millions of naira worth of properties [4]. In the year 2011 and year 2012, Nigeria experienced the worst flooding incidence, majorly caused by the opening of the Lagdo Dam in Cameroun [1].

As the rate of flooding increases in Nigeria, it affects more of the lower class in such a way that recovery from the occurrence is almost impossible without any aid. Generally, flooding poses a potential risk to settlements around riverine areas and floodplains which are areas occupied by low-income earners in Nigeria. This makes this class of people the most vulnerable to this natural threat to both lives and properties [2]. In recent times, Internally Displaced Persons (IDPs) settlements have sprung up in Nigeria to accommodate people displaced by floods and internal conflicts in the country. Some of these settlements are located in flood-prone areas, without necessary or adequate design precautionary measures carried out to alleviate the likely devastating effect of flooding in such areas. In the cause of flooding, many of the settlers in the camps who are already living under the trauma of being displaced from their homes, are likely to face another round of ordeal that poses a great danger to their lives and properties. Despite the aforesaid, no study was found to have been carried out in Nigeria towards developing a design proposal that uses resilient design approaches to combat flood in the country. Also, the possibilities amphibious structures present as a resilient strategy to combat flood, is yet to be examined in the development of a settlement in flood-prone areas in Nigeria.

It is against this backdrop that this study examined the potentials amphibious structures present as a resilient strategy to combat flood, in order to develop an architectural design proposal for an IDPs settlement that can withstand the peculiar challenges caused by flooding in Nigeria. The inspiration for the research was conceived from a design competition organised by Building 4Humanity Design Team on Building Resilience, in Portugal Spain in 2018. The main requirement of the brief, was the development of an architectural design proposal that proffers practical solution to any environmental problem, using a resilient design approach. Subsequently, the study was conducted to answer the sole question of “How can an IDPs settlement be designed to combat flood in Nigeria, using resilient design strategies?”

The aim of the study is therefore to develop an architectural design proposal of a sustainable IDPs settlement in a flood-prone area in Nigeria, using resilient design strategies. Consequently, the proposal was developed for a locality called Girei in Adamawa State in the Northern part of Nigeria. Adamawa State was selected to site the scheme, because it is one of the states in Nigeria where IDPs settlements are located as a result of displacement of citizens caused by internal conflicts, banditry and natural disasters, such as flooding. Girei was preferable to locate the proposal, because it is a flood-prone area that has witnessed devastating flooding in the past. According to [7], a recent case occurred in 2015 when the Lagdo Dam in Cameroun was opened.

As earlier stated, the proposal was designed for a specific area in the Northern part of Nigeria, but the ideology upon which the design was based and the sustainable innovative solutions employed, can be applied to design settlements in similar flood-prone areas around the globe. Therefore, the study is a useful guide for developing settlements in areas susceptible to flooding around the world, as well as a valuable educational material on issues relating to developing settlements in flood-prone areas. The contents of the study are also valuable reference materials for students, educators, building professionals and researchers to consult, use and develop further. The article was grouped into nine sections namely: abstract; introduction; literature review; methodology; result; conclusion; credit; acknowledgements; and references.

2. Literature Review

2.1. Causes of Flooding

The causes of flooding are numerous and are dependent on the region affected. [7] advanced that generally, flooding arises due to climate change and global warming. The author explained that greenhouse gases emission is the cause for these dramatic climatic changes over the last decade. There is no doubt to this claim, but according to [1], the reason for flooding in Nigeria is mainly due to human negligence in the physical environment which ultimately affects climatic change. This was said to be evident in the poor planning and disregard for the provision of appropriate and functional drainage channels, indiscriminate dumping of refuse into water bodies and drainage channels, where provided. However, apart from human negligence, the authors also revealed that majority of the flood in Nigeria are caused by overflowing of rivers, land reclamation and encroachment, collapsed dam embankments, torrential rainstorms, poor land management and policy planning, ocean lagoon surge and increased rate of rainfall.

Generally, in Nigeria, flooding occurs in three forms based on the cause. These include urban flooding, river flooding and coastal flooding. [8], identified four categories of urban floods as follows: local floods that occur several times in a year as a result of blocked drains; minor watercourses in built-up areas rising rapidly after substantial downpour and usually flowing through small channels beneath roads; major rivers passing through inner-city areas; and wet season floods in coastal cities and lowland. In general, flooding is to a large extent a natural phenomenon whose adverse effect can be escalated or reduced by human activities.

2.2. Flood-prone Areas in Nigeria

[2] advanced that certain areas are more prone to flooding than other areas in Nigeria. The authors itemised the following regions as generally more prone to flooding in the country:

i. Sections of the Southern parts of the country with low-lying areas where yearly raindrops are heavy;
ii. The Niger-Delta region;
iii. The floodplains of the larger rivers in Benue, Niger, Sokoto, Hadeja, Taraba, Imo, Cross River, Ogun, Anambra and Kaduna, among others; and
iv. Areas with flat low-lying terrain that may be flooded during or few days after a down pour by the South of Lake Chad.

2.3. The Need for Resilient Structures

Resilience can be described as being about people, plans and processes that incorporates sustainability in systems and places, such that growth is guaranteed and shocks are absorbed with minute disruptions. In other words, resilience is a system’s ability to prepare for, absorb the impacts and recover from a certain drastic hazard. A flood resilient condition will be a powerful framework that can contain and oversee flood at any dimension of event and still recuperates in a sensible time. This ought to be accomplished with next to zero misfortune or harm. Therefore, a resilient system should not be stripped of any of its resources after a flood but should be more grounded after the hazardous event.

According to [9], the key requirements for flooding in terms of building structures are in three categories namely: avoidance, resistance and resilience. The researcher stated that avoidance and resistance are usually seen as strategies used to keep water out of the building, while resilience is letting the water in and allowing the building to adapt to the new environment. Hence, in relation to flooding, a resilient building approach is a sustainable approach that is necessary to minimize the impact of flood [10]. Nevertheless, it is imperative to mention that resilience is not absolute. It should

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be recognised that complete resilience in all situations is not feasible, but steps that are incremental can be taken. It is of utmost importance to implement what is possible in a short term and progress to achieve better resilience in phases [11]. The resilience design approach is therefore considered a viable option for designing in flood-prone areas to achieve sustainable developments that will meet the test of time.

2.4. Social Resilience

Social resilience describes a type of resilience that goes beyond maintaining the building structure in times of flood. It involves a re-configuration of identity and novelties in the centre of self, either as an individual topic or an overall focus and also, to always consider its collective nature [12]. However, all meanings of social resilience concern to social elements, be they people, communities or associations and their capacities or abilities to endure, ingest, adapt to and change in accordance with ecological and social dangers of different sorts [13].

In very basic terms, social resilience is the capability of a community to adapt to challenges before and after a disaster, without any form of a decrease in their social life and community bond. It refers to the exact methods a social unit or community takes to aggregately adapt to or react to unsettling disturbances due to political, social and ecological changes [14]. [13], whose view was based on a critical review of relevant literature, social resilience can be viewed from the following three perspectives:

i. Coping Capacity: This involves the ability of a social unit to acclimatise to and conquer a wide range of difficulties;
ii. Adaptive Capacity: This refers to their capacity to pick up from previous encounters and modify themselves to future difficulties in their regular daily existences; and
iii. Transformative Capacity: This is about their capacity to create sets of foundations that encourage singular welfare and practical societal strength towards future emergencies.

In essence, while it is important to maintain resilient structures, it is also important to foster social resilience through architecture. This is to ensure that the social life of a people do not deter due to hazardous events such as flooding.

2.5. Resilient Methods of Combating Flood

Flooding occurs majorly in areas which are situated close to the coast, due to rising sea levels, high tides and coastal processes and hazards. These areas prone to flooding are known as coastal developments. Coastal developments include, but are not limited to portions of land adjacent to the sea, marine waters, coastal waters and all estuaries [15]. The methods of combating the challenges posed by flooding in these areas and adapting to these coastal hazards cover a wide range of options, but that which is pertinent to this study is that of “resilience”. Resilience in the development of building structures which involves the process and means of ensuring that the building erected has the ability to withstand any and all forms of flooding it is subjected to, without failing. According to [16], resilience adaptive strategies are broadly categorised into two namely: site strategies and reach strategies.

2.5.1. Site Strategies. This involves the different measures taken in preventing damage due to flooding to buildings and the properties within them. The strategies include implementing flood-proofing measures, such as, keeping the flood water out (dry flood-proofing) or avoiding the flood water through elevating the building or allowing the water to take action while minimising the damage caused by the water (wet flood-proofing) [16]. Figure 2.1 shows examples of resilience adaptive site strategies employed to combat floor.

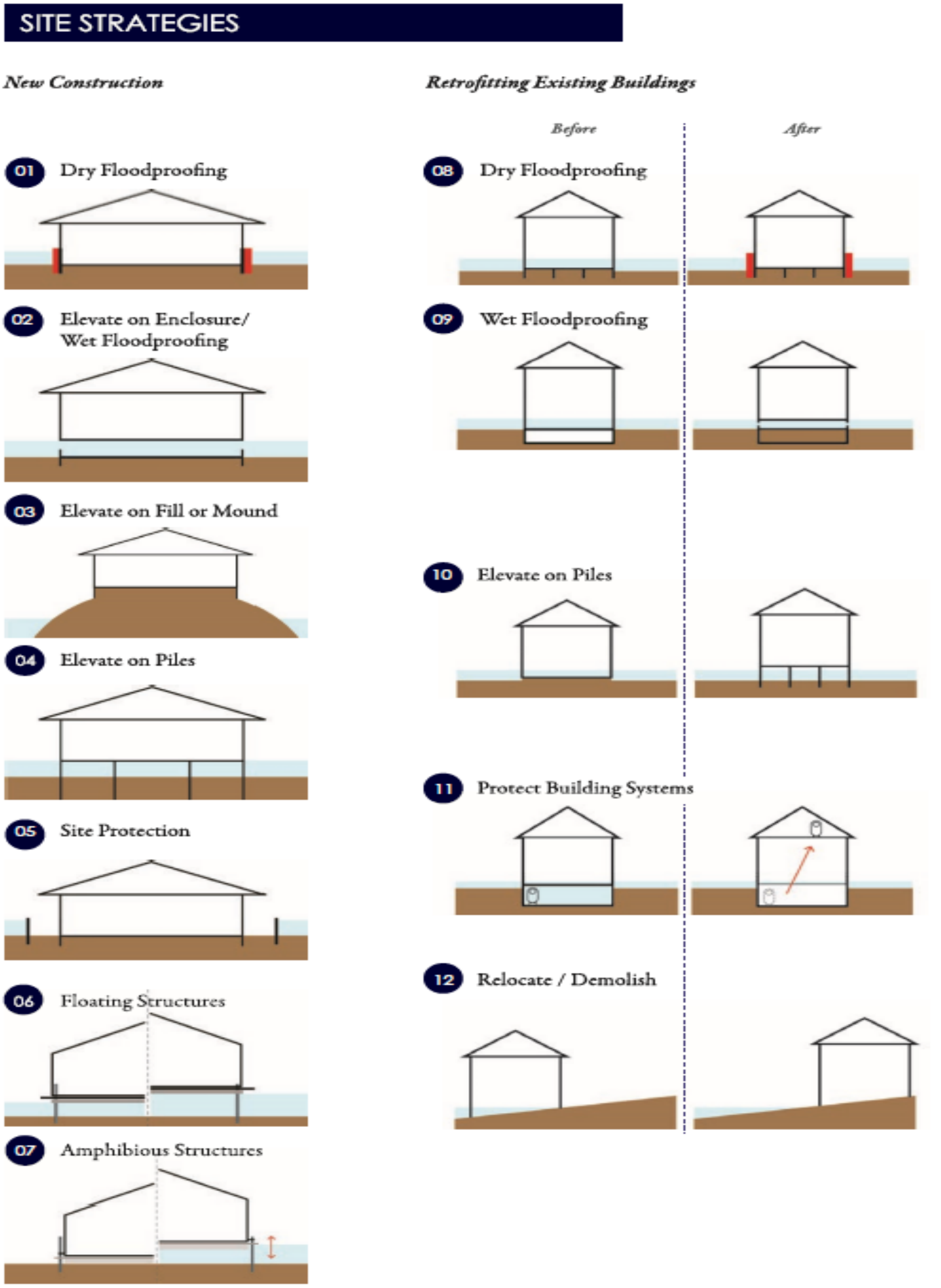

Figure 2.1: Resilient Adaptive Site Strategies
Source: [16].

