ISSN No:-2456-2165

Assessing Drainage Capacity and Managing Flood Vulnerability: Case Studies from Guyana's East Berbice-Corentyne Area

Michael L. Hackett
Affiliation: Department of Mathematics,
Physics & Statistics, University of Guyana, Tain Campus, Guyana

Abstract:- This study examines the recurrent issue of flooding in various regions of Guyana during the biannual rainy season and proposes strategies to enhance water resilience and mitigate the impact of flooding. The affected areas experience floods of varying depths during heavy rainfall events. These floods disrupt human activities, resulting in substantial economic losses across residential, commercial, agricultural, and industrial sectors.

This study delves into the historical context of drainage systems established by European colonizers and plantation owners, originally designed for optimal drainage under specific rainfall conditions. The study underscores the vulnerability of these systems to "short duration high-intensity rainfall" which leads to pluvial flooding.

Two case studies, focusing on Black Bush Polder and John's-Port Mourant, provide detailed insight into flooding scenarios and their causes. Inadequate drainage capacities, siltation, and canal networks are identified as factors contributing to flooding. The study emphasizes the need for maintaining efficient and clean drainage infrastructure to prevent flood exacerbation.

In response to the challenges of flooding, the study recommends a multi-pronged approach to building water resilience. Strategies include educating the population about flood risks, implementing warning systems, maintaining emergency supplies, enforcing building codes for flood resilience, designing permeable urban areas, and modernizing drainage systems.

The study concludes that while flooding cannot be eliminated, a combination of resilient infrastructure, community awareness, and innovative technologies can significantly mitigate its adverse effects. By implementing these measures, Guyana can achieve enhanced water resilience and be better prepared for flood challenges.

Keywords:- *Cusecs (Cubic Feet Per Second), Discharge Capacity, Drainage And Irrigation Area, Pluvial Flooding, Pooling, Drainage Coefficient, Short Duration High-Intensity Rainfall.*

I. INTRODUCTION

During the two annual rainy seasons May-July and November-January, some areas in Guyana often experience floods, ranging in depth from several inches to about four feet of water. Though not life-threatening in most instances, these floods can be highly disruptive to human activities, entailing high economic losses in homes, businesses, agriculture, and industry.The flood-prone areas are the intertidal coastal flood zones, reclaimed natural swamplands, and interior seasonal natural flood zones. The reclaimed drained areas have natural and artificial drainage. Hence, many areas on the coast (except the inland high sand reefs that rarely flood) and parts of the interior regions are prone to flooding during the rainy seasons.

The European colonizers and plantation owners of Guyana built gravity drainage systems that were designed to drain a maximum of 2.5 to 3.0 inches of daily rainfall, provided the rainfall was evenly distributed over 24 hours. If that amount falls in a few short hours – known as "short duration high-intensity rainfall," (Ramraj, 1990), and the ground is already saturated, the water will pool, and flooding will occur before the water is drained off in more than 24 hours. Flooding caused by excessive rainfall is called *pluvial* flooding. At that point, pooling of water occurs since it cannot be drained away fast enough, especially if the surface has some degree of impermeability or the ground has been saturated by water and so cannot absorb any more water. In this case, the surface run-off from the precipitation will exceed the drainage capacity, resulting in pluvial flooding. If this type of rainfall occurs for several days, or if the daily rainfall exceeds the maximum daily drainage capacity of the area, then the flooding will be prolonged for several days or even a week or more as the drainage system strains to remove the excess water. Flooding of this nature happened after the rainfall of 9.6 inches at Strathoven, East Coast Demerara, November 19, 2014, the 8.26 inches at Georgetown, July 15, 2015, the 7.5 inches at Bush Lot, West Coast Berbice, June 9, 2017, and the 7.4 inches at John's Village, June 22, 2017, (Hydromet Weather Briefs, 2014, 2015, 2017; Hackett, 2021).

