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MITIGATING THE IMPACT OF RAINFALL ON THE BONNY ISLAND BUILT ENVIRONMENT

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ABSTRACT

The location of Bonny bestows the Island with a climate that poses unique challenges to the built environment. Standout data, for instance, reveals that Bonny Island receives approximately 4000mm of rainfall annually, amongst the highest of any Nigerian town. Prior research established that presently, the Bonny Island built environment does not adequately respond to its insular climate. The adverse impact of heavy rainfall on the built environment especially in urban areas is regrettably obvious as rain delivers a significant amount of water for various deterioration mechanisms from rising damp to deterioration of concrete reinforcement. Also because of global warming there is potential for the intensification of extreme rainfall events and thus an increase in climate vulnerability of the built environment. However, the considerable negative consequences are mostly underestimated when not addressed holistically. The problem is the marked absence of research-based architecture and planning parameters and guidelines that mitigate the Bonny insular climatic challenges, which is available to the population at large. Consequential changes like the upsurge of employment opportunities of Nigeria Liquefied Natural Gas Company (NLNG ***SevenPlus***), the proposed deep-sea port, and the road link to the mainland with their consequent potential for heavy migration into the island can alter the demographics significantly, lunching a developmental and infrastructural explosion on Bonny Island. These changes all underscore the importance for researched mitigation strategies and guidelines in response to the rainfall, based upon current scientific knowledge, techniques, materials, and methods of construction. This study focuses on, identifying both advantageous and adverse rainfall impacts, mitigating parameters and weather management strategies specific to Bonny Island. The methodologies used in this *ex-post facto* research included literature review that established the inadequacies of the broad regional approach to climate response for design purposes, opting for site-specific climate variations as determinants of design parameters and guidelines. The approach is passive observational, relying on surveys, individual depth interviews and photographic documentation. Also obtained were secondary archival climatic data as well as prior information from the Bonny Island Joint Industries Committee (JIC), NLNG, SHELL and MOBIL. Data analysis identified persistently high rainfall and humidity as the most predominant climatic elements militating against comfort and sustainability of the Island's built environment. Guided by novel application of confirmed archival scientific principles and considerations for appropriate climate response objectives, the recommendations for mitigating the impact of rainfall on Bonny Island was determined.

Keywords:

Built Environment, Sponge Property, Climate Vulnerability, Rainfall Events, Climate Response.

1.0 INTRODUCTION

The location of Bonny Island between latitude 4° 22' and 4° 32' North and longitude 7° 8' and 7° 20' East, covering an area of approximately 215 square kilometers bestows the Island with a climate that poses unique challenges to the built environment. Standout data, for instance, reveals that Bonny Island receives approximately 4000mm of rainfall annually, amongst the highest of any Nigerian town. (Barbour, Oguntoyinbo, Onyemelukwe, & Nwafor, 1982).

Ideally, the built environment should protect and insulate people from exposure to the harsher extremes of the climate (Lawal, 2013). However, without information on climate response specific to the island, the climate affects the built environment, limiting its effective role. Furthermore, being an island, incorporating weather management techniques, guarantees more efficient and effective use of the land, (Ede, Adeyemi, & Joshua, 2013).

A study of urban housing problems in Nigeria reveals that most developments are not climate responsive. They lack good sanitation, ventilation, and effective drainage facilities, paying no heed to issues of climate and the environment (Barbour, Oguntoyinbo, Onyemelukwe, & Nwafor, 1982). Bonny Island is a part of this unpleasant picture and ignorance, apathy and weak institutions further worsen the situation. Research by Agboola (2011), Lawal (2013), Nwalusi, Anierobi, Efobi, & Nwokolo (2015) and Shemirani & Nikghadam (2013) reveal a consensus on the importance of climate responsive built environments. However, climate response is site specific (Giovani, 1976), (Szokolay, 1986), (Upadhyay, 2007), (Lawal, 2013). The study area Bonny Island falls within the tropical region defined by the geographical area between the tropics of Cancer ($23^{0}26^{'}$ N) and Capricorn ($23^{0}26^{'}$ S). The region is vast, and geographers view the "tropics" more as a family of tropical regions lying between and near the boundaries of the parallels, whose specific climate is as varied as the specific geographical context. This is corroborated by Lawal (2013), who holds that the built environment is the climate modifier that should respond to its specific prevailing climate, (Lawal, 2013; Nwalusi, Anierobi, Efobi, & Nwokolo, 2015). This study focuses on, identifying adverse rainfall impacts, in a bid to develop mitigating weather management strategies specific to Bonny Island without which the negative picture of climate vulnerabilities would propagate. Consequential changes like the upsurge of employment opportunities of (Nigeria Liquefied Natural Gas Company) NLNG ***SevenPlus,*** Island-mainland road link, and the Bonny deep-sea port, Danjuma (2020) with their potential for heavy migration into the island can alter the demographics significantly, lunching a developmental and infrastructural explosion on Bonny. It is thus imperative for guidelines to ameliorate adverse aspects of the Bonny insular climate.

This *ex-post facto* (after the fact) research relied on a mixed method of both qualitative observations and quantitative analysis of surveys. This research in environment directs attention and effort on issues that have already taken place, like the climate, with a view to identify any associated problems in order to determine and propose mitigating strategies. The approach is passive observational Cook and Campbell, (1979); Ede, (2009), with no chance of intervention by researcher. The effort is guided by the analysis of:

- Archival climatic data: Rainfall on Bonny Island.
- Results of public perception survey of climatic impacts on Bonny Island.
- Individual depth interviews of key stakeholders on Bonny Island.
- Direct observation with photographic documentation.

Following from the above, and in line with considerations for climatic response objectives, the mitigating options for rainfall drew on novel application of confirmed scientific data, materials and methods for the recommendations of climatic response for the Bonny Island built environment.

