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TECHNICAL ASSESSMENT REPORT – BLAIZE RAINWATER HARVESTING

Figure 0.1 - Blaize RWH system (© Communications Unit/GIZ Grenada)

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Abbreviations:

BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
Cu. ft	Cubic feet
Ft	Feet (dimension)
Imp. Gals.	Imperial Gallons
L	Litres
m (300m)	metres
m^2	Square metres
m^3	Cubic metres
mm	millimetres
NAWASA	National Water and Sewerage Authority
RWH	Rainwater Harvesting
Sq-ft.	Square feet

Executive Summary

Approximately 120 people live in Blaize, in the parish of St. Andrew, about 1400 feet (427 meters) above sea level. A 50,000-gallon (227 cubic meters) rainwater harvesting (RWH) system was constructed for the community in 2015 at an elevation of about 1600 feet (488 meters) above sea level. It was quickly recognized that the system was not collecting enough water to adequately meet the community's demand. Additional catchment roof area was constructed, yet it was still inadequate. In 2018, a project was undertaken to pump water from the nearby Carrier tank to the Blaize RWH tank, which successfully met the demand.

The Blaize RWH tank was constructed using reinforced concrete with a timber-structured roof covered with galvanized sheets. Water was directed into guttering and then into the tank, where chlorine was added before being distributed to the community via a pipe network.

This report presents an assessment of the Blaize rainwater system, aiming to identify the reasons for the inadequacy of the rainwater harvesting and to provide lessons learned that can be applied to the design and construction of similar systems.

The assessment revealed that while the structures were satisfactorily constructed and the catchment is in a reasonably suitable location, the total roof area is too small, the guttering was not cleared of leaves frequently enough, and high winds reduced the volume of rainfall collected. During a site visit in October 2022, it was discovered that the guttering system was practically non-functional, with parts lying on the ground, connections loose, and collection boxes clogged with leaves.

The recommendation is that the system should be utilized as a hybrid, maximizing the use of rainfall when available and using pumped water during drier periods. Therefore, the guttering should be replaced with a much stronger system, and a robust schedule for cleaning and clearing downpipe collection boxes should be established. Secondary uses for the facility should also be considered.

General recommendations and lessons learnt includes: New systems should be hybrids, with multiple water sources; concrete with hydrophilic crystalline admixture is better for constructing water tanks; manholes should be close to perimeter walls, with ladders or rungs installed for internal access; stainless steel material should be used for manhole covers, brackets and fasteners; roof sheeting should be coated on the underside; guttering system should be of durable material with appropriate design for maximum water collection; a maintenance manual should be developed along with the design of all RWH system.

TECHNICAL REPORT – ASSESSMENT OF BLAIZE RAINWATER HARVESTING SYSTEM

1 Background

Blaize is a village in the parish of St. Andrew, located between 1200ft (366m) and 1500ft (457m) above sea level, and has a population of 120 people. Prior to 2015 the residents used primarily rainwater harvesting and occasionally received water from NAWASA (National Water and Sewerage Authority) via trucks. A rainwater harvesting project was funded by the BMUV, designed and implemented by NAWASA, and constructed by a private contractor. This project was meant to catch rainfall, store in a concrete cistern, disinfect and distribute to all residents via a new pipe network.

The project was commissioned in December 2015, but shortly after it was discovered that rainwater was not sufficiently filling the cistern to provide the required water demand for the residents of Blaize.

The purpose of this report is to assess the design, operation, and maintenance of the system to determine its effectiveness and, most importantly, document the lessons learned to inform the design and construction of other rainwater harvesting systems.

In the following chapter, a general review and description of the design will be provide.

2 The Design

2.1 Design Requirements and Data

An inquiry was made with NAWASA personnel who participated in producing the drawings; this inquiry was about whether a hydrological assessment and hydraulic calculations was done to determine the design parameters. It was indicated that the individual who designed the system passed away and that his computer crashed, and that there is no known or seen record of an assessment done or design calculations made.

2.2 Actual Design, Drawings and Specifications

2.2.1 Location

The tank is located approximately 1600ft (488m) on the windward side of a mountain that has a 40% slope in the immediate area. The location was previously cultivated with medium size trees and shrubs including some agriculture crops like bananas. Heavy rainfall is evident in the area, which is supported by the rainfall data and personal investigation carried out in the area. The area can be windy at times.