II. LITERATURE REVIEW

Historically, the coastal plain of Guyana, due to its flat and low nature, has been prone to flooding from the sea and rain. This fact was recognized by the coastal engineer Gerald O. Case (1920, p. 5), thus: “Practically the whole of the cultivated lands of British Guiana and all the chief towns and villages are situated on the front lands, which are flat and from 3 to 4 feet below the level of high tide. The reclamation of the coastlands of British Guiana was commenced by the Dutch about the year 1750 and afterward continued under British rule. The maintenance of the sea embankments which protect the towns and cultivated lands of the Colony from inundation by the sea is therefore of primary importance to the Colony’s existence.” Now, over 100 years later, an independent Guyana is still faced with the same issue of flooding and flood prevention on its coastal plain.

Case went on to document floods of the early 20th century, thus, “Our inadequate and unscientific sea defences have been broken in several places within a few miles of Georgetown during the four weeks of the Commission’s [Sea Defence Commission, January 17, 1916] existence. The high spring tides have flooded through two great breaches at Triumph since we last met and have closed the public road during several hours for some days, washing away the parapets and causing great general damage” (Ibid, p. 7). Although the subject matter of this study is not the sea defence system, but the drainage system, the seriousness of the flood issue must be addressed by both systems since they are interconnected with each having effects and feedback on the other.

During 1995 - 1998, the U.S. Army Corps of Engineers conducted a Water Resources Assessment of Guyana. In the Executive Summary, it is stated: “Throughout the populated coastal plain and part of the interior highlands, there is a system of drainage and irrigation canals that feed shallow reservoirs, known as “conservancies,” that are designed to provide primarily irrigation water and secondarily other water needs. These drainage and irrigation systems have deteriorated because of lack of maintenance and can no longer sufficiently provide irrigation, much less other water needs.” (U.S. Army Corps of Engineers, 1998, p. i). Here it is evident that lack of maintenance of the system is a recurrent historic problem, and it needs to be addressed.

The water assessment report noted that: “An elaborate system of sea defenses, along with irrigation and drainage canals, is required to protect the area from flooding” (Ibid, p. 2). The very elaborateness and complexity of the system contribute to its expensive construction and maintenance and thus requires the need for technical knowledge of how the system works so that the best engineering principles and practices can be implemented.

The report also noted the lack of relevant hydrological data: “Hydrologic data are lacking throughout the country, particularly since the late 1960s when data collection decreased dramatically” (Ibid, p. 1). The lack of data on the drainage system would result in design practices and construction and maintenance works that do not follow hydraulic and hydrological principles, leading to possible systemic failures and flooding.

However, the report noted that, although the drainage system has deteriorated because of lack of maintenance, “The Government has initiated a major rehabilitation program to bring the drainage and irrigation systems back to full operating capacity. A new Drainage and Irrigation Board will oversee the development including the financing for the operation and maintenance of the systems” (Ibid, p. 7). Though this new Board may have been working assiduously since its commissioning, the results of its efforts have not been very fruitful as coastal flood events continue to happen from time to time. This research attempts to uncover some of the technical reasons for these shortcomings.

During the Proceedings of the First National Conference on Engineering & Architecture Education in Guyana organised by the Faculty of Technology, UG (2007), a presenter noted: “The government has not been giving any assistance to engineers in the country, nor to students pursuing engineering. Even the collection of basic data is hampered. It is taboo for students to visit certain areas, for example, Draining and Irrigation. The government must work closely with the University so that basic data can be collected” (p. 8). It should be noted that these hydrological data are in the public domain and should be readily accessible by students and researchers. Every effort should be made by the government and its agencies to assist interested persons in doing studies in this critical area as this would only be to the benefit of the development of Guyana.

In a StabroekNews letter, Sworn Land Surveyor Liu wrote: “It is my considered opinion that Georgetown and the coastal belt of Guyana need a comprehensive technical analysis of the drainage system… The drainage system needs more than just a cleanup campaign; it needs a full technical understanding of the entire system.” (Liu, 2014). Liu wrote about the dangers of building a drainage system without a technical understanding of the operations of the system. In his opinion, flooding will still recur unless a better understanding of the system is sought. Hence, there is a vital need for studies of these kinds to be done on Guyana’s drainage systems.