2.5.2. Reach Strategies: This involves interventions carried out in the water or upland which impact a long stretch of the coastal areas. They are usually implemented and managed by the government or public agencies. The goal of carrying out this adaptive strategy is to make the land stable against erosion, diverse tide levels, reduce the effect of wave forces, prevent neighbourhoods situated at uplands from flooding and also prevent the establishment of developments in areas that are considered vulnerable to the impact of flood [16]. Figure 2.2 shows some resilience adaptive reach strategies.

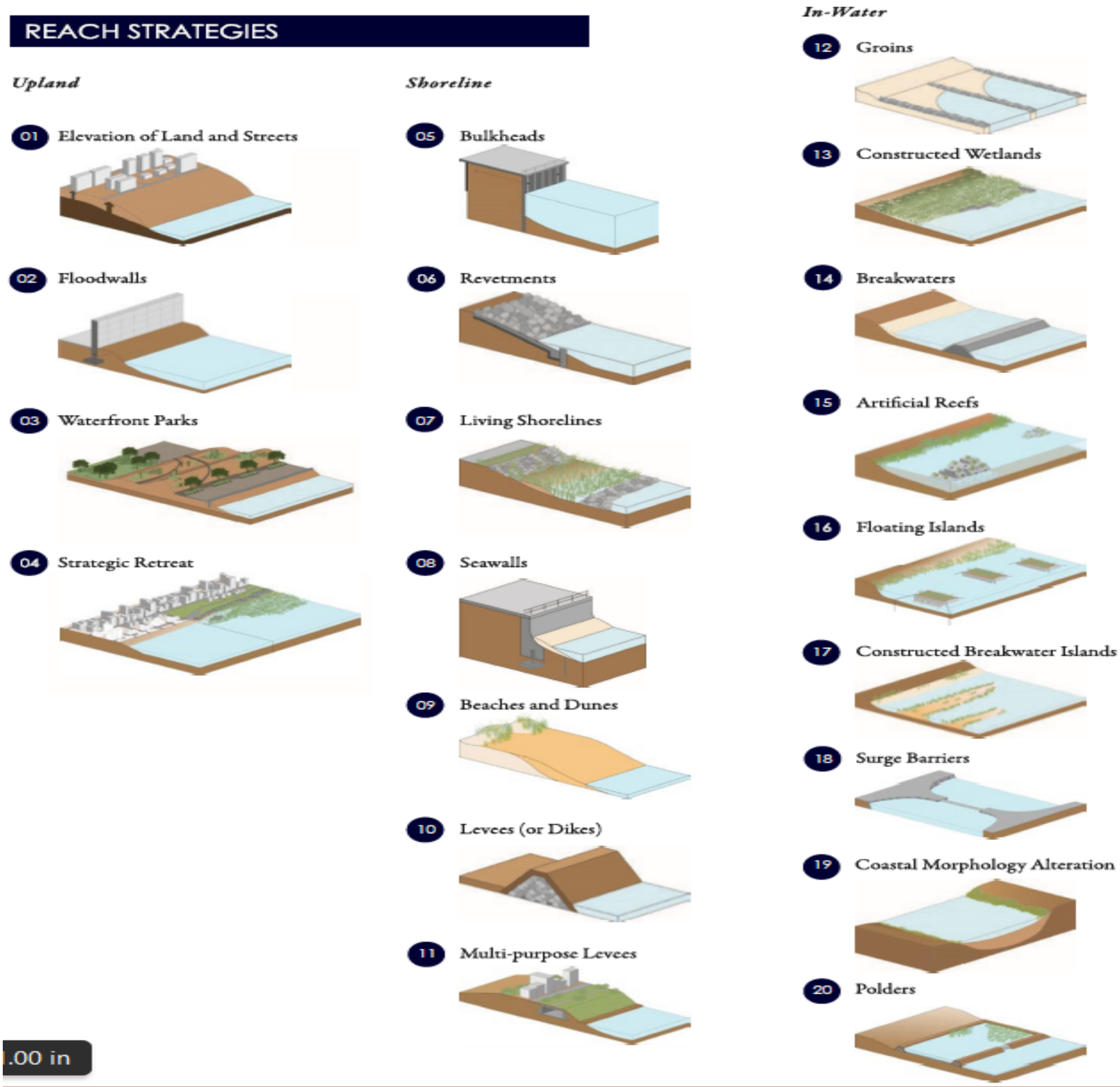

Figure 2.2: Resilient Adaptive Reach Strategies
Source: [16].

According to [17] in an article on ten methods that should be put in place to prevent impending flooding, the author advanced that the focus on combating the challenges posed by flooding should be on flood resilience as opposed to an implementation of solely defence schemes and emphasised that *"We are going to have to live with flooding, it is here to stay. We need to be prepared"* [17: p. 2]. To this end, the author suggested some general measures of combating the challenges posed by flooding which include: construction of buildings above flood levels, tackling of climate change, protection of wetlands and strategically planting of trees, restoration of rivers to their natural courses and improvement of soil conditions.

2.5.3. Construction of Buildings Above Flood Level. This depends on the specific area, in terms of the established flood level that has been estimated over time in the area. It involves the construction of all new building structures above the established flood level of the area. Through this means, orthodox defence schemes will be augmented with more inventive and innovative means to help minimise the risk of challenges posed by flooding in times to come [17].

2.5.4. Tackling of Climate Change. From the review of literature, it has been observed that scientists believe that change in climatic conditions has to a great extent increased the risk of flooding in many regions, giving rise to extreme weather conditions in areas where this phenomenon was initially unprecedented. It is therefore paramount for various governments to develop and introduce policies that will be beneficial to the environment in reversing any disastrous environmental policy made [17].

2.5.5. Protection of Wetlands and Strategically Planting of Trees. Wetlands act as sponges, helping to soak up moisture from the ground surface. Also, forests or areas populated with trees can help to *"slow down water when rivers overflow"* [17: p. 4]. Therefore, the conservation of existing wetlands, repair of damaged wetlands, reduction of deforestation, introduction of more wetland drainages and reforestation of areas located upstream, will contribute to a great extent in reducing the effect change in climate has on flooding and consequently, the challenges posed by flooding in various areas will be mitigated [17].

2.5.6. Restoration of Rivers to their Natural Courses. Over the years, in order to improve water navigation in various areas, many rivers were straightened from their original course. Restoration of these rivers to their initial course, by reintroducing their bends to them will help in increasing the length of these rivers, consequently delaying the flow of flood. This measure will help to reduce the challenges posed by the effect flood flow has downstream [17].

2.5.7. Improvement of Soil Conditions. The constant use of heavy machineries and inappropriate management of the soil can lead to the soil becoming compact. The consequence of this is that instead of the soil being able to readily absorb moisture, it only holds it for a short time and slowly let it go, causing runoff into water bodies such as rivers, streams etc. Improvement of the condition of the soil will ensure that the soil readily absorbs moisture in large quantities, preventing runoff into rivers that can give rise to flooding. [18] in an article on ten methods to avert flooding in urban areas, also noted various steps that should be engaged to avert the challenges caused by flooding. These measures include: creating a *"Sponge City"*; using green roofs and gardens at roof tops; creating flood routes and rivers overflow sections; and creating sustainable drainages, permeable pavements sidewalks and gardens.

2.5.8. Creating a "Sponge City". Kongjian Yu, the Dean of Peking University's College of Architecture and Landscape Architecture advanced that, a sponge city h holds, cleans and drains water naturally by ecological approach. Therefore, this concept as opposed to channelling rainwater away, makes use of the rainwater within its individual boundary. Examples of its uses are: urban farms and irrigating gardens, revitalising depleted aquifers, replenishing or replacing water employed in flushing toilets and processing it to be clean enough for drinking [18].

2.5.9. Green Roofs and Rooftop Gardens. These are roofs protected with plant life as shown in Plate 2.1. They help in absorbing rainwater, thereby reducing flooding. The advantages of this system for the users of the building structure is that it is a tool that helps in the management of storm-water and for the members of the community, it helps to mitigate storm-water runoff. Its benefits to the environment are: neutralising the effect of acid rain, prevention of combined overflow of the sewer and removal of nitrogen pollutants from the storm-water [19].

Plate 2.1: Green Roof and Rooftop Garden
Source: [18].

2.5.10. Floodplains and Overflow Areas for Rivers. The concept of floodplains involves retaining and absorbing water in areas deliberately preserved for this purpose, thereby helping to shield adjacent towns from the effects of flood. The advantage of floodplains ranges across protection from the challenges of flooding, conservation of nature and water management [18]. Plate 2.2 shows an example of floodplains and river overflow areas.

Plate 2.2: Floodplains and Overflow Areas for Rivers
Source: [18].

2.5.11. Sustainable Drainages: Permeable Pavement, Sidewalks and Gardens. This concept involves substituting impermeable materials such as, concrete, which when in contact with rainwater do not absorb the moisture, but rather blocks it and reroutes it to the drainage system, which eventually become clogged in times of heavy rains causing an overflow into streets and sidewalks, consequently leading to flooding. In this flood prevention and management method, the impermeable materials are substituted with a more sustainable drainage system, involving the use of permeable materials, e.g., grass and gardens as shown in Plate 2.3. This readily drains the rainwater into the soil. The infiltration process serves the double advantage of also sustaining plant life [18].

Plate 2.3: Sustainable Drainage – Permeable Pavement Sidewalks and Gardens
Source: [18].

2.6. Amphibious Architecture

[20] described amphibious architecture as structures that rest on dry land like conventional buildings, but when flooding occurs, they are able to rise and float on the water surface till the flood is drawn back. A buoyancy arrangement under the structure dislodges water to deliver floatation as required and an upright guidance arrangement allows the moving up and coming down of the structure to return to its exact position upon descent. This novel technique has been successfully applied since 2005 in the Netherlands and for about 40 years in rural Louisiana. Amphibious development is an adaptive measure to reduce flood risk that works in synchrony with normal cycles of flood in regions prone to flooding, instead of trying to impede them. This architecture can be achieved through a buoyant foundation, an integral mechanism for the goal of the system [20].

2.6.1. Buoyant Foundation. [20] explained that a buoyant foundation is a kind of amphibious footing, particularly developed to be fitted in an existing slightly elevated house, resting on short piers. The system comprises of three fundamental components as follows:

i. Buoyancy blocks under the structure that enables it to float;
ii. Perpendicular guiding supports that inhibit the structure from moving in any other direction apart from vertically up and down; and
iii. A structural sub-frame that binds the structure together as a unit.

As currently developed, buoyant foundations are not meant for coastal areas prone to storm-surge, inundation that consists of the actions of wave or for flows with high velocity. They are best meant for flat floodplain areas that are large, to areas that are safeguarded by embankments where the flood is due to overtopping, to coastal areas adequately safeguarded by peninsulas or barrier islands and to flood conditions that are related where the water is predominantly rising, instead of flowing rapidly [20]. Some advantages of amphibious structures itemised by [20] are as follows:

i. The structure is elevated temporarily to the required height needed to stay above water;
ii. The structure still stays in close proximity to the ground, hence less vulnerable to destruction by wind;
iii. Accommodates rising sea level and soil subsidence;
iv. The structure retains its former look after the flood;
v. Traditional architecture is preserved; and
vi. Original character of the neighbourhood is retained.

Figures 2.3A, 2.3B and 2.3C make clearer how an amphibious structure works.