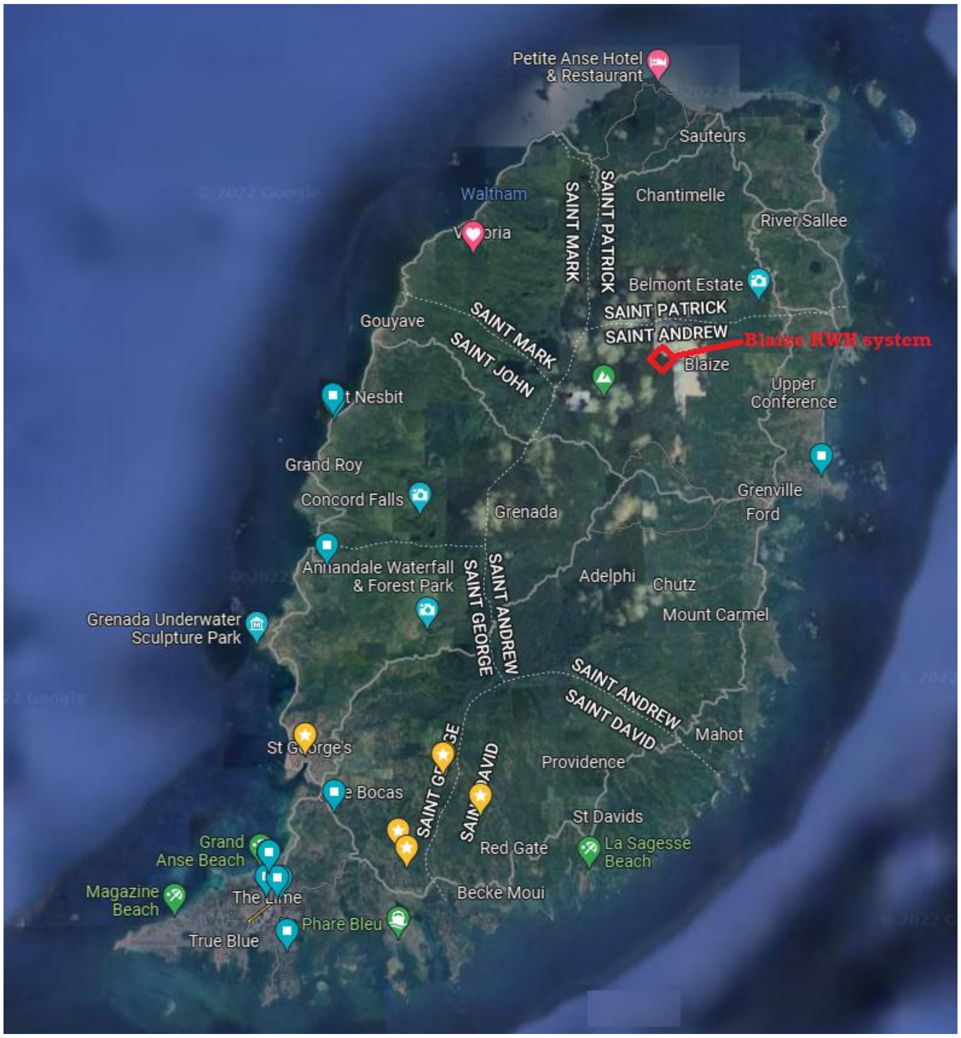

Figure 2.1 - Map of Grenada showing approximate location of the Blaize RWHS

2.2.2 Structure

The tank was designed to be a reinforced concrete structure, 51.6ft (15.75m) long by 16.67ft (5m) by 14ft (4.25m) from the bottom of the base to the top of the cover slab. The vertical walls are 10 inches (250mm) thick; the base slab was also designed to be 10 inches (250mm) thick and the cover slab 6 inches (150mm) thick with 2 manholes 3ft (900mm) by 3ft. More details of the structural design can be found in drawings done by O.F. dated 2014.

The design featured a timber structured roof, cladded with Aluzinc roof sheeting, on a gentle slope of 20% (12.5°). The dimension of the roof was designed to be 40.25ft (12.25m) by 53ft (16.15m), giving a total horizontal square area of 2,133.25 sq-ft (198m^2).