2.0 CLIMATE DATA: RAINFALL ON BONNY ISLAND

Climate refers to the statistics of the state of the environment over a long period, generally taken to be thirty years as defined by the World Meteorological Organization (WMO, 2017). The following rainfall data by Weather Spark illustrates the typical weather in Bonny based on a statistical analysis of historical hourly weather data and model reconstructions from January 1980 to December 2016, a period of thirty-six years. For weather data, the geographical coordinates of Bonny are 4.452° latitude, 7.171° longitude and 6 m. elevation. Elevation data is from Shuttle Radar Topography Mission (SRTM), by NASA's Jet Propulsion Laboratory.

Rain, one form of precipitation, has considerable effect on the exterior of building's materials, water/damp proofing, roof slopes and drainage (Ogunsote, 1991). Convectional rainfall predominant in Bonny is where the surface air over sea or land is heated generating convection currents where warm moisture bearing air rises and cools. Cooler air cannot hold as much water vapor; consequently, at dew point, condensation occurs. When the air is no longer able to counter gravitational forces, moisture falls as rain

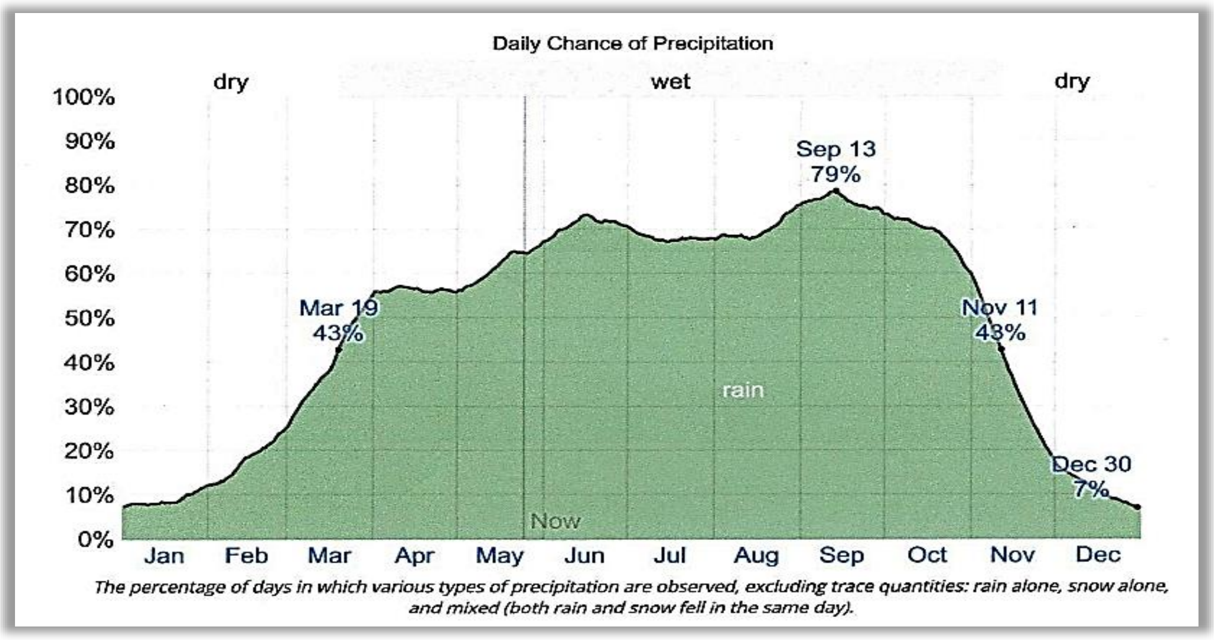

Figure 1 Daily Chance of Precipitation (Source: Weather Spark)

A wet day is one with at least 1 millimeter of liquid/liquid-equivalent precipitation. Figure 1 shows that the chance of wet days on Bonny Island varies very significantly throughout the year. The wet season lasts 7.8 months, March 19 to November 11, with greater than 43% chance of a given day being a wet day. The chance of a wet day peaks at 79% on September 13. The dry season lasts 4.2 months, November 11 to March 19. The smallest chance of a wet day is 7% on December 30.

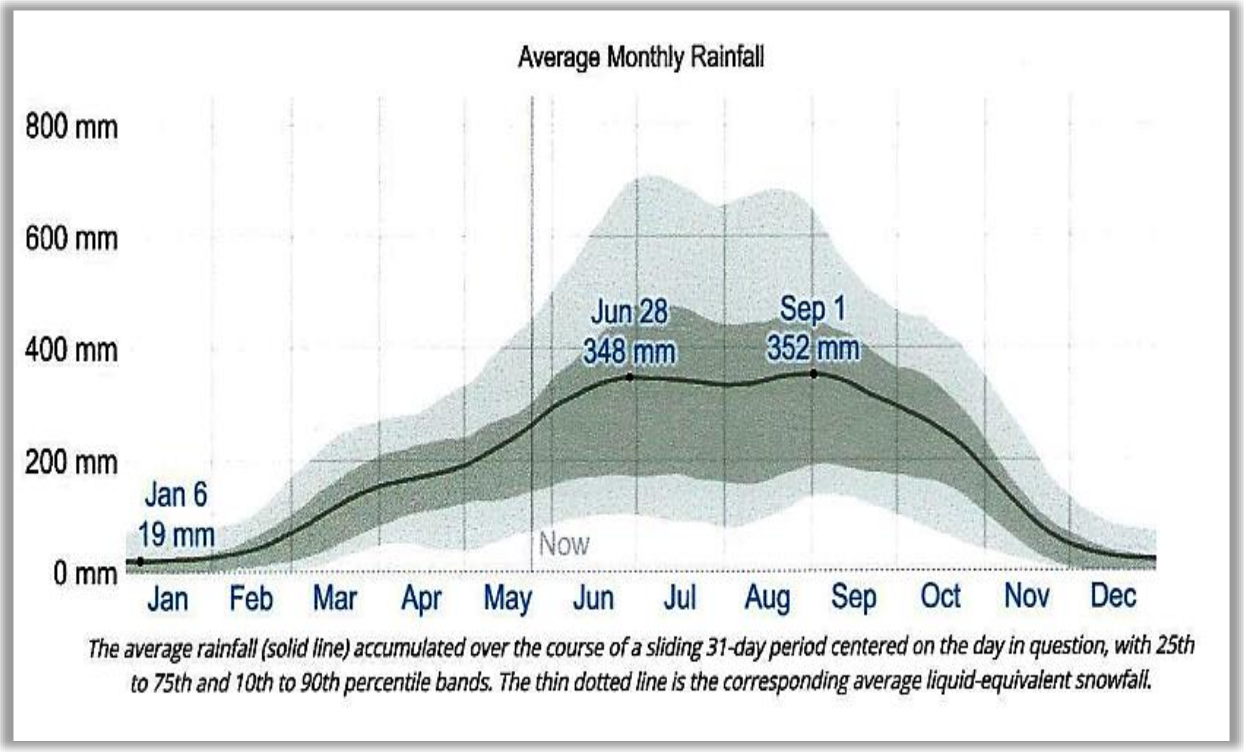

Figure 2 Average monthly rainfall. (Source: Weather Spark)