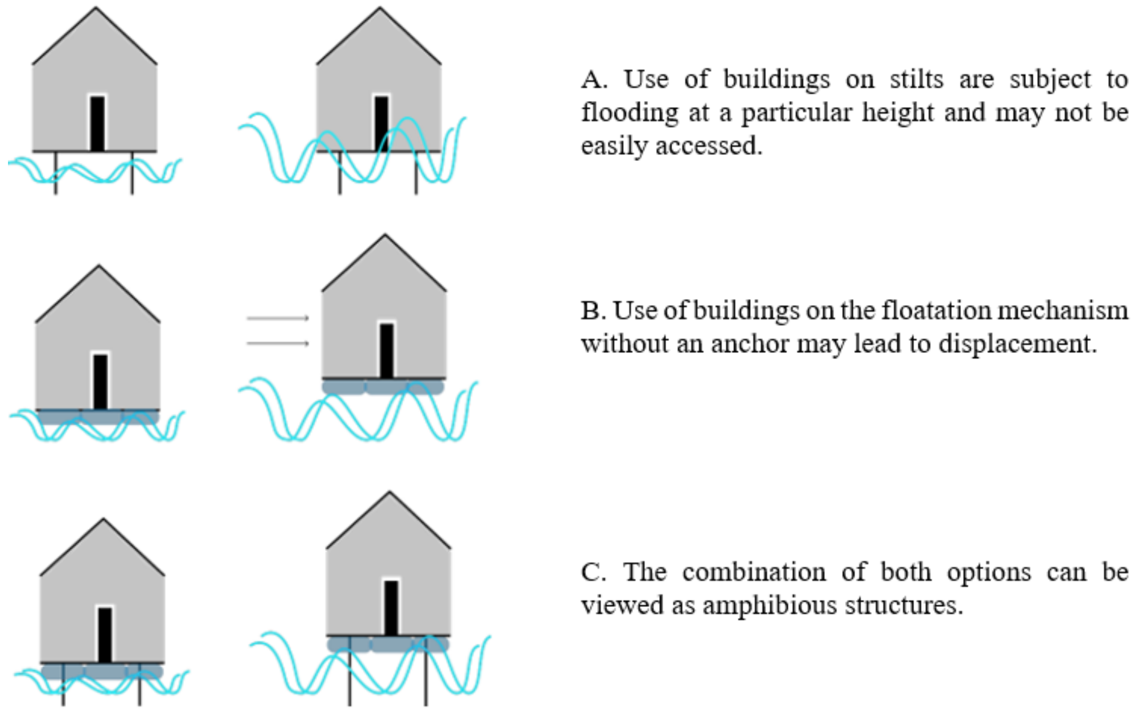

Figure 2.3: Principle of Amphibious Structure
Source: [20]

2.6.2. Sustainability of Amphibious Structures in Nigeria. Sustainability can be referred to as a structure's capacity to endure. In building designs, it is an essential factor to take into consideration in improving the quality of a structure. Sustainability of amphibious structures refers to the concept and constructive solutions for the structure to adapt to rising water levels during the flooding period [21]. To achieve sustainability of amphibious structures, light-weight wood and a hollow concrete base are used as the buoyant foundation for the structure. This gives it a mooring post for sliding, allowing the platform to float upward in times of flood. Also, plastic composite materials with lightweight characteristics are used, in addition to the application of modular systems and an open layout planning method [20; 21]. Amphibious foundations are resident-friendly and cost-effective substitute to elevation that is permanently static for housing in regions with rising flood not followed by flow speed that are high. In general, amphibious structures are proven to be low impact and low cost flood protection approach that can make the flood-prone society's resilience to increase in a time of misadventure [21].

2.6.3. Challenges of Amphibious Structures. Amphibious structures could be a solution for future and current issues in numerous localities, urban communities and scenes. Such issues can be seen especially in the requirement for more housing parts and development grounds in a few communities in Nigeria, because of the developing populace or potentially the gradually rising of ocean level in setting with the overall environmental and climate change. These may result in the innovation and use of floating bridges and structures when the water level is high to foster circulation and comforts in such conditions [22].

There are a lot of issues to consider while having structures on water, because of the distinctive water environment and its chemical and physical properties. Some of the issues of coasting houses and their bridges that float provided by [22] are:

i. *Local Climate Change:* The coastal areas of Nigeria are exceptionally populated. Millions of people live in areas helpless against coastal flooding. Climate change can impact on these coastal zones in a variety of ways. Coasts are sensitive to river or ocean level increase, variations in the recurrence of storms and waves along these areas increase precipitation and warmer temperatures of the sea. Also, the increasing climatic concentration of carbon dioxide are turning the seas into avenues for ingesting higher gas volume and that makes them to be increasingly acidic. This rising causticity may impact or influence the coastal and marine environments.

ii. *Indoor Climate Condition:* There is no issue to enhance the warmth protection exposed to the harsh elements season if there should be an occurrence of winter climate and raining seasons, for example, by an expanded force of the wind. Be that as it may, amid mid-year innovative solutions are fundamental so as to ensure a moderate indoor climate. Clients request an agreeable air disregarding the imaginative materials utilized in the structure.

iii. *Corrosion of Materials:* The physical elements, chemical reactions of salts, ions, PH-values, etc., and the distinct constituents of the local outdoor environment, result in deep decay of materials, thereby causing the materials to deteriorate over time. Metals react with oxygen and water, thereby causing a rusting effect on metals. Insect affects the wooden materials when not properly treated.

iv. *Algae Determination:* The microbiological development of planes is a worldwide topic. As a result of enhanced thermal insulation of building envelope, the exterior facades are inclined towards a regular state. Based on the current situation on floating houses investigated by Stopp and Strangfeld, algae's methodical dimensions are underway.

v. *Waste Disposal, Energy and Drinking Water Supply:* Supply a floating structure with gas, energy by electricity, consumption water, or district heating and the removal of the structure, are doable by centralised and decentralised arrangements. They also have to conform with up-to-date building regulations and environmental legislations

vi. *Inappropriate Skill or Technology:* Floating and amphibious structures are created to be sited where there is water and are planned and developed to adjust to water level that rises and falls. Floating structures are usually positioned in the water, but amphibious houses are located on top of water and made to float whenever there is a rise in the water level. Flexible mooring posts are usually attached to amphibious structures and are supported by foundations made of concrete. The structure moves upwards when water level rises, to float. The movement as a result of the water is limited by the mooring posts. The skill and technology to build and maintain such structures entail that they are handed by professionals. The resident of their location would need to maintain the integrity of the structure over time in order to avoid building failure due to deterioration of material. This may be cost demanding depending on the level of deterioration of the structure. Plate 2.4 shows the image of the Floating School in Makoko in Lagos State, Nigeria and Plate 2.5 is an image of the same school after it collapsed due to lack of maintenance after a heavy rainfall.

Plate 2.4 Plate 2.5
Images of Makoko Floating School in Lagos State, Nigeria, before and after it collapsed (L – R)
Source: [23].

2.7. Solutions to Flooding in Nigeria. Flooding disasters are growing without the implementation of effective mitigation techniques in Nigeria. Several parts of the country have become victim to flooding, which displaces lives and properties, leaving enormous damage along its path. One of the main solutions to mitigate the destructive effects used in Nigeria is raising structures to heights that cannot be affected by the flood. Some others include building drainages and canals to channel the flood to lagoons and rivers and sand filling flood-prone areas to lift them above flood level. Most of these solutions come at a very high cost which ordinary citizens cannot afford [23]. Hence, the ability to combat flood usually rests on the shoulders of the government, nongovernmental organisations, corporate bodies and community development groups.

3. Methodology

The goal of the study was to develop an architectural design solution to an environmental problem. This necessitated the use of qualitative research approaches that relied on the review of related documents on the subject to collect relevant data. This approach was considered apt for the study because it enabled useful design concepts, strategies and standards used in developing the design proposal to be identified from archival documents and examined in conformity with the norms of qualitative studies. [24] noted that quantitative data is employed in situations where the target of a study is to describe and interpret situations or occurrences. According to [25], in situations where the aim of the research centre around understanding, examining or describing situations, the use of qualitative research method is suitable.
Google search engine was majorly relied on to randomly search the internet to gather relevant data considered useful for the research. Only open access documents were used to help streamline the scope of the search and also avoid the difficulties usually associated with retrieving data that are not open accessed. The analysis of the data involved the identification and coding of relevant themes from the literature gathered, after which the themes were analysed and synthesised by thematic textual analysis. The outcome of the analysis became useful tips for developing the conceptual framework upon which the proposal was developed to answer the sole research question of, "How can an IDPs settlement be designed to combat flood in Nigeria, using resilience design approach?" The literature search, data collection and data analysis were conducted between August 2018 and January 2019. The result is presented with texts, architectural 2-dimensional and 3-dimensional images, tables and plates.

4. Result and Discussion

This section is the presentation of the result, which is the architectural design scheme that was developed to answer the research question. The approach adopted in presenting the result is to discuss the result as each aspect of the design is being unfolded. This method was preferable to the widely used method of separating the result from the discussion section, because it allowed for each aspect of the proposal to be first examined in detail before proceeding to the next part. This method is considered better as the result is an architectural design proposal, which is better understood when each aspect of the scheme is fully explained before moving to the next part.

4.1. Design Challenge Statement

Social conflict occurs abruptly and unexpectedly, displacing people and leaving them without a home for as long as it takes to provide a suitable shelter over their heads. In Nigeria, many people are victims of different kinds of disasters, ranging from natural occurrences such as flood, to conflict and community clashes. The victims regardless of these unpredictable disasters are subject to various losses and oftentimes displacements. In 2018, there were several occurrences of insurgency and violent attacks on local communities, causing a disturbing increase in the population of IDPs.

Reported interviews with members of existing IDPs settlements indicated that the existing camps provide a “miserable” living environment that makes life barely liveable as the inhabitants are denied basic amenities such as healthcare, means of livelihood, recreational areas and other facilities. This has led to an increase in the demand of sustainable solutions that can mitigate these situations. Unfortunately for the victims, some areas designated for their settlements are prone to flooding, causing a need for resilient design solutions that can withstand the flood, as well as other possible perceived threats.

4.2. Site Selection Justification

In 2012, Lagdo Dam in Cameroun submerged many settlements in Adamawa State in Nigeria such as Fufore, GIREI, Yola South and Yola North, causing various losses and displacing thousands of families. As a follow up to the incident, two IDPs settlements were established in GIREI, which was later affected by another flood in 2015 [26]. Hence, GIREI was considered as a suitable location to establish an IDPs settlement that is resilient to flood in Nigeria. Figure 4.1 is a map that shows the location of Girei in relation to the Lagdo Dam.

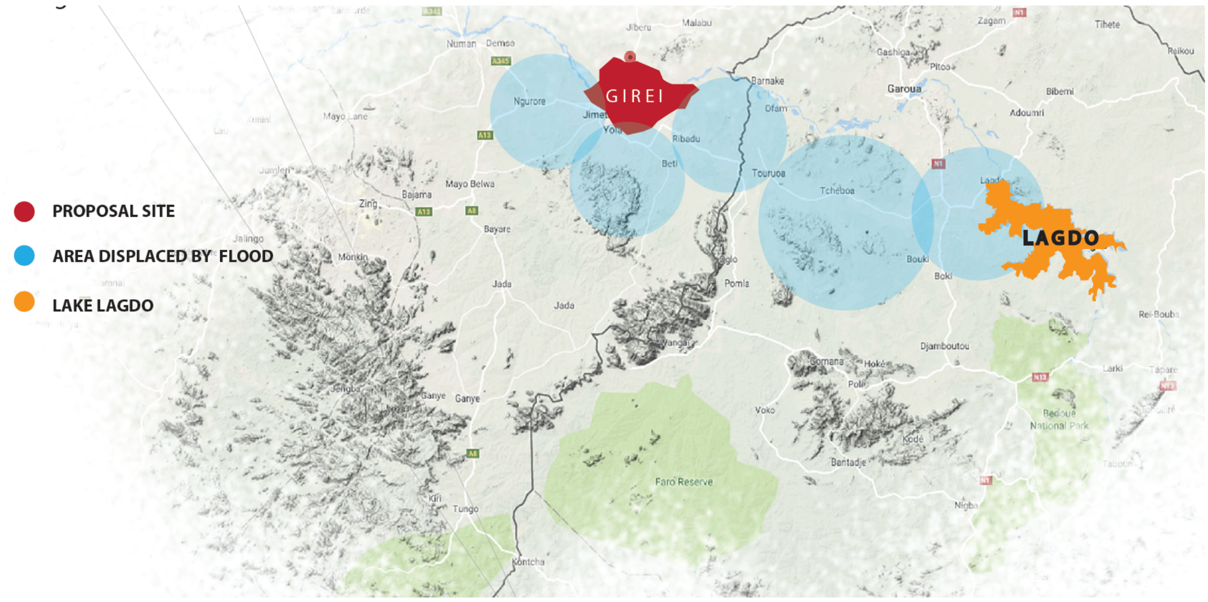

Figure 4.1: Location of Girei in Relation to Lagdo Dam
Source: [27].