In the year 2018 an additional roof was constructed being 52.5ft (16m) by 24.5ft (7.5m), giving a total 1,286.25 sq-ft. (120m^2). The cumulative catchment area is 3,419.50 sq-ft (318m^2).

2.2.3 Capacity

The internal dimensions of the tank are 50ft (15.25m) by 15ft (4.6m) by 13ft (4m) (11.5ft [3.5m] liquid depth), this allows for 53,724 imperial gallon of water storage (244m^3).

2.2.4 Demand, Consumption and Usage

An ICCAS briefing titled “Community Rainwater Harvesting Project in Blaize” shows that the projected water demand for the estimated population was (120 persons), would have been 20 US gallons (16.7 imp. Gals or 76 L) per person per day. That is equivalent to 2400 US gallons (1998 imp gals or 9,085 L) per day. Actual records from NAWASA indicates that consumption was estimated at 12.5 imp gals/person/day (56.8 L) in 2018 and increased to 15.3 (69.6 L) in 2021 (see Table 2.1 below).

Table 2.1 - Summary of consumption from the Blaize RWH system 2018 & 2021

Consumption calculation parameters	**2021**	**2018**
Total consumption from Blaize (Imp. Gals)	513,848.18	271,662.14
Number of connections	23	15
Average # of persons per connection	4	4
Total number of persons (estimate)	92	60
Days in the year	365	365
Consumption per person per day (imp. Gals)	**15.3**	**12.4**

The total usage almost doubled in just 3 years, growing by about 90%, which could be averaged at 30% growth per annum. It can be deduced that availability of water encourages population growth and consumption per capita, therefore it is particularly important to consider the demand growth potential.

Three residents were interviewed, all of whom gave verbal consent to use their names: David Francis, Clementina Matthew, and James Alexander. All interviewees indicated that the water supply has been of good quality and consistent since the system was commissioned, and especially after it was connected to the Carrier tank. Many residents have ceased from using their own domestic rainwater harvesting systems since the intervention. Clementina Matthew indicated that she still uses the domestic RWH system to wash and for gardening, while the others two interviewees said that they have since stopped using their domestic RWH.

It may be prudent to sensitize the population to continue to utilize their domestic RWH systems, to reduce the demand on NAWASA’s facility and realize some cost savings. Conversely, the likelihood is that people much rather pay for convenience.

2.2.5 Assessment of the design

A hydraulic assessment was carried out using rainfall data provided by NAWASA for the Blaize RWH system. Assumptions are being made that the year's (2018) data used can represent a typical year, but allowances must be made for drier years.

Table 2.2 - Parameters for calculating RWH effectiveness of Blaize system

Rainfall data from Blaize 2018			
Population connected (2021)	94	Pers.	
Demand per person	15	Imp gals/per./day	68 L/per./day
Roof/catchment area	3420	Sq-ft.	$318m^2$
Conversion from cu. ft to Imp. Gals	6.23	Imp gals/cu. ft	
Water storage tank/Reservoir	53,000	Imp gals.	$241m^3$
Collection loss coefficient	80%	percentage	

Table 2.3 - Calculation of Rainwater Harvesting Effectiveness of Blaize System

Months	Rainfall		Supply	Demand	Difference		Tank water level status	
	mm/mth	in/mth	imp. Gals.		imp. Gals.	Surplus/Deficit	imp. Gals.	Status
Jan	364	14.3	20355.9	43710	-23,354	Deficit	0	Empty
Feb	306	12.0	17112.4	39480	-22,368	Deficit	0	Empty
Mar	241	9.5	13477.4	43710	-30,233	Deficit	0	Empty
Apr	112	4.4	6263.4	42300	-36,037	Deficit	0	Empty
May	28	1.1	1565.8	43710	-42,144	Deficit	0	Empty
Jun	53	2.1	2963.9	42300	-39,336	Deficit	0	Empty
Jul	123	4.8	6878.5	43710	-36,831	Deficit	0	Empty
Aug	345	13.6	19293.4	43710	-24,417	Deficit	0	Empty
Sep	215	8.5	12023.4	42300	-30,277	Deficit	0	Empty
Oct	337	13.3	18846.0	43710	-24,864	Deficit	0	Empty
Nov	243	9.6	13589.2	42300	-28,711	Deficit	0	Empty
Dec	127	5.0	7102.2	43710	-36,608	Deficit	0	Empty
2018 (year)	**2494**	**98.2**	**139,471.5**	**514,650**	-375,178	Deficit		