To show variation within the months and not just the monthly rainfall totals, Figure 2 shows the rainfall accumulated over a sliding 31-day period centered on each day of the year. Rain falls throughout the year on Bonny Island and the town experiences extreme seasonal variation in monthly rainfall. The most rain falls during the 31days centered on September 1, with an average total accumulation of 352 millimeters. The least rain falls around January 6, with an average total accumulation of 19 millimeters.

2.1 Results of public perception survey of climatic impacts on Bonny Island.

Administration of public perception surveys was undertaken expeditiously due to safety, concerns. The intention to conclude fieldwork efficiently in the shortest possible time and fewest boat trips was borne of safety/security concerns of the Niger Delta waterways.

Most Desirable and Undesirable Climatic Condition

Respondents were asked to state their most desirable and undesirable climatic condition. The Most desirable condition was "Warm", accounting for 44.3% (Figure 3). The Most undesirable climatic condition was "Cold", representing 49.4% of that distribution (Figure 4). Furthermore, respondents were asked to state the climatic condition affecting their building most negatively. The modal condition was "Rain" accounting for 45.1%. Others were "Humidity", "Wind" and "Sun", accounting for 26.8%, 24.3% and 3.8%, respectively.

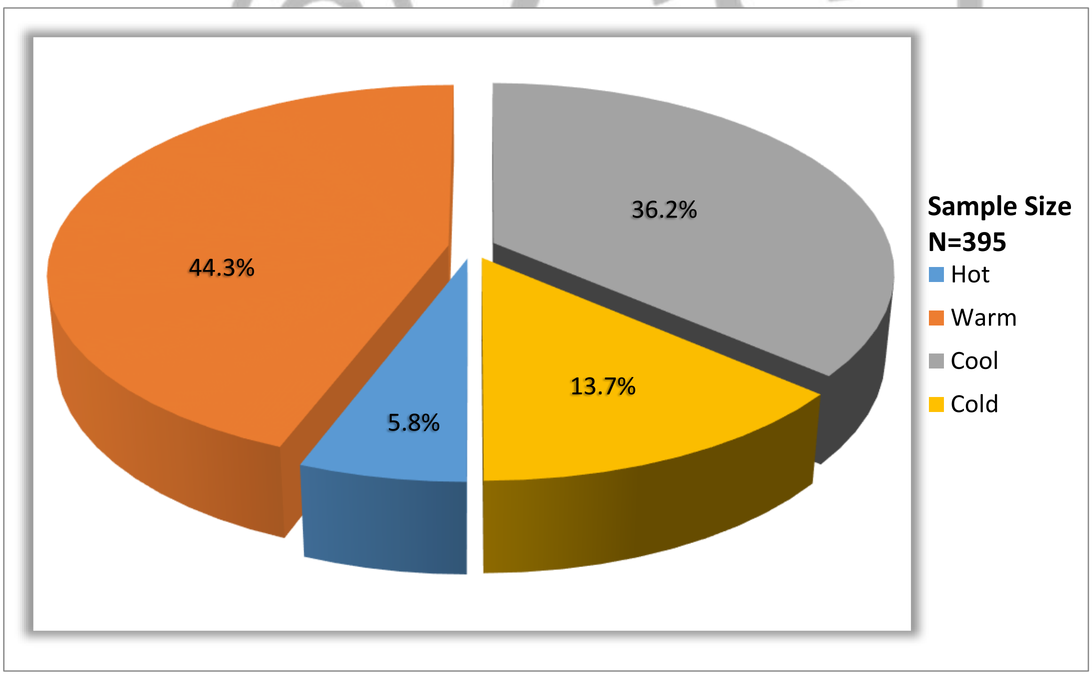

Figure 3 Percentage Distribution of Most Desirable Climatic Conditions (Source: Generated by Researcher)

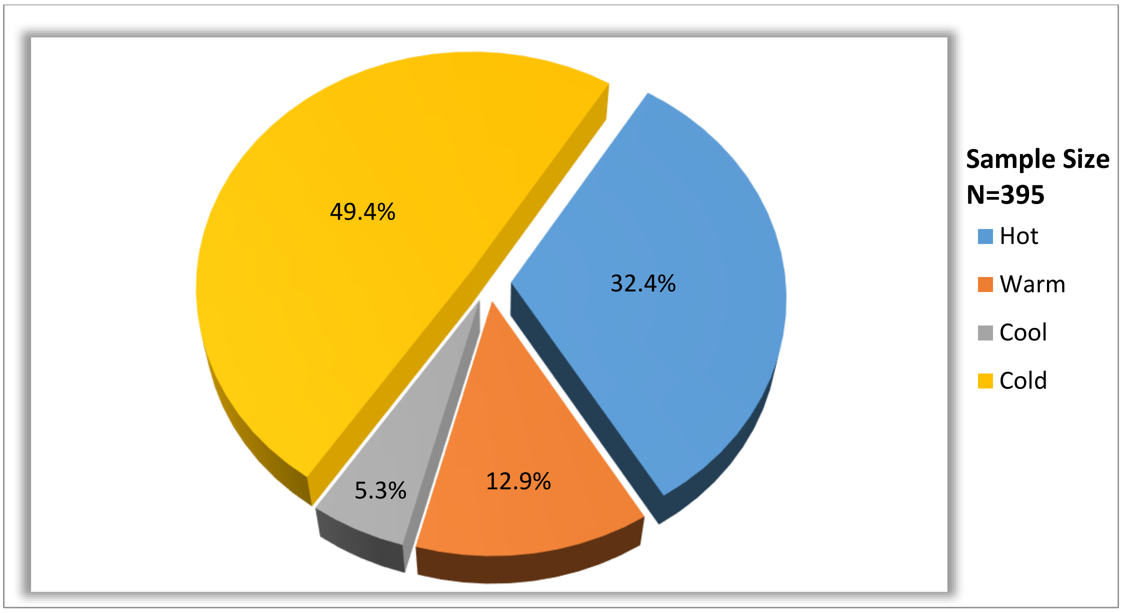

Figure 4 Percentage Distribution of Most Undesirable Climatic Conditions (Source: Generated by Researcher)