In 2015, Georgetown suffered some flood events due to heavy rainfall that overwhelmed the drainage system. Two floods, in May-June 2015 and mid-July 2015 are of significance. On June 1, 2015, Kaieteur Newsreported: “City and Coastland residents awoke yesterday to the all-too-familiar and depressing sight of homes, business places, Government entities and streets underwater, following heavy overnight rains, and with warning of more rains to come. Already swamped residents are being told to brace for further flooding with the Hydromet Office predicting heavy rainfall and thunderstorms over the next 72 hours.” (Heavy rains swamp Georgetown, Coastland, 2015) With all functional sluices and pumps working, depending on the high and low tide cycle, it took about three to four days for the flood waters to recede.

On July 15, 2015, heavy rainfall in Georgetown overwhelmed the drainage system, resulting in flooding again. Kaieteur News reported, "Over the past 24 hours the city has seen record-breaking rainfall which is much more than it was initially designed to take. Authorities have indicated that the city was intended to take off 2.5 inches of rain in 24 hours. Based on the extent of existing conditions, the city can only take off 1.5 inches in that time frame. But this time around there has been 8.26 inches of rainfall which was deemed unusual by the City's Mayor, Hamilton Green." (Hoppie, 2015). This flooding caused some businesses to lose millions of dollars in stock and equipment. Again, it took several days for the flood to recede. This time the Hope Canal 8-Door Sluice was brought into operation, and it helped to alleviate flooding along the East Coast of Demerara and to lower the East Demerara Water Conservancy to safe levels which had risen dangerously due to the recent heavy rainfall. Whether the Hope Canal and Sluice will be a long-term solution to flooding remains to be seen.

Given these ongoing flood events and their social, cultural, and economic impact, the Ministry of Public Infrastructure announced that the Government was assembling an overseas technical team and a local task force that will work in tandem to assess Guyana's drainage system and provide preliminary reports within six months. On July 23, 20215, Kaieteur News, reported the subject Minister thus: "[T]he reports will provide information dating back to the "British Guiana days" as a means of truly understanding Guyana's drainage system and solving the flood situation once and for all." (Preliminary report on Guyana's drainage due in six months, 2015). This would be an extremely useful governmental project and the expectation is that its findings will help to alleviate Guyana's flood woes.

The intersection of the country's natural drainage of rivers and creeks with the artificial drainage systems to produce a habitable coastal zone from a former intertidal flood zone is described thus: "Not all of them [rivers and creeks] play an important role in communication with the interior of the country, but they help to drain a land which would otherwise be largely a series of swamps. This natural drainage, aided by a small amount of artificial drainage, has made it possible to inhabit and cultivate some sections of the country." (Thompson, 1987). The weakness of this intersection is its vulnerability to flooding of habitable zones from excessive rainfall. It is this weakness that this research probes and attempts to find solutions or mitigation measures to manage flood events.

A general technical description of the artificial drainage system in colonial days reported that: "In British Guiana, the practice is to design gravity drains to accommodate 1.50 inches [of rainfall] per 24 hours, given their low standard of maintenance. If pumping installations are operated judiciously and full advantage taken of the storage capacity of the drains an allowance of 1.00 inch in 24 hours for the pumps should be sufficient. The figure suggested by the International Bank Mission of 0.80 inch is regarded as low." (Lacey, 1953). With anthropogenic climate change and increased amounts of short duration high-intensity rainfall, the 1.5-inch general drainage coefficient inherited from colonial days is no longer adequate to cope with our current drainage needs.