4.3. Design Approach

To tackle the issue of resilience in the flood-prone area, the following design strategies were employed:

i. Speed of Construction: The structures can be easily assembled within the shortest time possible.
ii. Materials: Majority of the construction materials can be locally sourced within Nigeria.
iii. Modularity: The design allowed for modular expansion and phase development.
iv. Labour: The construction processes are simple to allow for the participation of the locals.
v. Indigenous Design: The proposal aligned with the cultural, traditional and religious norms and values of the Northern part of Nigeria where the scheme was sited.
vi. Innovation: The scheme is ingenious, providing all that the displaced persons need to live a better life. Some of the facilities provided include: healthcare, recreational areas, residential quarters, worship areas, cattle mound and grazing area, as well as educational and vocational schools.

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4.4. Site Analysis

The proposed site for the design is located in Girei in Adamawa State, Nigeria. Girei is a town that also functions as a Local Government Area (L.G.A.) in the State. Amongst the numerous tribes in Girei are the Fulibe or Fulani tribe who are the most widely spread. The concept of this design was therefore majorly influenced by the culture of this cultural group.

4.4.1. Accessibility to the Site. The proposed site adjoins a major road known as the Numan Road. The access point to the IDPs settlement was therefore taken from the Numan Road as shown in Figure 4.2.

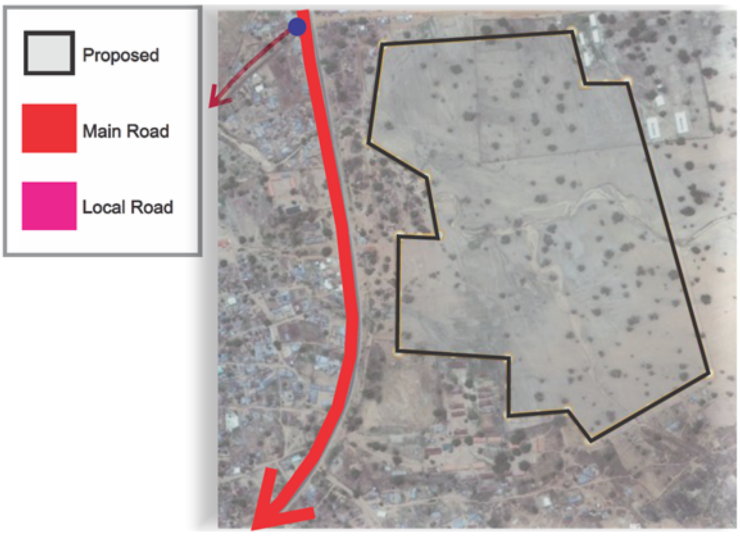


Figure 4.2: Accessibility to the Proposed Site
Source: [27].

4.4.2. Site Condition. The proposed site is relatively flat as compared to the surrounding regions. The site topography comprises of just one contour line cutting across the site. The land is sparsely covered with vegetation as shown in Figure 4.3.

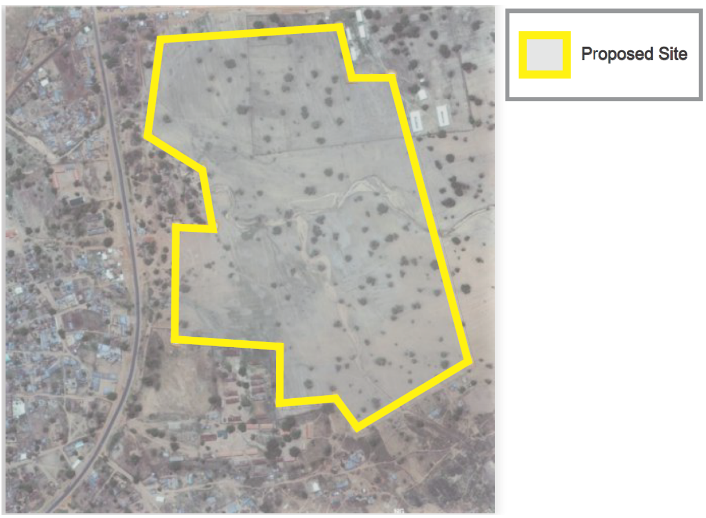


Figure 4.3: Site Condition
Source: [27].

4.4.3. Site Drainage. A trench, also known as a dry moat, was provided around the boundary of the proposed site at a gentle slope as shown in Figure 4.4. This was done to assist in the drainage of surface running water from the site during flooding. It is proposed that the sand to be excavated from the trench will be hipped at a convenient location to develop a cattle mound for the protection of the cattle of the settlers during flooding. The cattle mound will be elevated above the flood level. The water in the moat can be put to valuable use by pumping and channelling it for irrigation of the cattle grazing area. The dug-out trench around the boundary of the proposed site, also serves as a protective safety measure against unauthorised intruders into the settlement.

Figure 4.4: Site Drainage
Source: [27 and Authors Design].

4.5. Site Design

4.5.1. Site Concept. The boundary of the site is surrounded by a fence made of sharpened bamboo poles, which are tightly bounded together to provide additional security. The proposed site for the design was planned in such a way that the residences for old people (elderly dormitories) and the family residential units are positioned to shield the female dormitories. The units are used to form a protective ring around the female dormitories to protect them from external danger. The danger to the females includes: sexual assault or rape by security forces, as reported in some existing IDPs settlements in the country. Additional security for the females was provided by the use of a fence made with sharpened bamboo poles, around the boundary of the female dormitories. The site layout is divided into four parts namely: administrative, pre-settlement, residential and food area. The site planning and organisation was influenced by the Fulani culture. Figure 4.5 shows the site conceptual diagram.

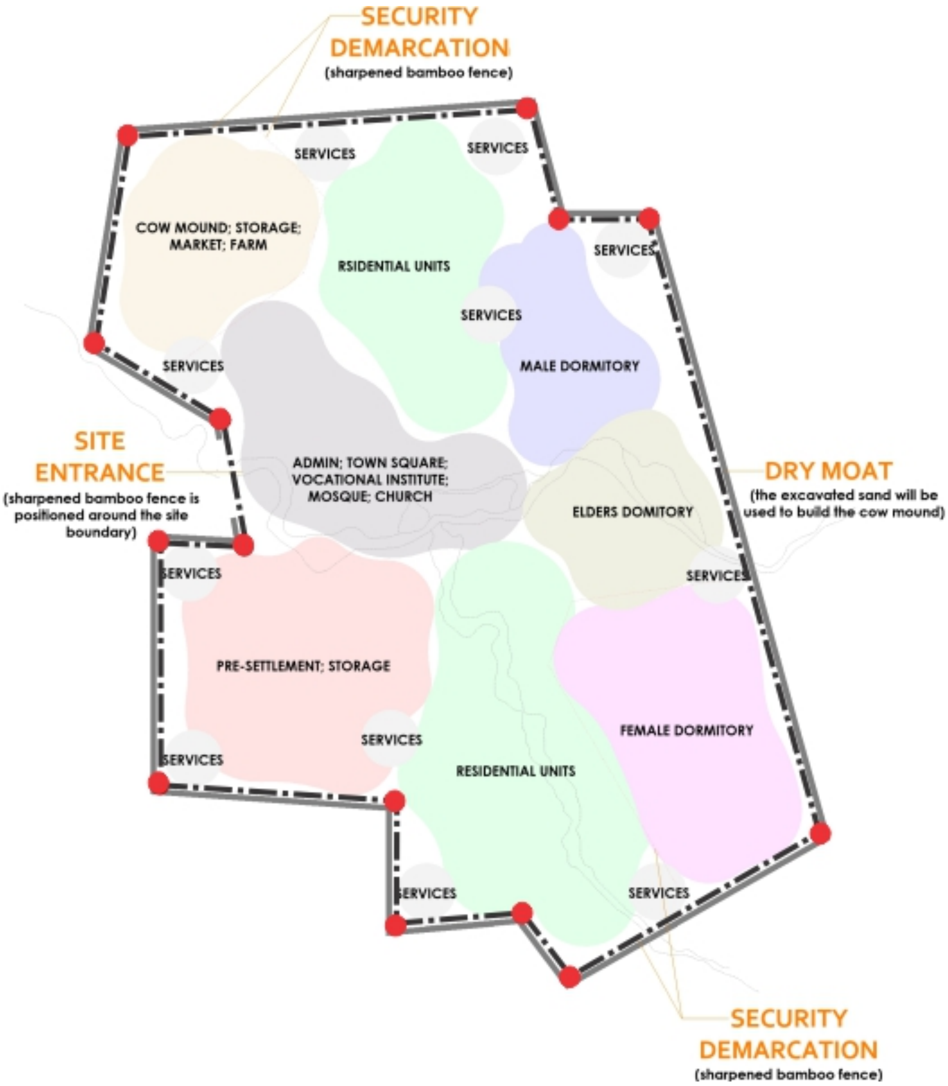


Figure 4.5: Site Conceptual Diagram

4.5.2. Site Phased Development. The scheme was designed such that it can be built in phases, starting from the most pressing needs of the people as at the point of displacement. The proposal could be developed in three stages as shown in Figure 4.6.

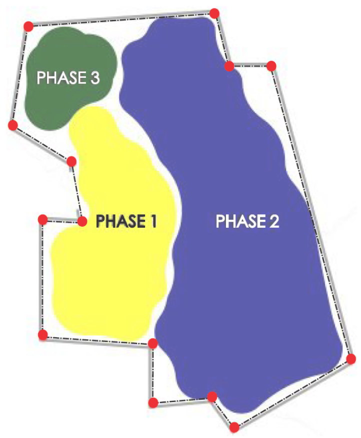


Figure 4.6: Site Phase Development Diagram

The developmental stages of the proposal as shown in Figure 4.6 are as follows:

i. *Phase 1:* Administration and pre-settlement facilities to be built first because they are the immediate needs of the internally displaced persons.
ii. *Phase 2:* Residential units that comprises of the incremental bedroom units; junior dormitories (age 3 months - 10 years); senior dormitories (11 - 25 years); the elderly dormitories (singles above 26 years, widows and widowers); and the female dormitories secured to prevent female children and youth assault.
iii. *Phase 3:* Support facilities such as the vocational centre, classrooms, clinic, cafeteria, grazing area and recreation.

4.5.3. Site Planning. The main tribe in Adamawa State is the Fulani tribe. This group of people have a peculiar lifestyle influenced by their culture and tradition. This includes early marriage, polygamy and certain hygiene rules. These aspects of their daily lives were taken into consideration in the planning of the site and in the design of the entire settlement. Also, their religion was also considered, which is predominantly Islam. Some of the facilities put in place regarding their way of life include the following:

i. *Town Square:* The Fulani culture encourages communal living among the tribe. The design incorporated this aspect of their culture by including a town square area for town gatherings and meetings.
ii. *Cow-grazing Area:* One of the major traditions distinct to the Fulani group is the rearing and herding of cows. This aspect of their culture was included in the settlement by providing a cattle grazing area for their cows.
iii. *Mosque and Church:* A mosque facing Mecca (North) was provided in the scheme as the Fulani people are predominantly Muslims. However, Nigeria being a secular state allows for freedom of religion. Hence, a church space to accommodate the minority was also provided and situated away from the mosque.
iv. *Ba-shiga (No Entry) Concept:* The Fulani culture forbids grown up males to freely enter the female living quarters. Their culture demands that there should be a clear separation between the male and female areas. This was incorporated in the settlement planning by locating the female dormitories away from the male residences in addition to providing a fence around the female dormitories. Figure 4.7 is a presentation of the site plan of the scheme showing all the facilities provided.