Type of Flooding Conditions

Table 1 presents the types of flooding in the study area. The modal type of flooding was "Temporary Flooding" (Plates 2) representing 47.8% of the distribution. When asked how long flood lasts, the modal response was "No flooding", accounting for 31.6%. Others were, "Under One Hour", "Under one Day", "Under One Week" and "Under one Month", accounting for 25.2%, 23.4%, 12.3% and 7.5%, respectively.

Table 1 Percentage Distribution of Flooding Types in the Study Area

S/N	Type	N	%
1	None	111	28.2
2	Temporary Flooding (Clears Soon After Rain)	188	47.8
3	Seasonal Flooding (Always In The Rainy Season)	57	14.5
4	Permanently Waterlogged	37	9.4
Total		**395**	**100**

(Source: Generated by Researcher)

Negative Impact of Rainfall on Building

Table 2 shows the impact of rainfall on buildings in the study area. The most common first mentioned negative impact of rainfall on buildings was "Peeling/fading of paints", accounting for 42.5% of respondents. For the second mentions, it was "Fungus attack", accounting for 41.6%. Furthermore, the most common third mentioned impact of rainfall on buildings was "Rising dampness", accounting for 48.4%.

Table 2: Percentage Distribution of Impact of Rainfall on Buildings in the Study Area

Impact	First Mentions		Second Mentions		Third Mentions	
	N	%	N	%	N	%
Temporary Flooding	117	29.9	42	14.3	24	8.7
Peeling of Paints	166	42.5	110	37.5	17	6.2
Fungus Attack	55	14.1	120	41.6	98	35.6
Rising Dampness Penetration	34	8.7	11	3.8	133	48.4
Leaking Roofs/Defective Roof Drains	19	4.9	8	2.7	3	1.1
Total	**391**	**100**	**293**	**100**	**275**	**100**

(Source: Generated by Researcher)

Wind Damage to Building (Driving Rain)

Respondents were asked to rate the effect of wind damage to their building. The modal rating was "Minor", accounting for 47.5%. However, those who said "Major" accounted for just 5.7% of respondents. (Response was used as an indicator of the magnitude of driving rain for triangulation of climate data).

2.2 Summary of Consensus Opinions from Individual Depth Interviews

On the existing Bonny Island urban fabric, most interviewees were not satisfied with the existing situation. They felt that not much could be done to the existing situation, but with concerted/collective effort, it was possible to chart a positive path for the future. They would rather have collective focus on future developments, with all stakeholders working together in a holistic effort at design of the urban fabric before execution in accordance with appropriate regulations and guidelines. They acknowledged that the Development Control Department of the Bonny local government responsible for the approval and monitoring of new developments was overwhelmed by the lack of funds, human/material resources and the absence of research-based guidelines optimized for mitigation of the Island's specific climatic challenges.

Most interviewees saw the climate as a disadvantage, while others felt that in addition to the climate other issues like; poor/non-execution of existing masterplans, the year-round wetness (rain) and the prohibitive cost of quality construction compounded the problems of climate. Those that saw the climate as a main disadvantage blamed the persistent rainfall and its attendant issues of temporary flooding, waterlogged soil, driving rain etc., as the number one problem. The heat (interpret as humidity) was considered a close second.

Not many of the interviewed stakeholders had suggestions for the authorities. Those that did acknowledge that the piece meal approach to development of the Bonny Island built environment, one plot at a time was not efficient nor satisfactory and that a holistic implementation of masterplans or urban designs under the careful supervision of an efficient development control department was necessary for uniform development. They also suggested that the driver of the masterplan implementation (NLNG, Local Government or other stakeholders etc.) must have the legal authority to impose order.

2.3 Results of Direct Observation (Photographic Overview)

Qualitative information obtained by passive direct observation and documented in the form of photographic data is self-evident, requiring little or no analytical narrative. The data is valuable for triangulation of other data sources thus increasing the validity and reliability of the research. The photographs show an obviously serious problem of rainwater damage in its various forms and consistently authenticate the data from surveys, Individual Depth Interviews, and archival climate data.

FLAKING, EFFLORESCENCE & FUNGUS GROWTH

FLAKING, EFFLORESCENCE & FUNGUS GROWTH

Bonny Vocational Center & Bonny LGA Offices.


FLAKING, EFFLORESCENCE, FUNGUS GROWTH & RISING DAMP.


TEMPORARY FLOODING

Buildings On Hospital Road & Pipeline Road.

Plate 1


TEMPORARY FLOODING


TEMPORARY FLOODING

Temporary Flooding: Hospital Road & Ukpo Avenue.


STORMS GATHER


TEMPORARY FLOODING

Storms Gather On NLNG Jetty Road, & Temporary Flooding, Akiama-Oguade Road.


FLACKING & FUNGUS GROWTH


FLACKING & FUNGUS GROWTH

Rainwater Damage; Mccauley Street & I. T. Williams Street.

Plate 2


FLACKING, RISING DAMP & FUNGUS GROWTH


FLACKING, RISING DAMP & FUNGUS GROWTH

Rainwater Damage; Building on Mccauley Street.