Minimum workable roof area	12,619.8	Sq-ft.
Average monthly rainfall (inches)	8.2	inches
Supply to demand ratio	27%	

The calculations of Table 2.3, clearly show that the roof area of 3420 sq-ft. ($318m^2$) is insufficient, with only 27% of the demand being met. Using the typical rainwater supply and demand, the roof will need to be almost 4 times larger in area, to meet the demand. The following table (Table 2.5) provides calculations to show that the catchment size needs to be approximately 6.3 times larger than the existing, for the system to meet demand in most months of the year when the full population is connected.

Table 2.4 - Parameters for calculating rainwater harvesting potential with appropriate catchment size

Rainfall data from Blaize 2018			
Population (factored for growth)	120	Pers.	
Demand per person	20	Imp gals. /per/day	91 L/per./day
Roof/catchment area	22,000	Sq-ft.	2044 m^2
Conversion from cu. ft to Imp. Gals	6.23	Imp gals/cu. ft	
Water storage tank/Reservoir	53,000	Imp gals.	241m^3
Collection loss coefficient	80%	percentage	

Table 2.5 - Calculation using more appropriate roof area

Months	Rainfall		Supply	Demand	Difference		Tank water level status	
	mm/mth	in/mth	imp. Gals.		imp. Gals.	Surplus/Deficit	imp. Gals.	Status
Jan	364	14.3	130944.5	74400	56,544	Surplus	53000	Full
Feb	306	12.0	110079.7	67200	42,880	Surplus	53000	Full
Mar	241	9.5	86696.7	74400	12,297	Surplus	53000	Full
Apr	112	4.4	40290.6	72000	-31,709	Deficit	21291	About half
May	28	1.1	10072.7	74400	-64,327	Deficit	0	Empty
Jun	53	2.1	19066.1	72000	-52,934	Deficit	0	Empty
Jul	123	4.8	44247.7	74400	-30,152	Deficit	0	Empty
Aug	345	13.6	124109.4	74400	49,709	Surplus	53000	Full
Sep	215	8.5	77343.6	72000	5,344	Surplus	53000	Full
Oct	337	13.3	121231.5	74400	46,832	Surplus	53000	Full
Nov	243	9.6	87416.2	72000	15,416	Surplus	53000	Full
Dec	127	5.0	45686.7	74400	-28,713	Deficit	24287	About half
2018 (yr.)	**2494**	**98.2**	**897185.4**	**876000**	21,185	Surplus		

Minimum workable roof area	21480.5	Sq-ft.
Average monthly rainfall (inches)	8.2	inches
Supply to demand ratio	102%	

With a roof area of 22,000 sq-ft (2044 m2) the system can meet demand for 9 out of 12 months. The roof and tank will have to be relatively very huge in the dry months for the demand to be met year-round. The table above (Table 2.5) indicates that the catchment size needs to be approximately 6.3 times larger than the existing in order for the system to meet demand in most months of the year, when the full population is connected. Also factors like increase in demand per capita and decrease in rainfall needs to be considered.

The table below shows how long it will take to fill the tank, if rain fell without ceasing, at a constant rainfall intensity.

Table 2.6 - Calculation of duration to fill rainwater harvesting tank

Conditions	**Catchment area**	**Rainfall Intensity**	**Flow/fill rate**		**Time to fill**
	Sq-ft	In/hr	cu-ft/day	Imp. Gal/day	days
Initial roof area - moderate rain	2,133.25	0.3	1,023.96	6,379.27	8.3
Increased roof area - moderate rain	3,419.50	0.3	1,641.36	10,225.67	5.2
Initial roof area - heavy rain	2,133.25	1.0	3,413.20	21,264.24	2.5
Increased roof area - heavy rain	3,419.50	1.0	5,471.20	34,085.58	1.6
Tank capacity		53,000			
Collection loss coefficient		80%			

Calculations in the table above indicates that to fill the tank, when usage is zero, rain will need to fall for 5.2 days (24 hours a day), all conditions being average.