A 1970 specific technical description of the Rose Hall Village (now Town) Drainage and Irrigation Area reported that: "The area is provided with pumped drainage by one Vickers Gill single Stage Axial Flow Pump, with a design point of 120 tons per minute (72 cusecs) at 10 ft total head. Allowing for 20 hours maximum pumping per day, the provision of 72 cusecs pumping capacity for 906 acres, is equivalent to drainage coefficient of 1.57 inches [of rainfall] in 24 hours. This is ample for sugar cane." (Rowe, 1970). The pump eventually became dysfunctional and in 2015 was replaced by a Hydro Flow Pump with a discharge capacity of 200 tons per minute (120 cusecs). (Suseran, 2014). This increased discharge capacity raised the daily drainage coefficient to 2.63 inches of rainfall, a 67.5% increase in comparison to the old pump. Since the installation of the new pump, the frequency and severity of flooding in the Rose Hall Town area have been significantly reduced.

This extant research was done within chronological and geographical constraints of the East Corentyne area and should contribute in some way to the national effort to understand Guyana's drainage system so that flooding in Guyana will be better managed and its effects better mitigated.

III. ASSESSING THE DRAINAGE COEFFICIENT OF A DRAINAGE AREA

- Drainage area in terms of acreage and other area units is obtained from Rowe's "A Report on Declared Drainage and Irrigation Areas in Guyana" (1970) and verified using the area measurer in Google Earth Satellite Maps. If the area is not reported in Rowe's document, then the area measurer in Google Maps is used.
- ✓ Discharge capacities of pumps are obtained from engineers' reports in the relevant literature or from verified reports of news media.
- ✓ Discharge capacities of sluices are determined by measuring the width and depth of the rectangular sluice channel and applying the Chezy-Manning equation for open channel flow (Potter, 2000, p. 157):

$$Q = \frac{A(R^{\frac{2}{3}})(S^{\frac{1}{2}})}{n}$$

The discharge capacity is also called the volume flow rate, *Q*.

Q = volume flow rate (m^3/s)
A = Cross-section area of channel (m^2)
R = Hydraulic radius of channel (m)
S = Slope or gradient of channel (dimensionless)
n = Manning coefficient for channel wall material ($s/m^{1/3}$)

$R = A/P$, where P = wetted perimeter of channel (m)
A = width× depth
P = width + (2 × depth) … See Figure 1 and Figure 2.

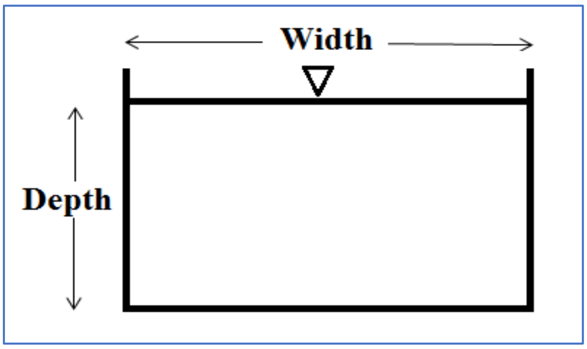

Fig. 1: Diagram showing a cross-section of a rectangular channel through a sluice.

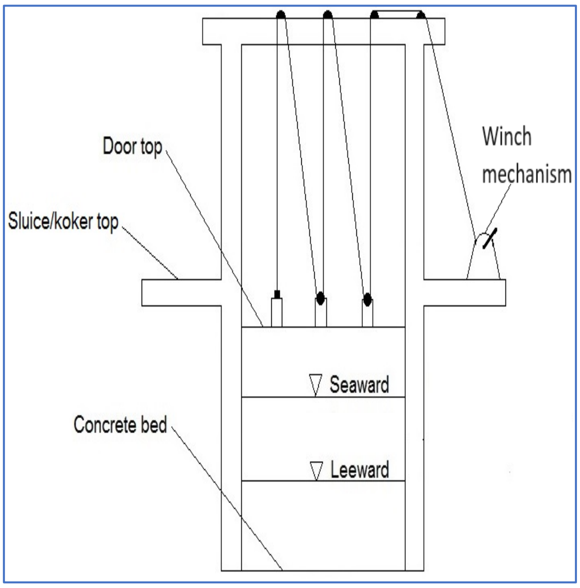

Fig. 2: Diagram showing a sluice

Since "the average gradient of the main rivers is only one meter every five kilometers," as reported by Merrill (1993, p. 34), this figure of $S = 1/5000 = 0.0002$ is used in the Chezy-Manning equation to calculate volume flow rates. A Manning coefficient of $n = 0.014$ s/m$^{1/3}$ for unfinished concrete is used for the sluice wall material in the Chezy-Manning equation. (Potter, p. 157)