3.0 IMPACT OF HEAVY RAINFALL ON BONNY ISLAND BUILT ENVIRONMENT.

On Bonny Island, based on climate data authenticated by the public perception survey and photographic documentation, rainfall is the standout element of concern with respect to climate vulnerability of the built environment as seen in the photographic plates, particularly plate 2. As implied in the theme of the 86th German Conference of Environment Ministers, (UMK) 2017, heavy rainfall events affecting the environment undoubtedly pose an extraordinary risk to life, limb, and wellbeing. The currently significant amount of rainfall on Bonny Island Rainfall, (about 4000mm. annually) is likely to worsen. Because of global warming an increase in global temperature of 1.5°C - 2°C is expected by the middle of the century. Warmer air carries more water, which increases the potential for precipitation. Climate projections show that global precipitation will increase by about 2% for every degree rise in temperature (Kreienkamp, Huebener, Linke, & Spekat, 2012). Thus, on Bonny Island, precipitation volumes along with its attendant ills are likely to be higher than current volumes, which underscores the need for mitigation strategies.

While the extent of the built environment's vulnerability to rainfall ultimately depends on the materials and methods of construction, other factors for consideration include the following:

- Rainfall intensity and duration that may result in temporary flooding, dampness penetration and water inundation from wind-driven rain.
- Site location regarding the topography/landform, ground sealing, natural drainage, and development densities.
- Soil type and consistency as it concerns water penetration and moisture carrying capacity.

Water or moisture deposited on buildings because of rainfall may be from raindrops falling at their terminal velocity or because of wind-blown driving rain, which attacks the building envelope. Driving rain (or wind-driven rain) is the horizontal component of precipitation reaching a fictitious (as in the case of free driving rain) or a real vertical surface (Hogberg, 1998). The combined actions of gravity and wind vector determine the raindrop's trajectory. Straube, (2010) reiterates that water deposited on the above grade-building envelope by driving rain is larger than any other source of moisture in almost all building types and climates. Rainwater represents a significant threat to the built environment above and below grade as it infiltrates the perimeter material of buildings (walls, foundations, etc.) penetrating cracks/joints to cause dampness on the interior surfaces.

3.1 Effect of Rain on Bearing Soil

A consequence of the persistent rainfall on Bonny Island is water-saturated soils. Depending on soil consistency, rainfall intensity, duration, and frequency (IDF), a certain amount of infiltration occurs, and soil moisture increases. The temporary flooding problem on Bonny Island ranges from mild to heavy depending on the specific location and season. There are no intensity, duration, and frequency (IDF) figures specific for Bonny Island, but of the rainfall intensity studies of ten cities in southern Nigeria (Ondo, Ibadan, Wari, Benin, Oshogbo, Ikeja, Port-Harcourt, Umudike, Calabar and Enugu), Port-Harcourt, (the closest), 40miles north of Bonny Island has the highest rainfall intensity (207.40mm/hr.), (Oyegoke, Adebanjo, Ajani, and Jegede, 2016). Bonny Island is reasonably expected to have a higher (IDF) than Port-Harcourt as it has approximately 30% more annual rainfall. Where the soil is saturated or where the soil does not lend itself to infiltration (clay), there is the tendency for surface accumulation of water. The consequence of this is the flooding problem, corroborated by; a study of the Bonny Island soil association map Figure 4, soil infiltration rates Table 3, result of surveys Table 1 and 2, individual depth interviews, and the direct observation of the survey team. This form of temporary flooding with its attendant ills will eventually runoff if terrain or drainage patterns permit. Repeated runoff may result in undesirable surface erosion and ultimately in the exposure of building foundations.

The dampness penetration of unsealed foundation walls and the eventual capillary rise of moisture in the walls of the building reveals itself as watermarks (Plate 2) or stains on affected walls. This condition sometimes referred to as rising damp may cause cracks, crumbling plaster and mold.

Table 3 Soil Infiltration rates.

Soil type	applied infiltration rate	infiltrated volume (rain volume V = 3,600 m^3, duration of rain D = 1 h)	Share of rain volume
Clay	0 mm/h	0 m^3	0 %
Clay loam - loam	5 mm/h	~ 380 m^3	10 %
Loam - sandy loam	10 mm/h	~ 620 m^3	17 %
Sand	20 mm/h	~ 1000 m^3	30 %