Figure 4.7: Site Plan

4.6. Design Development

The design was developed to achieve both physical and social resilience in the following ways:

4.6.1. Social Resilience. The design enables social resilience in three ways. Firstly, it allows the IDPs develop preventive strategies against what displaced them, by providing opportunities for them to be part of the building process of the settlement if they so desire, as a way of creating a stopgap employment for the displaced persons. To this end, local materials and simple construction processes, many of which the locals are familiar with, were employed. Secondly, the present challenge of sexual harassment exposed in some IDPs settlements in the country was considered and a design solution to remedy the anomaly was provided. Lastly, the design also made provisions that accommodated the cultural and religious background of the inhabitants of the locality where the settlement was sited, which is envisaged to foster societal harmony within the camp.

4.6.2. Physical Resilience. The design utilised the problem of flood to better itself by adapting into a new design during flooding. The buildings were designed to utilise the floatation theory by allowing the flood to push the floor platform vertically upwards, thereby triggering the roof dormers to create an entirely new design during flooding as shown in Figure 4.8. Therefore, instead of the flood becoming a destructive environmental element, it is used to create an ingenious solution to the damaging problem usually caused by flooding.

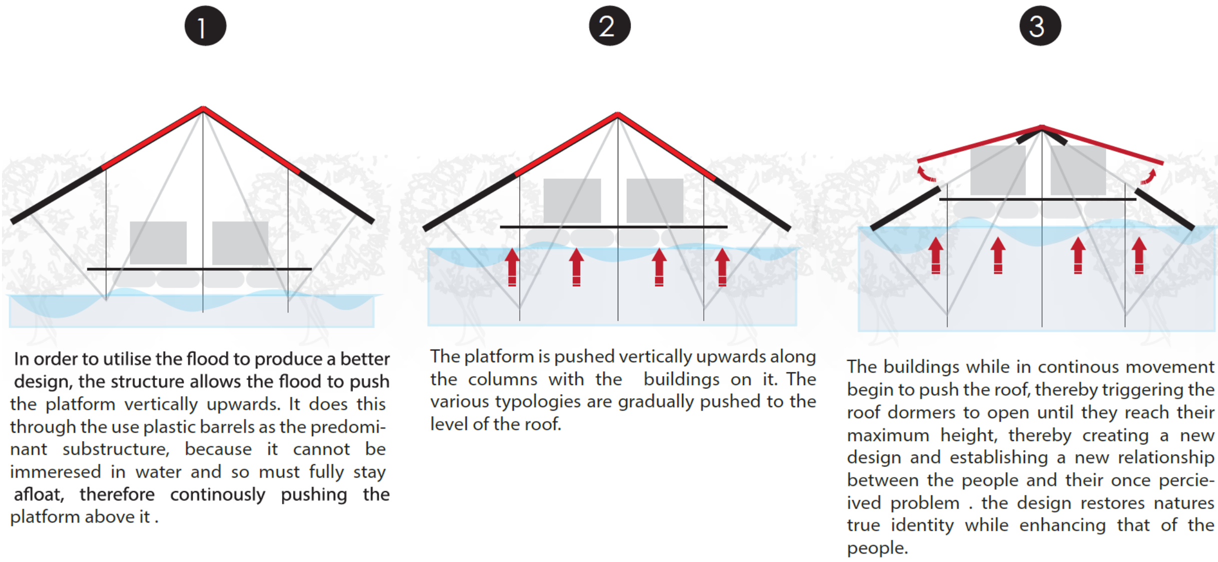


Figure 4.8: Structure Design Depicting Physical Resilience

Presently, the highest recorded flood level in Adamawa is 3 metres, while the average flood level is 1.5 metres. Hence, the maximum flood level of 3 metre was envisaged and designed for as shown in Figure 4.8.

4.7. Platform Schematics

Having used the floatation theory to achieve physical resilience, social resilience was achieved by creating a platform to resonate with something the settlers are used to, known as the "Bukaru", a native term for grass house. The design materials proposed are locally sourced materials comprising of a canopy, a platform and partitions. All these could be made using different sizes of bamboo, whose construction is simple enough to allow the locals to participate in the construction of the structures in the settlement. The design schematics was developed to achieve a dynamic structure as shown in Figure 4.9, without compromising functionality and other necessary design considerations such as, natural lighting and ventilation.

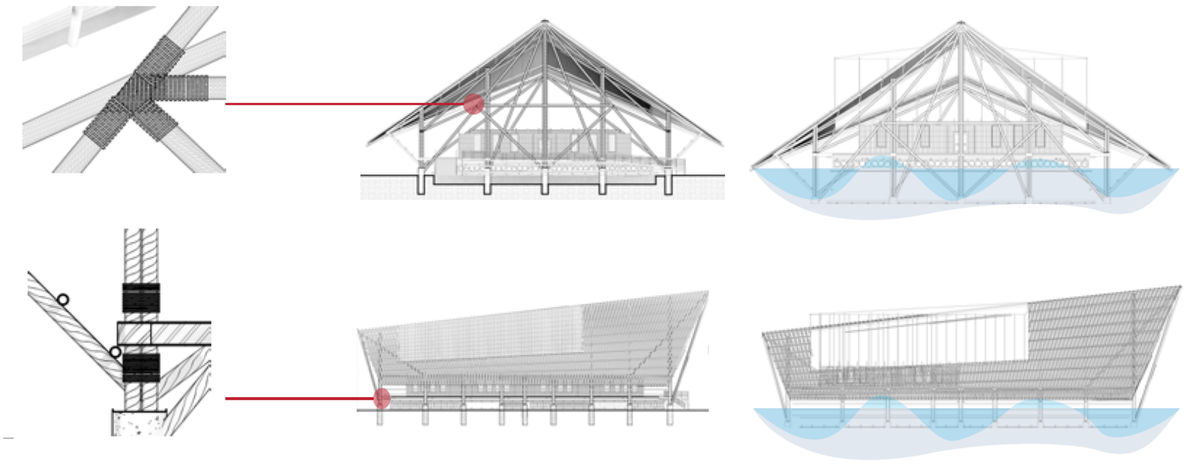


Figure 4.9: Platform Design Schematic Diagram

The platform shown in Figure 4.9 is the basis upon which all the building typologies where developed. The design adopted the buoyant foundation of the amphibious structure which is the part of the structure that moves vertically upwards along the bamboo supports, with the capacity to return to its original position after the flood. The platform was developed as a modular unit which can be partitioned to accommodate different building typologies. The platform technology is simple. It is designed such that with adequate supervision, it can be coupled by the users themselves to give them a sense of building back their home, as opposed to living in a platform built for them. Canoes can be anchored to the platforms to facilitate movement of inhabitants within the settlement during flooding when the structures rise.

4.8. Design Layout

Each building typology was designed to enable a safe place for the physically challenged to live regular lives while maintaining their identity and way of life. In order to achieve easy expansion of each building layout, the typologies are designed to easily add spaces and remove spaces without compromising their primary functions. The building typologies are as follows:

i. *Family House:* This is the residential facility for displaced people that have a family. In order to maintain family bond, these typologies are designed using the modular concept and consideration to the Fulani culture of polygamy. The Fulani culture allows the men to marry up to four wives. Hence, the bedroom units were designed such that they can easily be modified to accommodate more bedrooms in case a man has more than one wife. More bedrooms can easily be incorporated in the modular units as shown in Figure 4.10, while Figure 4.11 shows the arrangement of the modular units on a platform.

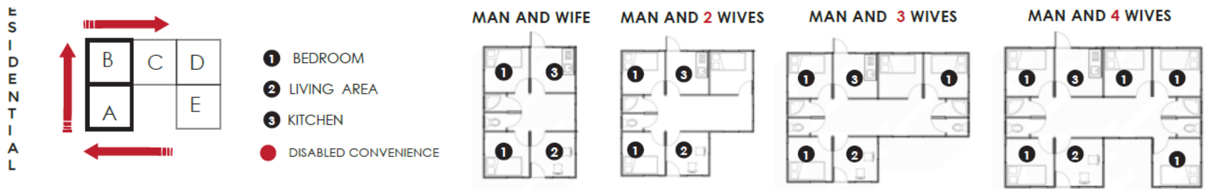


Figure 4.10: Incremental Development of a Family House to Accommodate more Wives

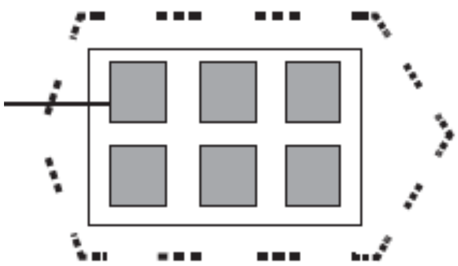


Figure 4.11: Arrangement of Modular Units on a Platform

ii. *Clinic:* Some displaced persons can have some form of illness or injuries due to the fact that they are displaced as a result of social conflict. Thus the need for a clinic on the site to cater for such persons, as well as those with other day to day health issues.

iii. *Vocational Institute:* This was provided for the training of the IDPs, such that those of them who do not have a steady means of livelihood before being admitted into the settlement, can develop useful skills they can fall back on to live a gainful life after leaving the settlement. Some of the vocations that such persons could be trained in include: basket weaving, clay works, tailoring, bead making, barbing and hairdressing, amongst others.

iv. *Cafeteria:* This is an eating facility to be run by the administrators of the settlement. It was included in the scheme to provide food for the elderly, children as well as others in the camp who have no means of livelihood.

Figure 4.12 shows the modular designs of the cafeteria, clinic and vocational institute, while Figure 4.13 is a presentation of how each unit can be placed on a platform.

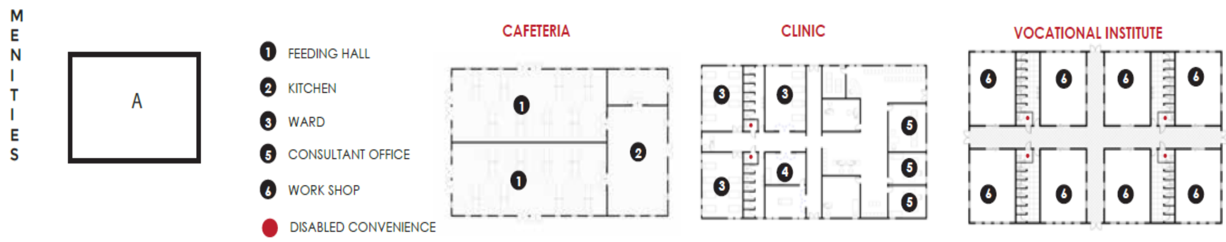


Figure 4.12: Cafeteria, Clinic and Vocational Institute Units

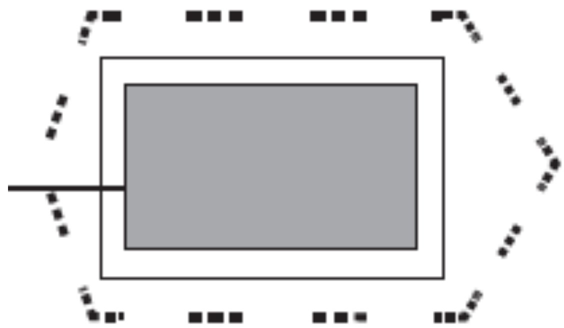


Figure 4.13: Arrangement of the Individual Units on a Platform

v. *Dormitories:* This is to provide residential accommodation for the elderly and children displaced without their families. They are grouped into the male and female dormitories and located at different sections on the site. Figure 4.14 is a presentation of a typical modular dormitory unit and Figure 4.15 shows the arrangement of the dormitories on platforms.