- Daily drainage volume of water by a sluice or pump in the drainage area is calculated using the equation:
  $D = Q \times t \times 3{,}600$
  D = daily drainage volume (m^3)
  Q = volume flow rate (m^3/s)
  t = daily drainage time of the sluice or pump (hours)

If an area has more than one sluice or pump, the total daily drainage is obtained by summing the individual drainage volumes.

During low tides, the sluice doors are opened for about 2 to 6 hours twice daily, depending on the rate of rising and falling of the tide, to allow gravity drainage of excess water. When the tide rises, the sluice doors are shut to prevent seawater from intrudinginland. (U.S. Army Corp of Engineers, 1998). The doors are open for an average total of 8 hours daily.

- The daily drainage coefficient of the drainage area is determined using the equation: (Rowe, 1970):

$$D.C. = \frac{\text{Daily Drainage Volume}}{\text{Drainage Area}} = \frac{D}{A}$$

$$D.C. = \frac{Q \times t \times 3{,}600}{A \times 1{,}000}$$

  $D.C.$ = daily drainage coefficient (mm)
  Q = volume flow rate (m^3/s)
  t = daily drainage time of the sluice or pump (hours)
  A = Drainage are (km^2)

- Volume of rainfall in the area is assessed using the equation: $V = r \times A \times 1{,}000$
  V = Daily rainfall volume (m^3)
  r = Daily rainfall (mm^3)
  A = Drainage area (km^2)

Daily rainfall, r, is measured by an international standard rain gauge installed in an area by the Hydrometeorological Service, Ministry of Agriculture. There are over 136 rain gauges installed across the ten administrative regions of Guyana. This researcher is a rainfall observer responsible for collecting daily rainfall measurements for Hydromet at the John's Science Centre, University of Guyana, John's Settlement. (Daily Rainfall Observations, 2023).

- A comparison of the historical daily record of rainfall for an area, such as John's Settlement-Port Mourant, with the knowndrainage coefficient of the area will yield an estimate of the frequency and severity of flooding in the area from excess rainfall. If the daily rainfall is less than or equal to the daily drainage coefficient, $\boldsymbol{r \le D.C.}$, then the area is unlikely to flood. If the daily rainfall exceeds the daily drainage coefficient, $\boldsymbol{r > D.C.}$, then the area is likely to flood, depending on the amount of excess rainfall over drainage.

IV. ASSUMPTIONS AND LIMITATIONS OF STUDY

This study assumes (i) that the ground has already been saturated by rainwater, (ii) that all ground storage for water has been filled to capacity, and (iii) any flooding will be pluvial flooding, that is, flooding caused by pooling due to excessive rainfall. Hence, no attempt is made to quantify groundwater saturation, ground storage capacity, or permeability of surfaces in the drainage area, as the principal focus is on the correlation and causation between rainfall and flooding in the drainage surface areas. This is a limitation of using the daily drainage coefficient alone to determine the flood vulnerability of an area. However, once the foregoing assumptions are kept in mind, the study will still produce useful results that suggest mitigation measures to manage flooding in areas that have experienced excessive rainfall.

V. BLACK BUSH POLDER DRAINAGE AND IRRIGATION AREA

Area: 27,000 acres = 109.26 km^2; Number of sluices 3 & doors 12. Location & Description of Sluices: (1) Adventure: three doors (2) Eversham: four doors (3) No.43-Joppa: five doors. Each door has a width of 4.57 m and a design water depth of 1.75 m. Daily duration of opening of sluices = 12 hours maximum.