Source: DAS, 2008

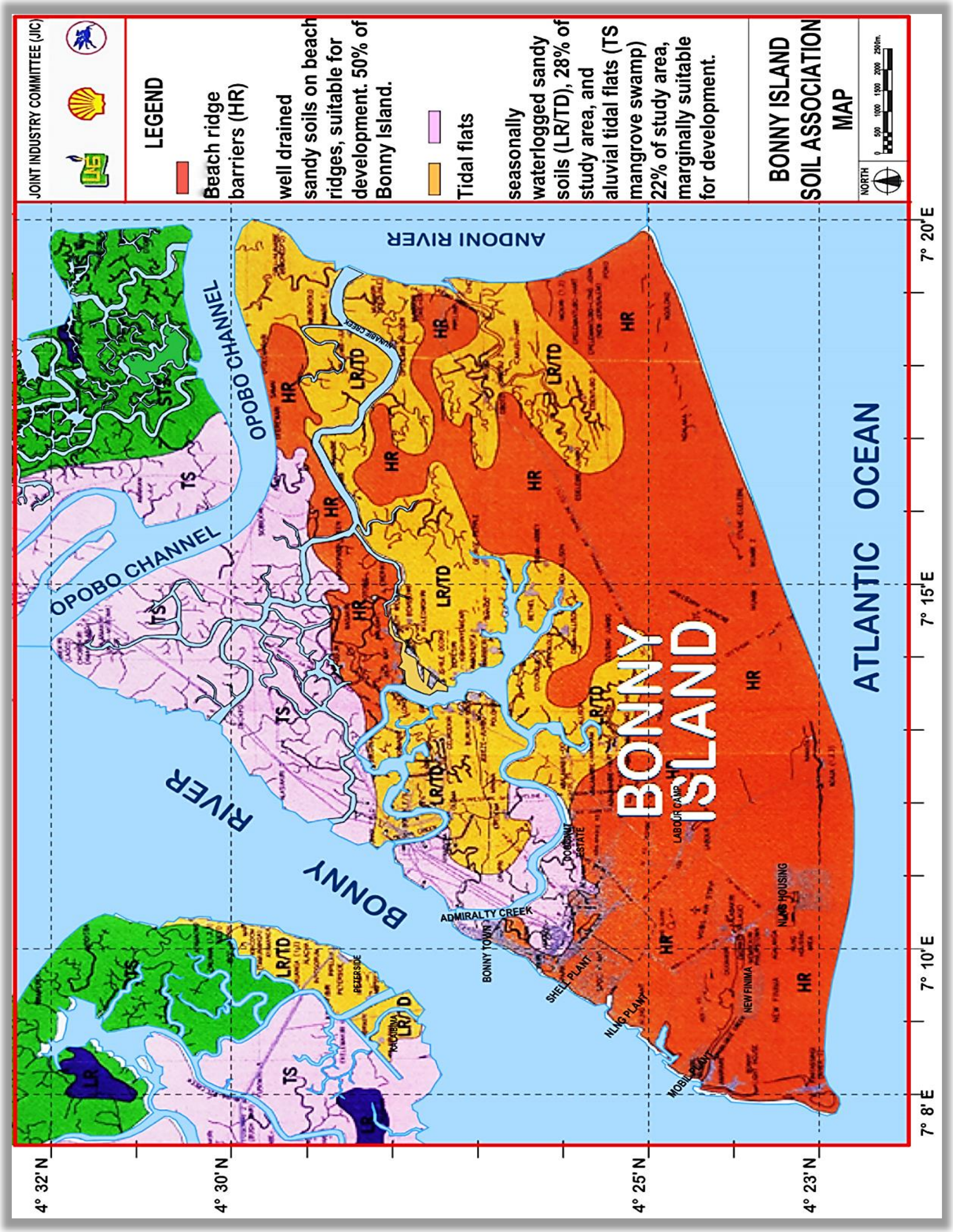

Figure 4 Bonny Island Soil Association Map
Source: (Al-Handasah & Uptonville, 2001)

Under conditions of temporary flooding, moisture penetration could occur through non-watertight openings like ground floor entrances and garage doors. Observed degradation of the built environment on Bonny Island due to rainfall includes one or more of the following:

- **Unstable Foundations**

  Foundation issues are traceable to the destabilization of the bearing substrate due to water. inundation. The expression of unstable foundations are vertical or diagonal cracks in walls.

- **Fungus stain and harmful growth**

  These thrive in the Bonny Island environments of permanent dampness, high humidity and low ventilation. They include creepers, molds and mildew on walls, and roofs.

- **Erosion of mortar joints**

  This is the consequence of salt crystallization due to the combined action of weathering by winds, the effects of plant growth, water penetration and permanent dampness.

- **Peeling paint (flaking)**

  This normally appears on surfaces, alternatively exposed to excessive amounts of rain, wind and sun. The paint becomes chalky wrinkled or blistered, peeling, or flaking off.

- **Defective plastered renderings**

  Surface cracks found on exposed building surfaces columns, beams and ceilings in hot humid climates because of biological attacks due to rain penetration. .

- **Defective Roof/Rainwater Channels**

  These rainwater channels include sagging or missing eaves, roof gutters, corroded or broken downpipes or down spouts and inefficient ground rainwater discharge of channels

- **Dampness Penetration Through Walls**

  The cause of this is water penetration through various routes. The most common way is either ‘rising damp’ through capillary action or from condensation due to inadequate ventilation.

3.2 Driving Rain.

As observed on Bonny Island, driving rain delivers a significant amount of water for various deterioration mechanisms. The mantra for sustainably designed built environments concerning rainfall is to prevent, protect and resist moisture in its various forms, (precipitation, driving rain, air humidity and condensation). The three-D's: **Deflection, Drainage, and Drying** describe a holistic approach to driven rain control, (Straube J. , 2010). This requires knowledge of rainfall levels, wind vectors and building material properties. From calculations by Straube (2010), supported by field measurements (Schwarz 1973; Sandin 1988; Flori1992; Henriques 1992; Kuenzel 1994; Straub 1998; Blocken and Carmeliet 2000), wind tunnel test (Inculet, 1994) and computer modeling (Choi 1994; Karagiozis et al 1997), we get a picture of the rain deposit pattern of driving rain as it encounters squarely a vertical surface based on the Rain Deposit Factor (RDF) figures, (Figure 6). Mitigation strategies in response to driving rain derives from the following observations of the aerodynamics of driven rain:

- Rain deposits on a vertical plane increase with height, consistent with wind speeds at the height. Tall buildings facades receieve higher levels of driving rain (Straube J. , 2010).
- Rain deposits increase towards the edges of the vertical plane, which is also consistent with the aerodynamics of the wind as it wraps around an object in its path.
- Hip (peaked) roofs with deep eaves affect the aerodynamics, redirecting airflow over the building, with wind eddies pushing down under the eaves. As observed Straub (1998), hip roofs not only leak less (easy run-off) they reduces the amount of driving rain on the walls.

Design options in response to driving rain that build on the foundation of these observations may not entirely solve all the problems associated with driving rain but would mitigate the impact and improve the situation. With a knowledge of the foregoing and Bonny Island's climatic data, it would be instructive to consider the following:

1. Choosing lower buildings (bungalow), siting to drain away from building (5% slope min.), and landscaping with plants to reduce wind speeds.
2. Avoid the use of parapet walls without overhanging roofs or coping. Overhangs and peaked (hip) roofs reduce rain deposits by approximately 50%, (Straub, 2010). They protect by redirecting airflow and sheltering perimeter walls on all four sides.
3. Moisture that reach the walls form a film of water and flow down under gravity. Wall trims, architraves, and drip edges (flashing) direct the flow away from fenestration.
4. Three wall types identified for their resistance to moisture are:
   - Storage mass wall (single Wythe masonry block wall).
   - Perfect barrier wall (curtain wall system).
   - Drained screened wall (masonry wall with metal cladding).