3 Construction

3.1 General Assessment of Construction

The RWH tank and catchment roof was constructed by Farray's Construction Services Ltd. Considering the harsh conditions and the limitations of not being able to utilize all necessary construction equipment on the site, it could be considered that the construction was done reasonably well, and the design was maintained to a great measure.

3.2 Alteration to the Design

A few alterations were noted:

- "S" profile unpainted galvanize were used instead of Aluzinc roof sheeting.
- Upon discussion with the contractor, it was noted that the rubber water stop was excluded from the construction joint and replaced with a hydrophilic Crystalline grout.
- There were a bit of formwork bulging when concrete load was applied. This was due to the softness of the soils and ability to anchor formwork struts and supports adequately.
- Wooden post to support the roof were replaced with 10" by 10" reinforced concrete columns
- Concrete manhole cover was replaced with a fiberglass cover.

3.3 Effect of Alterations

Most changes made had no negative outcomes on the structure, but in most cases improved the efficiency of construction or the quality of the structure.

4 SWOT Analysis of the Blaize RWH system

4.1 Strengths

- The reinforced Concrete tank is probably the best option for the Blaize RWH system, as it will be very resistant to storm events, weathering and corrosion and will also require very little maintenance.
- The location is good, as it is elevated above most users, which allows for a cost-effective gravity supply. Also, the location receives substantial amounts of rainfall, a good factor for a RWH system.

4.2 Weaknesses

- The catchment roof is located on the windward side of island, which results in rain falling with high winds. One of NAWASA's supervisor affirmed that he has visibly witness, the wind greatly affecting the collection and effective runoff of the rainfall on to the roof and into to guttering.
- The roof is susceptible to damage from storm-like events.
- Guttering material and configuration do not allow for longevity and maximum capture of runoff rainfall.
- Investigation and information provided by NAWASA management and supervisory team, indicated that an operator frequently visits the site to take care of the system, and ensure that chlorine residual amounts are within limits, and do landscaping maintenance. However, there is no indication of frequent cleaning of the guttering, as this is critically important for roof catchment to RWH systems. During a site visit, it was noted that both water collection downspouts were almost completely blocked with leaves (see Figure 4.1 below). It was also noticed that a significant part of the guttering was broken off and left unrepaired.

Figure 4.1 - photos showing leaves in guttering at Blaize.

- Location is conducive to corrosion of metal components, due to the high moisture in the atmosphere at that elevation and sodium chloride from the ocean breeze.

Figure 4.2 - Photos showing corrosion of screws and equipment latch at Blaize

Figure 4.3 - Photo showing corrosion to the underside of roof sheeting where it sits on purlins

- Vehicular access to the tank is relatively poor.

4.3 Opportunities

- The site has the potential for a secondary usage, like a storage room under the catchment roofs, or a tourist lookout point, as the view to the Atlantic Ocean and St. Andrew landscape is magnificent. The facility can also be used as an education and awareness centre where student and other interested persons can come to understand the idea and processes of rainwater harvesting. There is good income generation potential from these options.

Figure 4.4 - Photos showing view from the Blaize RWHS

- Expandability of the catchment roof and tank is possible on the site.

4.4 Threats

- Hurricanes and storms pose a threat to the roof system and can cause significant damage, resulting in the failure of the system to collect water.
- The tank and catchment are located out of the view of the public and almost secluded in the mountain. This provides the potential for security mishaps: breach of the fencing; damage and vandalism of the structures; tampering with the equipment and possible compromise of the water quality and safety for drinking.
- Climate change could further result in lower rainfall and decrease the effectiveness of the system.

5 Assessment of the Rainwater Harvesting System

5.1 Assessment Context

Subsequent to the commissioning of the RWH system, it was discovered that there were some inadequacies, as the tank never collected much water at all. While the construction was good, the pipe network was adequate and the location appears ideal, harvesting the rainfall in the location was not occurring as desired.