Figure 4.14: Typical Modular Dormitory Units

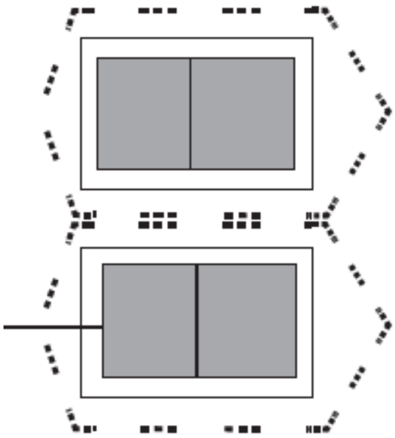


Figure 4.15: Arrangement of the Dormitory Modular Units on Platforms

4.9. The Family Units

During the design of the individual units, the following considerations were put in place:

i. *Hygiene:* The Fulani tradition frowns at the location of toilets and bathing areas in the same space. The design ensured that these two spaces were properly segregated as shown in Figure 4.16.

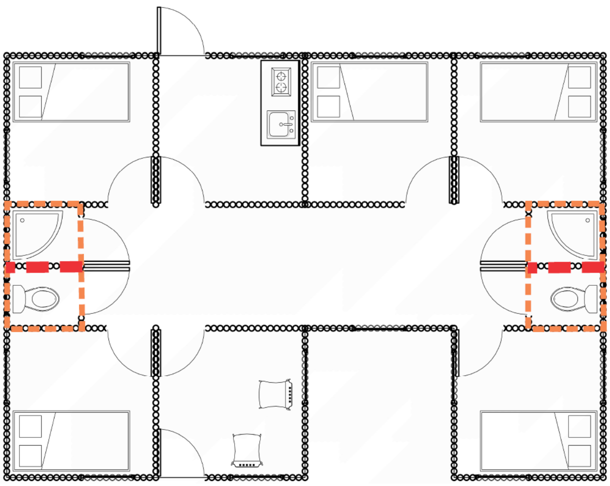


Figure 4.16: Floor Plan of the Family Residential Unit

ii. *Ba-Shiga (No-entry) Concept:* The Fulani culture involves the women being placed in a secluded area, with the main entry to their section being through the man's area, thereby allowing the man to be a natural security that can protect the women from any pending danger or assault as shown in Figure 4.17.

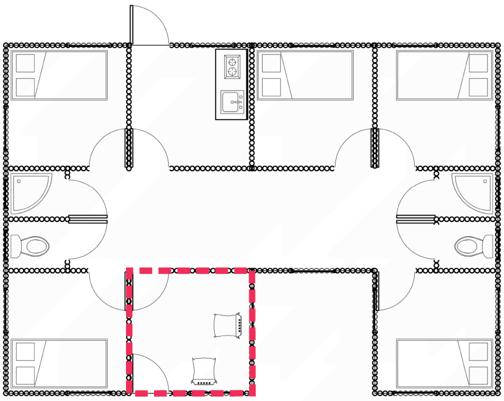


Figure 4.17: Plan of the Family Residential Unit Emphasising the Fulani No-entry Culture

4.10. Structure Situation Before and During Flood

The structures are designed to rise to a maximum height of 3 metres during flooding. This is the highest flood level in Girei as earlier mentioned. Figure 4.18 are images of how some typical building type units will look like before and during flood.

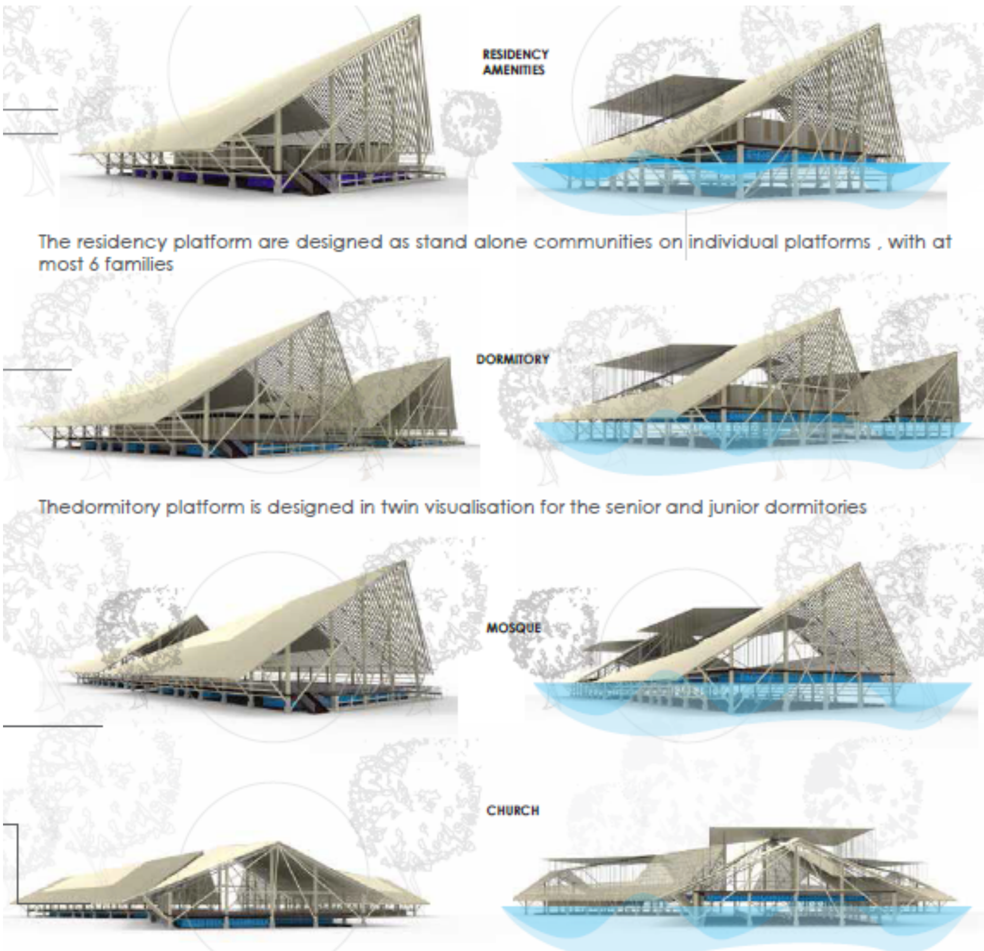


Figure 4.18: Some Building Typologies Before and During Flooding

4.11. Finishing Materials

The finishing materials used create an understanding of the spatial context for everyone including the physically challenged, especially the blind. They allow for easy navigation when the visually impaired touch surfaces. This was done in accordance with the universal design ideology which entails that designs should be accessible and usable by everyone regardless of people's ability status [28; 29; 30; 31]. Table 4.1 shows the wall, floor and ceiling materials used for the residential units generally.

Table 4.1: Finishing Materials Used in the Residential Units

Living Spaces	*Wall*	*Floor*	*Ceiling*
Bedrooms	50 mm diameter bamboo wall system held in place by U-shaped hardwood floor bracing.	Timber floor system laid on tarpaulin (damp proof membrane), supported by 50 mm by 75 mm floor joists, without raffia mat.	Woven raffia mat ceiling system inserted in support poles.
Bathrooms	50 mm diameter bamboo wall system held in place by U-shaped hardwood floor bracing.	Timber floor system laid on tarpaulin (damp proof membrane), supported by 50 mm by 75 mm floor joists, without raffia mat.	Woven raffia mat ceiling system inserted in support poles.
Living Areas	Scratched 50 mm diameter bamboo wall system held in place by U-shaped hardwood floor bracing.	30 mm woven raffia mat laid on timber floor system encased with tarpaulin (damp proof membrane), supported by 50 mm by 75 mm floor joists.	Woven raffia mat ceiling system inserted in support poles.

4.12. Images of Key Building Components

Figure 4.19 is a presentation of images to show the key building components used in the design proposal.

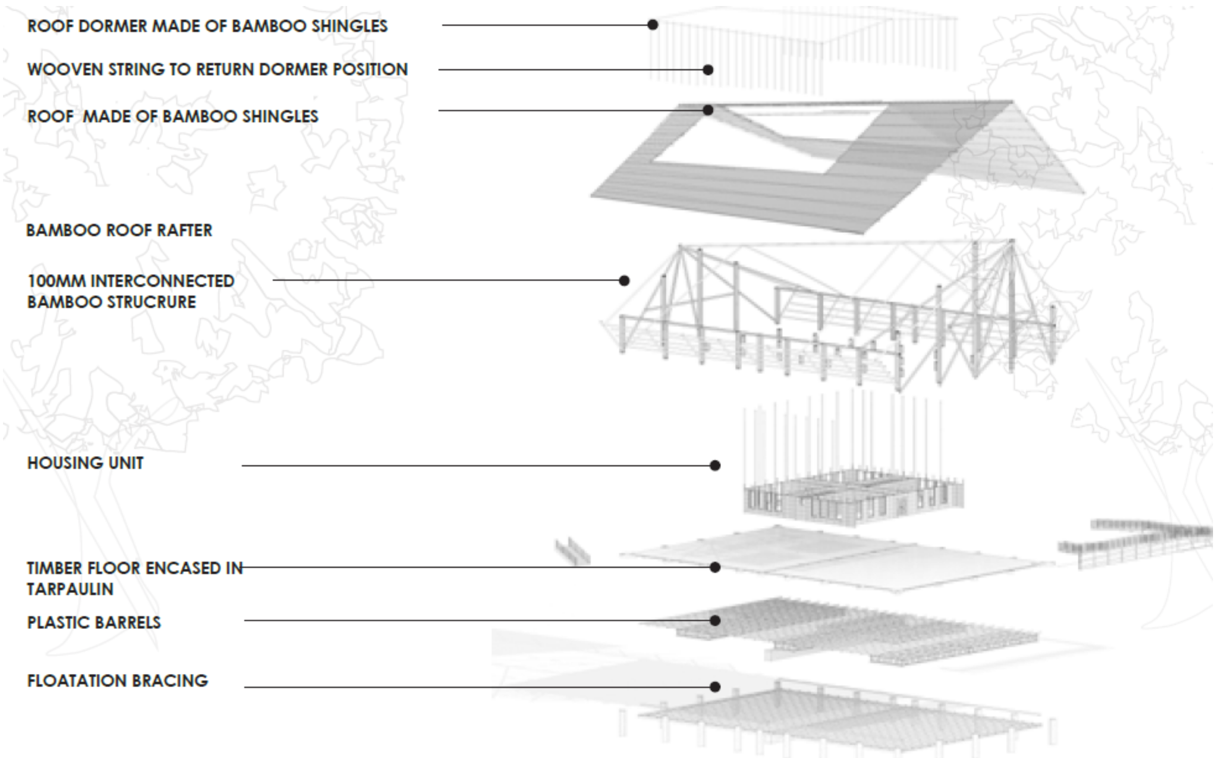


Figure 4.19: Images of Key Building Components

4.13. Building Design Step-by-Step Process

Step 1: Steel pegs are hammered into the dry sand along the perimeter of the proposed platform. This is done to establish skin friction between the sand and the steel to form the primary support for the platform. Bamboo poles are then attached to the steel pegs as shown in Figure 4.20.

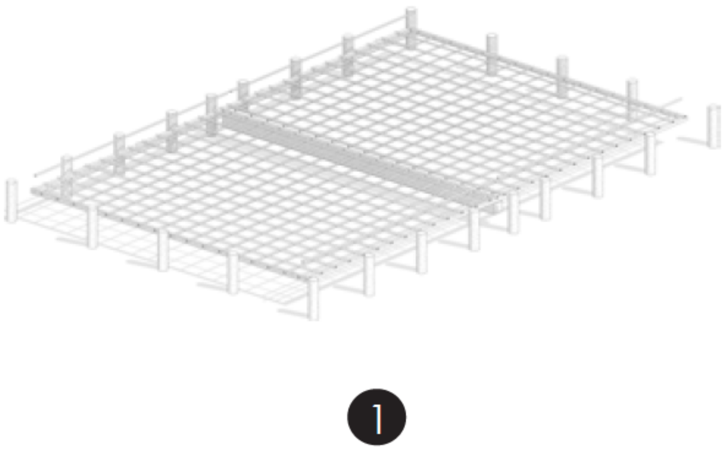


Figure 4.20: First Step of the Platform Construction

Step 2: In order to create an easy base for the floatation mechanism, a grid bamboo system is created which will allow the water to pass through the spaces and interact with the plastic barrels to float the platform. The grid system is made by tying horizontal and vertical bamboo sticks together at stipulated intervals. The barrels are then laid within the boundaries of the grid as shown in Figure 4.21.