Table 1: Volume flow rate calculations for one sluice door

Parameter	**Value**	**Chezy-Manning equation**
Width, W (m)	4.57	$Q = \frac{A(R^{2/3})(S^{1/2})}{n} = \frac{8.00(0.991^{2/3})(0.0002^{1/2})}{0.014}$ = 8.03 m^3/s
Depth, D (m)	1.75	
Area, A (m^2)	8.00	
Wetted perimeter, P (m)	8.07	
Hydraulic radius, R (m)	0.991	
Slope, S	0.0002	
Manning coefficient, n (s/m$^{1/3}$)	0.014	
Volume flow rate, Q (m^3/s)	8.03	

Table 2: Daily drainage coefficient for Black Bush Polder sluices

Parameter	**Value**	**Drainage coefficient equation**
Volume flow rate for 1 sluice door, Q_1(m^3/s)	8.03	$D.C. = \frac{Q_{12} \times t \times 3{,}600}{A \times 1{,}000} = \frac{96.36 \times 12 \times 3{,}600}{109.26 \times 1{,}000}$ = 38.1 mm
Volume flow rate for 12 sluice doors, Q_{12}(m^3/s)	96.36	
Maximum duration of opening of sluices, t (hr)	12	
Daily drainage volume, D (m^3)	4,162,752	
Drainage area, A (km^2)	109.26	
Drainage coefficient(mm)	38.1	
Drainage coefficient, $D.C.$ (inch)	1.5	

A. Drainage Pumps

In 2015, drainage pumps, each with a discharge capacity of 200 cubic feet/second (5.66 m^3/s) were installed at No.43-Joppa and Eversham to assist in draining Black Bush Polder during high tides when the sluice doors cannot be opened. ($183M drainage pump commissioned at Eversham, 2015; $587M Berbice drainage pumps commissioned, 2015).

Table 3: Daily drainage coefficient for Black Bush Polder pumps

Parameter	**Value**	**Drainage coefficient equation**
Volume flow rate for 1 pump Q_1(m^3/s)	5.66	$D.C. = \frac{Q_{12} \times t \times 3{,}600}{A \times 1{,}000} = \frac{11.32 \times 12 \times 3{,}600}{109.26 \times 1{,}000}$ = 4.48 mm
Volume flow rate for 2 pumps, Q_2(m^3/s)	11.32	
Maximum duration of operation of pumps, t (hr)	12	
Daily drainage volume, D (m^3)	489,024	
Drainage area, A (km^2)	109.26	
Drainage coefficient(mm)	4.48	
Drainage coefficient, $D.C.$ (inch)	0.18	

The area will flood once the daily rainfall exceeds the combined drainage coefficient of the sluices and pumps of 42.6 mm (1.68 inches) after ground saturation has been reached and all ground storage has been filled.

B. Flooding In Black Bush Polder

The Black Bush Polder area, Corentyne, Berbice was built from reclaimed swamplands and was designed to have a best daily drainage coefficient of 38.1 mm (1.5 inches) by gravity drainage through multiple-gate sluices located at Adventure, Eversham, and No. 43-Joppa, but due to siltation in the mile-long outfall channels that drain into the Atlantic Ocean, is only about 1 inch daily (Rowe, 1970). Diesel-fueled pump stations were installed at the Eversham and No. 43-Joppa sluices to aid gravity drainage when the sluices cannot be opened at high tides, but these add only 4.48 mm (0.18 inch) to the drainage coefficient. With the siltation in the outfall channel, even the combined drainage coefficientof 42.6 mm (1.68 inches) might not be achieved. On May 24, 2021, Johanna BBP received 70.6 mm (2.8 inches) of rainfall which exceeded the combined drainage coefficient of 42.6 mm (1.68 inches). That rainfall was the highest reported in Guyana for that day. Black Bush Polder was flooded. (Hydromet Weather Brief, 2021; Hackett, 2021).