5.2 Possible reasons for the Inadequacy

It should be noted that the possible reason that the system was not as effective as desired, will be stated, and can be considered not absolute but may represent a combination of them, thou assessed scientifically and empirically:

- Design inadequacy:
  - Most significant, is that the roof or catchment size was not sufficient in area to collect rainfall – see data in
  - Table 2.3 and Table 2.5
  - Gutter profile not best suited
  - Roof slope not enough

- Little or no maintenance of the guttering system. Rainwater harvesting systems, designed with roofs in areas with trees, always require frequent cleaning of the guttering and downpipe collection chambers. When the site was visited to conduct this assessment (October 2022), downspout collection chambers were blocked with leaves on the mesh wire was placed to prevent the leaves from entering the downpipes (see Figure 4.1). Additionally, it was noted that operators do not have a schedule for cleaning the guttering, and it's not a practice of theirs to do so.

5.3 Attempted Remedy of Issues Creating the Inadequacy

Sometime after the initial commissioning of the Blaize RWH system, and the subsequent discovery of the inadequacy, attempts were made to remedy the situation. The following were done:

- The additional roof of 1,286.25 sq-ft. ($119.5m^2$) was constructed and connected to the tank.

Figure 5.1 - Photo of Blaize RWH system showing both roofs

- "L" shaped galvanize rain stops, with a vertical portion of approximately 8" were affixed, perpendicular to the slope of the roof to minimize rain fall fly away (see Figure 5.2).

Figure 5.2 - Photos showing "L" shaped rain stops installed to prevent rainwater flying away

- Drip edge galvanize flashing was installed to allow runoff water to fall directly into guttering and prevent loss.

Figure 5.3 - Photo showing drip edge installed to improve collection of water into guttering

After the initial attempt to remedy the situation, there was a miniscule improvement in captured volume of water, however, the system remained inadequate.

In 2018 the decision was made to pump treated water from Carrier water storage tank to the Blaize storage tank. This was done and now works effectively to provide the residence with potable water. Nonetheless, as a rainwater harvesting system, Blaize facility was never effective.

6 Recommendations and Lesson Learnt

6.1 Recommendations for the Blaize RWH System

To date the guttering of the Blaize RWH system remains unrepaired and blocked with leaves. This therefore means that the roofs that are in good condition, are non-functional. It is in the best interest of all, to do the following which will realize the utilization of the catchment roofs and the maximum collection of rainfall whenever there is:

- Remove all existing guttering and install a much more durable gettering system, with a suitable profile for effective water collection. Fasteners should be of stainless steel, brass or non-ferrous materials.
- Develop and implement a vigorous maintenance schedule or standard operating procedure (SOP) for cleaning of the guttering and maintenance of the system.
- Fiberglass covers need to be analysed for toxins or carcinogens, as they have been seen to be producing a white powder (see Figure 6.2) on the top of manholes, possibly from abrasion when the covers are removed and replaced. If proven dangerous they should be replaced with a better system (see Ch 16. and Figure 6.3)

Figure 6.1 - Photo showing fibreglass manholes cover

Figure 6.2 - Photos showing powder substance under manhole covers and manhole walls

These recommendations will reduce the reliance on the treated water supply from the potable storage at Carrier, during periods of heavy rainfall and improve the safety of the water supply. The system will then function as a hybrid.

6.2 Technical Recommendations and Lessons Learnt for Other Systems

- Because of the huge catchment area required for small populations, rainwater harvesting would be best suited for buildings where the ratio of persons to the size of the roof area is smaller. The recommendation is that communal RWH systems should be constructed as hybrids, utilizing water from multiple sources.
- Concrete tanks offer more resilience to climate events, require less maintenance and have greater social benefits during construction. Therefore, it is recommended to use concrete tanks wherever possible for communal RWH.
- All concrete mix should contain hydrophilic crystalline admixture, that makes the concrete impermeable, prevents algal growth, protects the internal reinforcement from corrosion, eliminates the need for other water stop technology, and ultimately increases the longevity of the concrete structure. This application has already been successfully used in some of NAWASA's recently constructed tanks.
- Each tank should be designed with at least two intake pipes, one to be an axillary intake.
- 3ft by 3ft (1m by 1m) Manholes should be located close to perimeter walls, to allow for ease of access into the tank
- Air & watertight, tamperproof manhole covers, with fall prevention grill/grating should be the preferred options similar to images shown below.