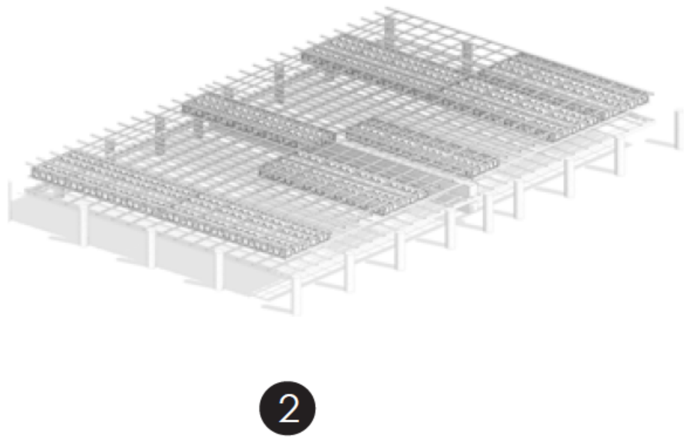


Figure 4.21: The Second Step of the Platform Construction

Step 3: The damp proof membrane (monolithic tarpaulin), is used to encase the plywood in order to protect the water from harming the base. The plywood floor system is then attached to the bamboo poles with the aid of 5 mm steel brackets as illustrated in Figure 4.22.

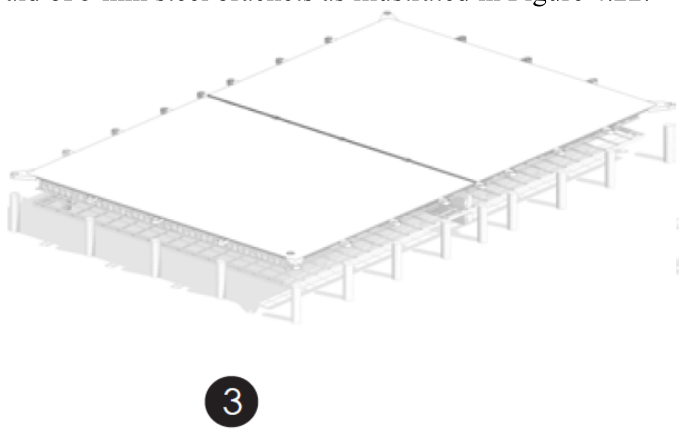


Figure 4.22: The Third Step of the Platform Construction

Step 4: The 100 mm bamboo rafters are tied together to form the shape of the platform and emulate the design concept. Sandbags are then laid on top of the rafters to provide an impervious membrane to moisture as shown in Figure 4.23.

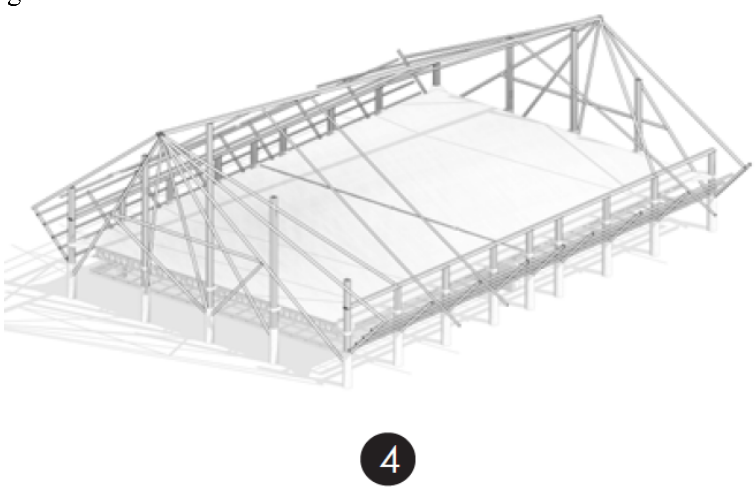


Figure 4.23: The Fourth Step of the Platform Construction

Step 5: The roof is made by interlocking bamboo poles cut in half. After which it is attached to the previously pegged bamboo posts and rafters as shown in Figure 4.24.

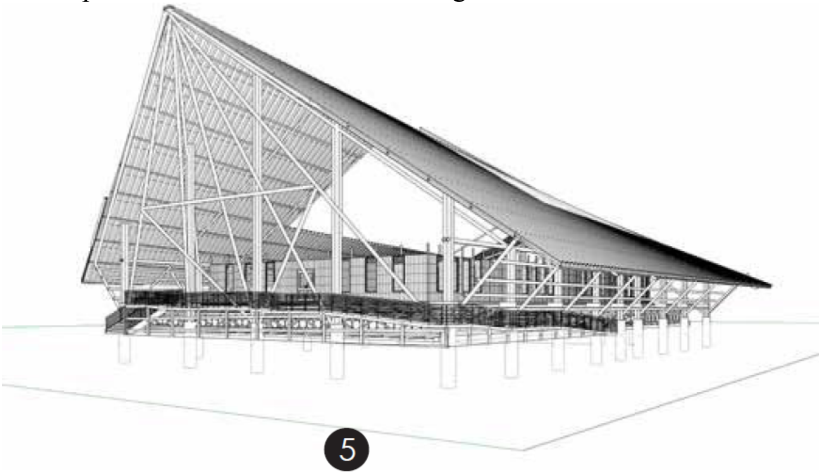


Figure 4.24: The Fifth step of the Platform Construction

4.14. Key Materials Used

4.14.1. Site Concept. 100 mm Gadua Bamboo was selected as the main construction material for the structural posts as well as the roof of the platform. 50 mm Gadua bamboo was chosen for the construction of the walls of the individual buildings. Bamboo was selected for a number of reasons some of which include: its peculiar strength and availability in Nigeria; its durability and lightweight characteristics; and its workability ease. Figure 4.25 shows examples of how the bamboo can be used to create walling components.

Figure 4.25: Walling Components made with Bamboo Sticks

The walls of the building are designed to be constructed by tying vertical bamboo sticks with a raffia twine along a track made using hardwood. The bamboo sticks are closely spaced to ensure privacy. The roofs of the buildings are designed to have overlapping halved bamboos tied together with waterproof membrane such as, used cement bags to prevent water seepage into the building spaces.

4.14.2. Hardwood. Hardwood planks are used for the floor of the platform, which is then enclosed with an impermeable material such as large monolithic piece of tarpaulin to prevent water seepage, which may cause the wood to decay over time. The hardwood floor was selected because of its lightweight, ease and speed of construction. Plate 4.1 is an example of how the hardwood can be used to construct the floor component.

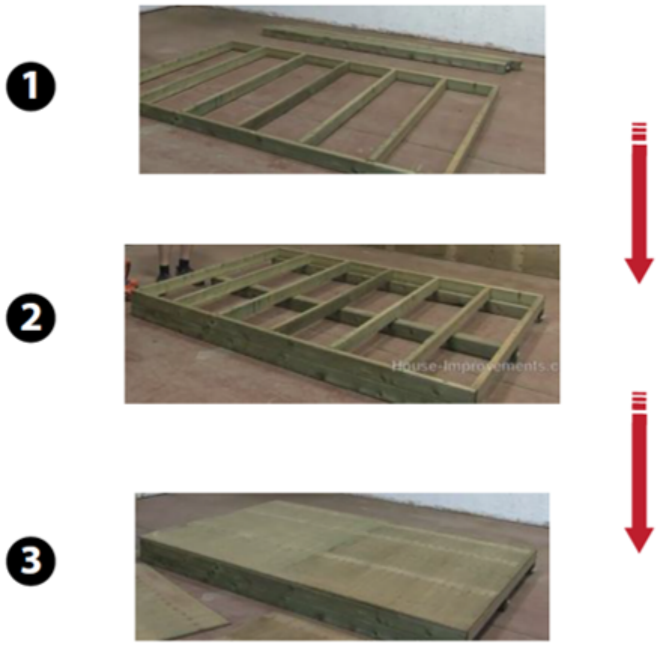
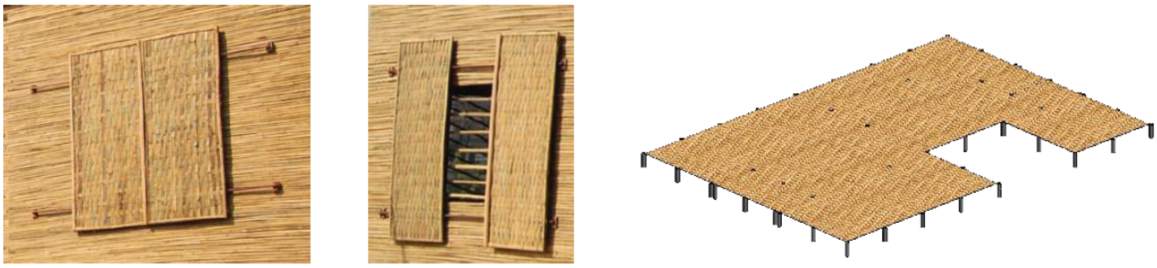


Plate 4.1: Process of Constructing the Timber Floor
Source: [20].

4.14.3. Plastic Barrels. Plastic barrels are readily available materials used to achieve buoyancy which enables the building to float when it interacts with water. They are positioned beneath the floor of the building within a timber frame, such that they cover the entire area of the floor platform to balance the weight of the load on the platform. Plate 4.2 shows an example of how the plastic barrels are coupled to achieve buoyancy.

Plate 4.2: Plastic Barrel used to achieve Buoyancy
Source: [20].

4.14.4. Raffia. Raffia is a fibre obtained from leaves of the raffia palm, an indigenous tree found in the Northern part of Nigeria, where the proposed site is sited. It is usually used for making mats, baskets and hats. However, for this project, woven raffia is used for the doors, windows and ceiling of the buildings. It was selected, because it is lightweight, readily available and the Fulani people are already used to it. Figure 4.26 shows examples of how the raffia can be weaved to make window and ceiling components.



woven raffia sliding window *woven raffia ceiling*

Figure 4.26: Woven Raffia Weaved to make Window and Ceiling Components

4.15. Innovative Design Strategies.

4.15.1. Site Concept. The concept of the proposed design was inspired by the Fulani native term for their home known as “Bukaru”. Bukaru translated literally means grass house as mentioned earlier. The building design was developed along this line as shown in Figure 4.27. This was done to enable the Fulani group to appreciate the uniqueness of their culture, with the primary goal of providing a familiar building structure which can help to lessen the pain of being displaced.

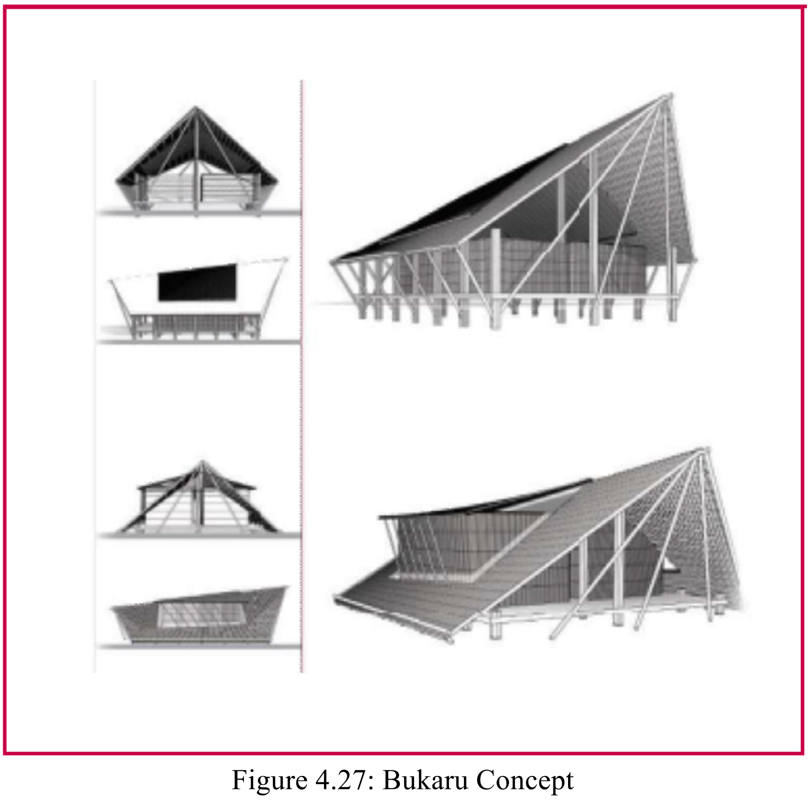


Figure 4.27: Bukaru Concept

4.15.2. Amphibious Structures. An amphibious structure utilises a form of floating foundation which allows a building to be constructed on land, but able to move vertically upwards when affected by flood. The structural system designed for the building is able to lift the building through the use of buoyancy blocks or any similar material such as plastic barrels, positioned beneath the building. The buoyancy blocks are then connected to the sub-frame of the foundation and guideposts are installed at intervals to keep the building in place along the horizontal axis, while simultaneously allowing it to rise vertically upwards during a flood and settle vertically downwards after the flood. Figure 4.28 shows how different structure types behave under flooding.