Storage mass wall is preferable against driving rain on Bonny Island as it has enough storage mass to absorb moisture and release by evaporative drying before it penetrates the interior space. Waterproof rendering and flashings keep the water at bay, (Figure 5).

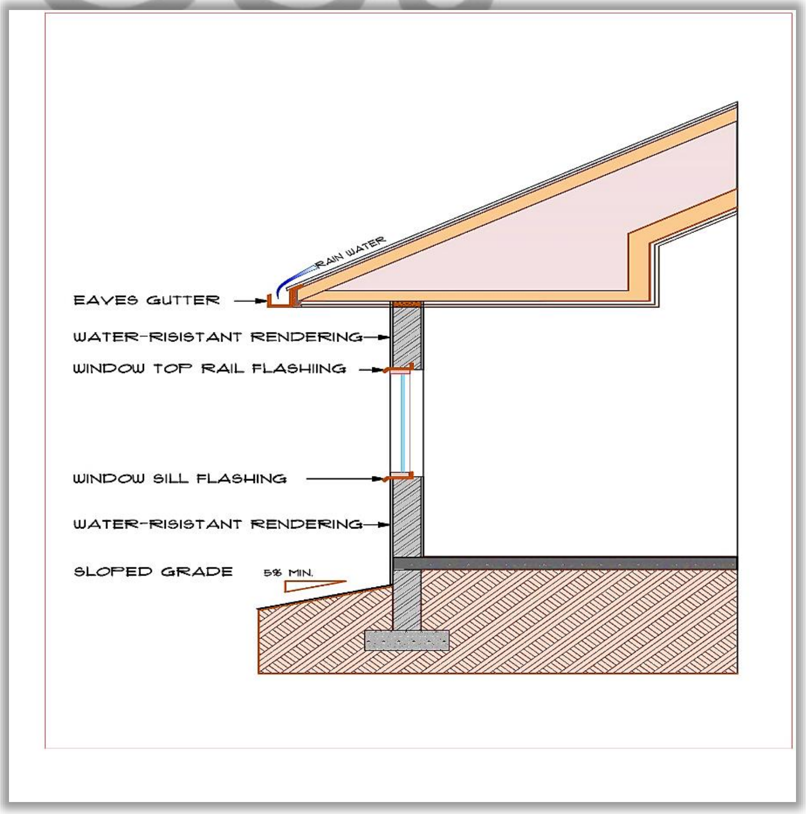

Figure 5 Schematic Representation: Perimeter Wall Arrangement for Protection from Driving Rain. (Source: Generated by the Researcher)

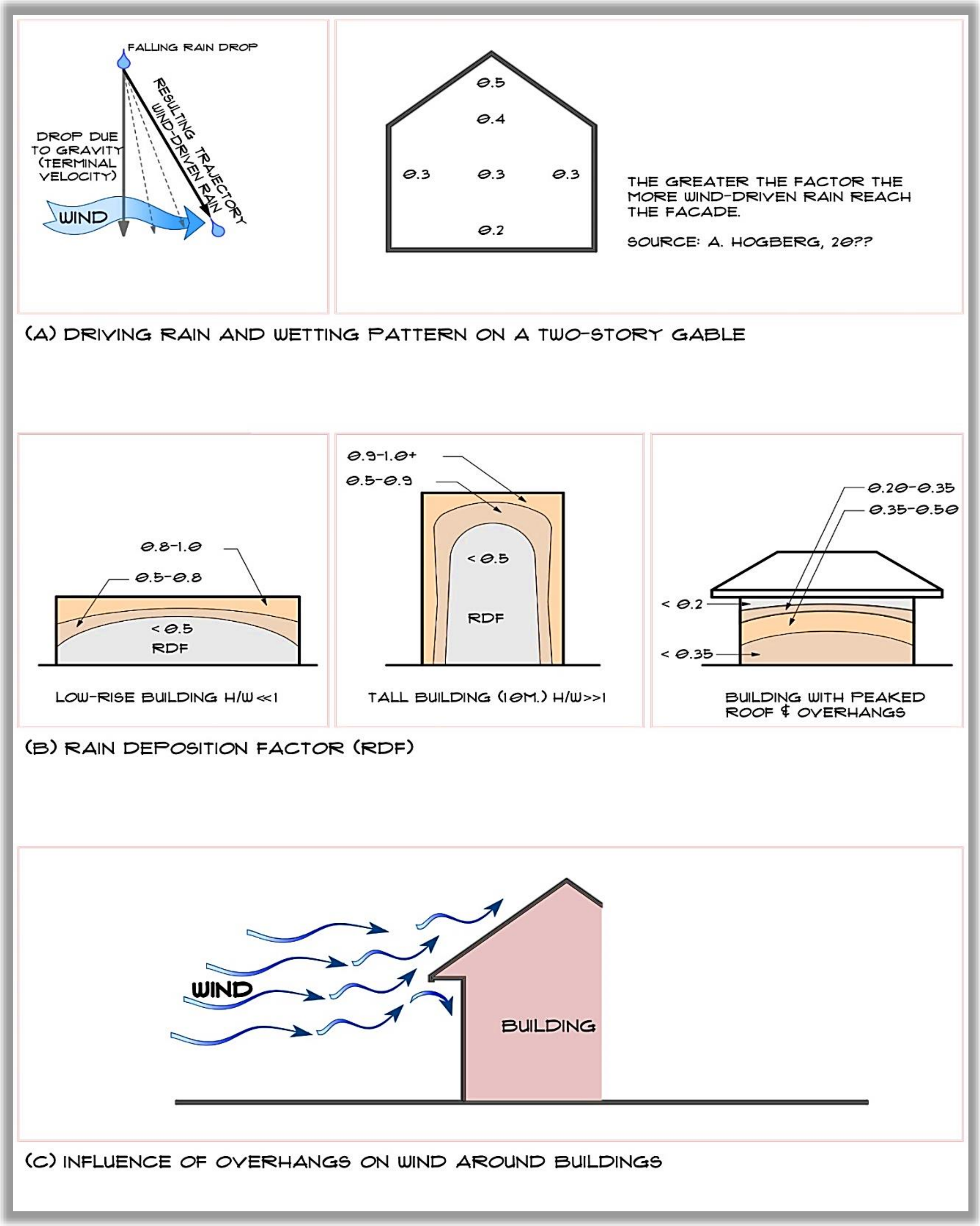

Figure 6 Driving Rain; Rain Deposit Factor (RDF) (Source: Straub, 2010)

4.0 MITIGATION STRATEGIES FOR RAINFALL ON BONNY ISLAND.

Mitigating counter measures take the form of management strategies or procedures for handling rainwater volumes and promoting new design options that are resilient to rainwater inundation. This involves construction and or modification of physical structures to reduce the impact of heavy rainfall on individual properties and holistically on larger catchment areas.