Figure 6.3 - Proposed stainless manhole cover options (see Photo Credits pg. 18)

- Internal ladder or rungs should be fitted in the tanks from the manhole.
- Tanks should have an overflow pipe leading to a suitable drain or watercourse and should be 1.5 times the diameter or the inlet pipe.
- Tanks should have a washout pipe in a sump or semi-sump configuration and should not be smaller than 4" (100mm) diameter. The washout should be fitted with a gate or butterfly valve leading to a suitable drain or watercourse.
- Concrete tanks should have at least 2 insect proof vents and one port for automatic water level measurement instrument (size to be determine by size of probe)

- Roof sheeting should be from galvanize, aluzinc, galvalume or similar material and to be coated with paint or epoxy coating on the underside. Moisture in most RWH systems locations are absorbed by the timber and causes corrosion to the underside of the sheeting (see Figure 4.3).
- Stainless steel roofing brackets are encouraged or at least a good alloy bracket that is resistant to corrosion.
- All fasteners (screws, nails and bolts) should be stainless steel (see Figure 4.2).
- Guttering systems should be of durable material and the profile should allow for effective collection of water. Concrete troughs should be highly considered.
- Highly efficient and durable “leaf shedding” chambers and “first flush” systems should be installed to prevent debris, leaves and other unwanted matter from entering the cistern.
- Secondary usage (income generation: social component/tourism/agriculture/education) of the facility may be considered if applicable, once it will pose no risk to the safety of the water supply.
- Security risk assessment should be carried out for each RWH system individually and mitigation measures employed.
- An operation and maintenance manual should be developed along with the design of all RWH system. The manual should contain cleaning schedules or standard operating procedure (SOP) and the like and should be followed by operators of the system.

6.3 Administrative Recommendations and Lessons Learnt for Other Systems

- All designs of projects should be carried out under project management/governance framework that specifies all steps in the design & build process.
- Design requirements and parameters must always be documented and signed off by heads of department, before publishing for tender or construction.
- Designs information and drawings should be stored in multiple formats (hard copy and electronically) in varying location (cloud storage and onsite shard drive) to disallow lost and facilitate continuity if someone leaves the job or dies.

7 Overall Conclusion

The Blaize rainwater harvesting system was designed and built without proper hydraulic modelling, leading to a grossly undersized catchment. While better maintenance could improve efficiency, it would not significantly enhance effectiveness. The decision to pump water to the tank has proven to be a good solution and currently works well. Other communal rainwater harvesting systems should be designed as hybrids, primarily due to the significant variation in rainfall between the wet and dry seasons, and the substantial catchment and tank sizes required for a standalone RWH system.

8 Photo Credits

Figure 2.1 - Map of Grenada showing approximate location of the Blaize RWHS- © https://www.google.com/maps/@12.13216,-61.6843726,34972m/data=!3m1!1e3

Figure 4.1 - photos showing leaves in guttering at Blaize. - © Communications Unit, GIZ Grenada

Figure 4.2 - Photos showing corrosion of screws and equipment latch at Blaize- © Communications Unit, GIZ Grenada

Figure 4.3 - Photo showing corrosion to the underside of roof sheeting where it sits on purlins - © Communications Unit, GIZ Grenada

Figure 4.4 - Photos showing view from the Blaize RWHS - © Communications Unit, GIZ Grenada

Figure 5.1 - Photo of Blaize RWH system showing both roofs - © Communications Unit, GIZ Grenada

Figure 5.2 - Photos showing "L" shaped rain stops installed to prevent rainwater flying away - © Communications Unit, GIZ Grenada

Figure 5.3 - Photo showing drip edge installed to improve collection of water into guttering - © Communications Unit, GIZ Grenada

Figure 6.1 - Photo showing fibreglass manholes cover - © Communications Unit, GIZ Grenada

Figure 6.2 - Photos showing powder substance under manhole covers and manhole walls - © Communications Unit, GIZ Grenada

Figure 6.3 - Proposed stainless manhole cover options – 1st Photo © Manhole Covers - Morrow Water Technologies & 2nd photo © Square Dolphin Stainless Steel Manhole Cover 202 Grade, For Construction at Rs 5500 in Hosur (indiamart.com)

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