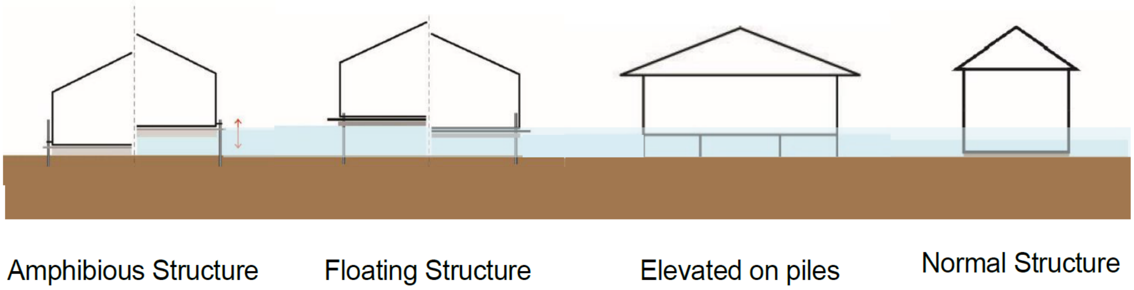


Figure 4.28: Types of Building Structures and their Action during Flooding
Source: [20].

4.15.3. Shed Dormer Roof. The roof of the building was designed to incorporate a shed dormer roof. The shed dormer is sloped towards the same direction as the principal roof and at the same angle with the principal roof. The roof dormer is triggered to open as the platform moves vertically upward and comes in contact with it as shown in Figure 4.29.

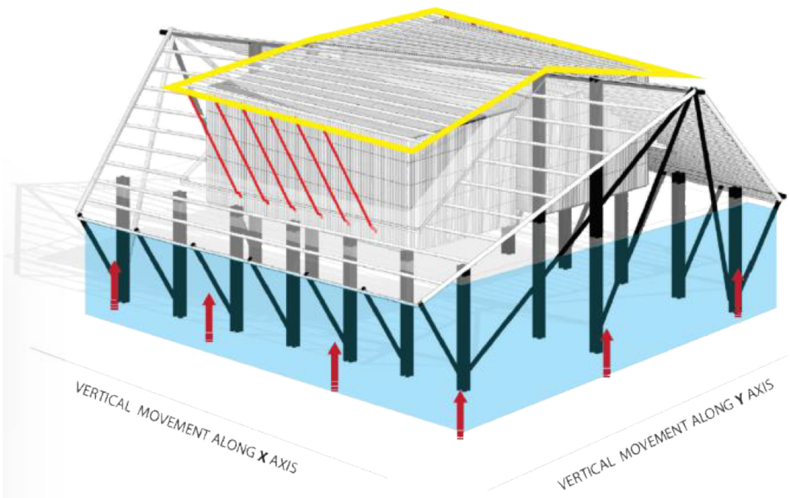


Figure 4.29: Shed Dormer Roof

4.15.4. Humus Toilet. The humus toilet bowl was employed to address sanitary needs of the settlers in the camp. The humus toilet comprises a manually constructed platform with a removable compartment for disposing of human waste. It utilises sawdust, ash or soil to aid decomposition. This method of waste disposal is an ingenious way of ensuring that in times of flood, human activities can still be carried out without interruption. Also, the waste material can be used as humus for farming after about a month. Figure 4.30 and Figure 4.31 are presentations of the humus toilet and how it is located in a structure.

Figure 4.30: Humus Toilet Bowl

Figure 4.31: Humus Toilet Positioned in a Structure

4.15.5. Eco-cooler. An eco-friendly cooling system known as eco-cooler was employed to cool the buildings, due to the high temperature of the geographical region where the project was sited. The thermodynamics principle used here is known as the “Joule - Thomson Effect” and the procedure is referred to as “Throttling”. It makes use of plastic bottles which have different diameters as a means to reduce indoor temperature and ensure thermal comfort of the indoor environment as shown in Figure 4.32. As hot air rushes into the larger diameter of the plastic bottles, it comes out through the bottleneck with a higher pressure to improve the thermal comfort of the residents. Research has shown that this method of cooling the indoor environment lowers indoor temperature by about 10 degrees.

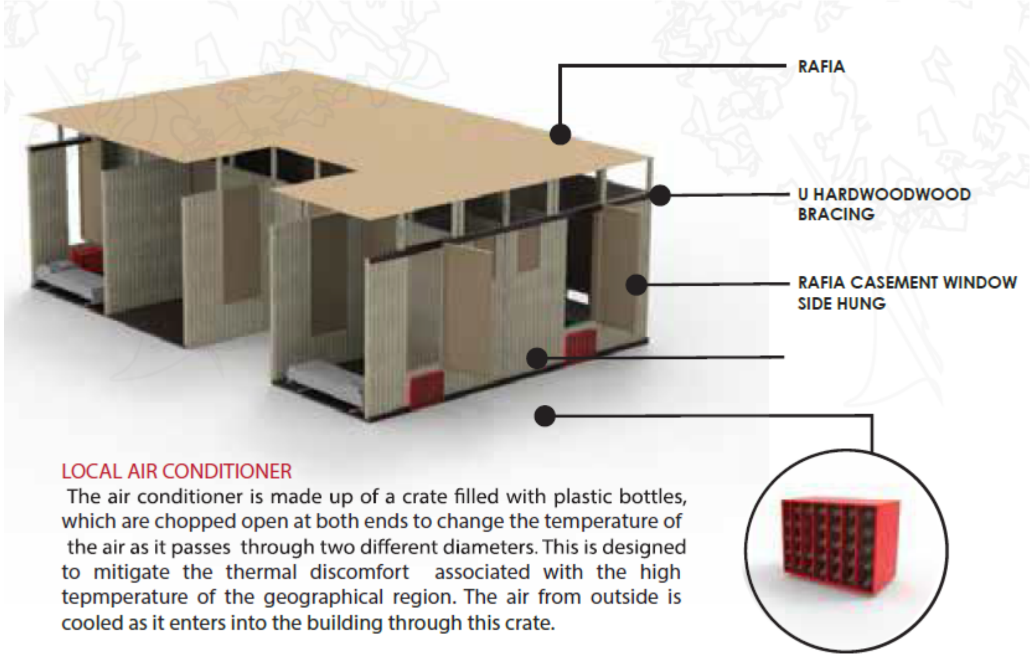


Figure 4.32: Location of Eco-cooler in the Building

The following figures 4.33, 4.34 and 4.35 show the IDPs settlement situations before, during and after flood respectively.

Figure 4.33: The IDPs Settlement Design Proposal Before Flood

Figure 4.34: The IDPs Settlement Design Proposal During Flood

Figure 4.35: The IDPs Settlement Design Proposal After Flood

5. Conclusion

The research goal was to develop an architectural design proposal for an Internally Displaced Persons (IDPs) settlement that can withstand the peculiar challenges caused by flooding in Nigeria, using

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resilient design strategies. The paper promoted the use of flood plains of Adamawa State (specifically Girei) for the development of the IDPs settlement using resilient strategy of amphibious structures made of sustainable materials such as, bamboos, thatch and impervious membranes, all buoyed up using water tight plastic drums. Based on the design, culture of the Fulanis (who are the envisaged main beneficiaries) and weather conditions, each structure and its appurtenances differ within the camp, depending on its use, type and number of occupants. Though the project is an architectural design proposal, it is intended to support human existence by providing a solution to a social problem in flood-prone areas of Northern Nigeria with minimal conflicts.

The resilient design approaches adopted were social resilience (integrating the culture of the people in the building process and design requirements) and physical resilience (adopting the use of amphibious structures that uses the theory of floatation to withstand the negative effect of flood). The combination of both strategies allowed for a design proposal that addressed an environmental problem without compromising the socio-cultural setting of the community where the project was sited. This design conceptual approach is considered sustainable to meet the envisaged challenges associated with flooding in order to stand both the test and taste of time.

A significant contribution of the study is the conceptual idea upon which the design proposal was hinged. Usually, architectural designs of settlements are developed to resist the adverse effect of weather or nature. However, the idea upon which the design proposal was developed is for the structures in the IDPs settlement not to resist flood, but to co-exist with the flood. This is the idea that motivated the choice of amphibious structures as a strategy to combat flood. The structures were designed to rise during flood and return back to their natural state after the flood subsides. This means that the settlement structures will float, but remain stable and usable during flooding. After the flood subsides, the structures are expected to return back to their normal position without any damage to the buildings or properties of the inhabitants. Another significant contribution of the study is the development of an IDPs settlement scheme that combats flood in Northern Nigeria using a combination of resilient design strategies and sustainable local materials. A combination of amphibious structures strategy and simple sustainable innovative design solutions were used to develop a scheme that provided an answer to an environmental problem, as well as the peculiar social, cultural and religious issues associated with the community where the scheme was sited. Also, the study has established a new empirical basis upon which further studies can be developed on the topic.

Due to the large scale of the scheme, it is envisaged that the architectural proposal will require a substantial amount to turn the project into a reality. Hence, regardless of the ingenuity of the design, the authors recognise that for such a settlement to be successfully implemented, it will require government initiative, but with the support of the private sector in the form of private companies, religious bodies, as well as local and international non-governmental organisations. Also, this study focused mainly on solving the issue of flooding using amphibious strategy as a resilient design approach. Further studies can also explore the possibility of employing more resilient design strategies to tackle other natural environmental challenges such as earthquakes, draughts, landslides, volcanic eruptions and tsunamis in the development of human settlements. In addition, the authors recognise that the approach used to gather and analysis data to develop the proposal, constitute a limitation for the research as some valuable data might have been excluded from the data gathering and analysis process. But that does not in any way take away the valuable contributions of the research earlier highlighted. As a follow up to advancing knowledge in the field, related studies could be conducted using a wider scope to gather and analyse data.

6. Credit

The credit for this research work goes to the following six authors: Sholanke A. B., Chilaka D. A., Oti M. A., Nelson S. A., Nnatuanya M. C. and Udezi B. E. The status and contributions of the authors are as shown in the following table:

Table 1: Authors' Status and Contributions

SN	Name	Status	Contributions
1.	Sholanke A. B.	Author	Conceptualisation, Formal Analysis, Funding Acquisition, Methodology, Project Administration, Resources, Supervision, Validation, Visualisation and Writing (review & editing).
2.	Chilaka D. A.	Co-author	Data Curation, Formal Analysis, Investigation, Software, Visualisation and Writing (original draft).
3.	Oti M. A.	Co-author	Data Curation, Formal Analysis, Investigation, Software, Visualisation and Writing (original draft).
4.	Nelson S. A.	Co-author	Data Curation, Formal Analysis, Investigation, Software, Visualisation and Writing (original draft).
5.	Nnatuanya M. C.	Co-author	Data Curation, Formal Analysis, Investigation, Software, Visualisation and Writing (original draft).
6.	Udezi B. E.	Co-author	Data Curation, Formal Analysis, Investigation, Software, Visualisation and Writing (original draft).

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