VI. JOHN'S-PORT MOURANT DRAINAGE AND IRRIGATION AREA

Area: 13,000 acres = 52.6 km^2 (from Google Earth) Number of sluices: 1 (dysfunctional and closed), Number of pumps: 1 (operational) Location & Description of Pump: Ankerville, Guyana Sugar Corporation's Recirculation Pump Volume rate of discharge of pump = 200 cusecs = 5.66 m^3/s Daily duration of operation of pump = 20 hours maximum

Table 4: Daily drainage coefficient for John's-Port Mourant pump

Parameter	Value	Drainage coefficient equation
Volume flow rate for pump Q (m^3/s)	5.66	$D.C. = \frac{Q_{12} \times t \times 3{,}600}{A \times 1{,}000} = \frac{5.66 \times 20 \times 3{,}600}{52.6 \times 1{,}000}$ = 7.75 mm
Maximum duration of operation of pump, t (hr)	20	
Daily drainage volume, D (m^3)	407,520	
Drainage area, A (km^2)	52.6	
Drainage coefficient(mm)	7.75	
Drainage coefficient, *D.C.* (inch)	0.31	

The area will flood once the daily rainfall exceeds the drainage coefficient of 7.75 mm (0.31 inch) after ground saturation has been reached and all ground storage has been filled. This is a very inadequate drainage coefficient for such a large drainage and irrigation area. To increase the drainage coefficient by 0.20 inch to 0.51 inch would bring drainage relief to the area. This can be done with the installation of a one-door sluice of width 5.18 m and design water depth of 1.75 m as described in the calculations in Tables 1 and 2. The proposed new sluice can be built in the same canal at Tain where the old sluice is located but further north closer to the sea for better drainage efficiency.

A. Flooding In John's-Port Mourant

The flooding in the John's-Port Mourant area began on May 28, 2021, following three days of total rainfall of 5.33 inches (135.4 mm), while Babu John and Chesney New Housing Schemes flooded on June 1 after three days of total rainfall of 4.07 inches (103.5 mm).

Much of the floodwater came from the system of interconnected canals that bring fresh water from the Upper Berbice River and Canje River into the agricultural areas and farmlands in East Berbice during the dry seasons. The system is fed by the Canje River and by the 14-mile Torani Canal that links the Upper Berbice River to the Canje River. In the rainy seasons, the Torani Canal helps to drain excess surface run-off precipitation into the Canje River, and the water then drains to the Atlantic Ocean. However, extremely high rainfall can cause the canal networks to be overwhelmed beyond their draining capacity and this would result in flooding as the excess water drains through the East Berbice drainage and irrigation system to reach the Atlantic via the numerous outfall channels on the coast.

In the few days before the flooding in East Berbice, heavy rainfall in the Upper Berbice River basin flooded inhabited areas such as Kwakwani among others. It was the floodwater from this area that wended its way downriver into the East Berbice canal networks and contributed to the flooding there.

To help remove the excess floodwater quickly from the East Berbice area, the drainage system of pumps and sluices on the coast was supplemented by many small privately owned and operated mobile pumps. Some pump owners volunteered their services, while others demanded payment from the regional authorities for the fuel consumed to operate their pumps. Eventually, the floodwater drained in about one week.

The maximum designed drainage capacity of an area is reduced by vegetation-filled canals, silted-up canals, garbage-filled canals, filled-in canals, and human inefficiencies in operating and maintaining the drainage infrastructure, and protective back dams, sideline dams, and sea dams. Hence, an area might be draining at a reduced dailycoefficient of 1.5 inches or even less, resulting in longer drain-off times for backed-up floodwaters. The drainage system must be maintained in an efficient condition so that the shortest possible drain-off times can be achieved in times of excessive rainfall and areas spend minimum time under floodwater.