4.1 The Sponge Property Concept

The sponge property concept is a derivative of the 'Sponge City' concept. It is a strategy adopted by the Chinese in Chengde and the Germans in Hanover. The Chinese city of Chengde is an example of a sponge city. A sponge city is described as an approach for the near natural management of rainwater as well as the possibility for cooling off cities. The concept of a sponge city has considerable appeal for urban Bonny Island from its strengths, rainwater management and urban cooling. When the principle reduced to the individual property level, it becomes sponge property. During rainfall, rainwater is channeled to a reservoir for use as non-portable water, but with the capacity for the controlled release of excess water to the surface drain after the rain event, in anticipation of the next rainfall. As rainwater is retained in reservoirs, the infiltration into soil, runoff water and temporary flooding is reduced or permanently avoided. When applied holistically in an urban area, the entire area benefits and some of these benefits include:

- Reduced flooding since all rainfall in the area will not lead to surface runoff at the same time. Surface drains are unlikely to overflow, thereby reducing the risk of flooding.
- The reservoir is a source of non-portable water reducing the use/cost of portable water.
- The sponge property promotes the increase of green areas and green roofs that compliment sponge action, releasing up to 90% of water through evapotranspiration.

The benefits of the sponge property principle are also financial. As the measure protects the property from temporary flooding, the value of the property increases as well. The area benefits from the controlled delay of discharge water into surface drains, runoff is reduced in the event of heavy rainfall and potential flooding is avoided. There will be cumulative benefits to a larger area if these measures are carried out. This strategy combined with other measures ensures complete protection of the built environment at large.

With sponge property, the recommendation is for a holistic approach to property development of larger plats of land by reputable developers rather than the unitary approach where every individual is responsible for his own property development. This approach to neighborhood development has urban scale impacts. Economies of scale apply and there is a reduction of urban heat sources. Holistic planning for site and services is far more efficient and the advantages of the sponge property concept for weather management dramatically increase. Development of the design for the built environment should exploit the natural lay of the land for surface water run-off away from building by taking the "high ground" where feasible, increasing potential for passive release of retained rainwater into surface drains after rainfall.

Maintaining a low building profile (ie. bungalows/one-storey structures) and incorporating verandas and balconies offers a 'cool' spatial extension of the adjacent indoor space but effectively provides horizontal overhangs for the respective door openings thereby protecting from direct solar penetration or driving rain through the doors/adjacent windows.

The building envelope should both protect the interior from rain and effectively insulate from overhead solar radiation. This implies steep roof slopes (30º+) with deep vented ceiling space such as hip roofs that are quite effective in reducing the adverse impact of driving rain. Building placement should guarantee solar rights and the consequent hygienic (drying) benefits of the sun.

4.2 Water Resistivity.

The magnitude and extent of water degradation ultimately depends on the building materials and the duration of exposure. However, because building materials work in a composite arrangement to deliver the desired response to the prevailing climate, prudence suggest a listing of the more viable options.

Table 4 Water Resistant/Non-Resistant Materials.

Building materials	Example	Water sensitivity
based on gypsum	• Filler and structure gypsum • Gympsum boards • Plaster gypsum	high
based on lime	• Mortar, plaster • Sand-lime bricks	marginal to none
based on cement	• Mortar, plaster • Concrete, precast concrete parts • Building bricks, plaster • Screed	none
fired	• Clay bricks • Clinker bricks • Stoneware • Stoneware	none
made of wood	• Beams • Boards	low
	• Lightweight wood wool building boards • Parquet • Chipboards	high
made of asphalt	• Sealing sheets • Paint coats	none
made of metal	• Steel girders • Copper/zinc sheets • Lead skirting	none
made of plastic	• Plastomers (e.g. polyethylene, polystyrene) • Thermosets (e.g. polyester, epoxy resin) • Elastomers (e.g. nitrile rubber)	low to none

Source: BDZ/VDZ (2002)

The Table 4 lists a colour coded hierarchy of water-resistant building materials that work in synergy with the following recommendations:

1. Sloping the terrain away from the building into predetermined groundwater channels.
2. Sealing perimeter foundation walls with watertight concrete/damp-proofing membrane.
3. Storage of rainwater in targeted depressions, surface/sub-surface storage tanks or blue roofs for later use or active release in anticipation of the next rainfall event. Green roofs also store limited amounts of rainfall for slow release by evaporation and transpiration.
4. Removal of ground water sealing allows for more infiltration into the soil, reducing surface run-off until the point of water saturation of the soil.

5.0 CONCLUSION

The built environment is a static artefact that continues to impact people long after the completion of its construction, getting the right climate response starts from as early as the planning stage of the neighborhood plat layout, and on to the building's own orientation, form, relation to the ground plane, and material selection. Generally, on Bonny Island the recommendation is for a holistic approach to property development of larger plats of land by reputable developers rather than the unitary approach as this has urban scale advantages.

The sponge property concept when applied holistically has definite advantages for rainwater management because, as rainwater is retained in reservoirs, the infiltration into soil, runoff water and temporary flooding is reduced or permanently avoided. Design options in response to driving rain that build on the foundation of the aerodynamics of driving rain; low building profile, avoiding parapet walls and composite selection of water-resistant materials, not only mitigate the adverse effect of driving rain but promotes the three-Ds (deflection, drainage, and drying of moisture in its various forms (precipitation, humidity, and condensation).

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