It should be borne in mind that with even highly efficient drainage conditions, once rainfall exceeds the maximum drainage capacity, flooding will occur, as it takes some time even for the best system to drain off excessive rainfall flood waters. But with a highly efficient and clean system, we can be satisfied that we have fulfilled our engineering, operational, and administrative best practices. In summary, flooding will happen when rainfall exceeds the combined maximum drainage capacity of an area, the ground storage capacity, and the absorption by the ground until saturation is reached.

Fig. 3: Simplified drainage and irrigation map of East Berbice, showing the main canals that bring fresh water from the Canje River into the agricultural lands stretching from Canje to Skeldon.(Satellite image: Google Earth, 2021)

The canals shown in Figure 2 are the irrigationarteries for agriculture in East Berbice, but in the May – July heavy rainfall season when they overflow from the Canje River Basin, they cancause flooding along the coast, as happened in mid-2021. The area enclosed in red is the flooded parts of the backlands up to June 6, 2021. It is theexcess water from that area that flowed to the coast, resulting in floods that then exited to the sea via the sluices and pumps.

VII. EFFECTS OF SOLID WASTE AND OTHER DISCARDS IN THE DRAINAGE SYSTEM

Dumping solid waste and discarded building materials in the canals and drains does not cause the initial flooding but it prolongs the flooding. The cause of the initial flooding is the high concentration of water in an area during a sudden heavy rainfall resulting in pooling, especially on impermeable surfaces, so that the water takes some time to run off through drainage structures to lower levels. Even if all drainage structures are clean and clear and in maximum working order, once rainfall exceeds the drainage capacity of the area, pluvial flooding is inevitable, as it will take some time for the flood waters to drain away. Excess flood water cannot drain away instantly or even rapidly enough to prevent some degree of flooding. Even the best-designed structures can be overwhelmed by extreme rainfall events. If an area has a maximum best drainage coefficient of 3 inches and gets 5.4 inches of rainfall, it will take 43.2 hours to drain away that rainfall water: (5.4 in/3 in) x 24 = 43.2 hrs. The dumping of solid waste in the canals and drains prolongs the flood by slowing the runoff of water and reducing the drainage coefficient of the area, maybe to as little as 1 inch so it takes 129.6 hours to drain away the rainfall water: (5.4 in/1 in) x 24 = 129.6 hrs. Solid waste can also block pumps so the pumps must be stopped, opened, and cleaned. Solid waste must be properly disposed of and not dumped into the canals and drains. The drainage structures must be allowed to work unimpeded by not putting into them solid waste and discarded building materials. The flood water needsto go down as fast as possible. Every piece of solid waste impedes the free flow of water.

VIII. DISCUSSION

From the foregoing descriptions, it should be now obvious that even the best drainage system in clean conditions and working at maximum efficiency will be overwhelmed if the rainfall is high enough, causing pluvial flowing to occur. Hence, we must learn to be resilient to survive and overcome the effects of flooding.

Drainage engineers have always tried to design drainage systems to discharge excess rainwater as efficiently as possible to prevent flooding altogether or to remove excess floodwater as fast as possible. Drainage systems are designed with two basic considerations: (i) cost and (ii) probability of a catastrophic flood happening, together called a cost-benefit ratio. The probability of such an event occurring is specified as 1-in-50 years, or1-in-100 years, or 1-in-500 years, etc. The longer into the future we design and build for, the more costly the drainage system becomes. A country's budget is limited and must prioritize other critical areas. Hence, drainage systems must be built with a cost-benefit ratio in keeping with the budget of a country.What do we do when rainfall is so intense and heavy that the most efficient drainage system is overwhelmed and cannot discharge the water fast enough and so catastrophic flooding occurs and is even prolonged for some period? In this scenario, the best that can be done is to ensure that the population within the flooded area is water-resilient enough to survive the flood and to recover fully from the effects of the flood after the floodwaters have receded. What does it mean to be water-resilient? The beginning of water resiliency is educating the population about the causes, effects, risks, and hazards of flooding. Then armed with this knowledge, the population will be better prepared in terms of psychology, materials, resources, emergency apparatus, and other assets to best respond to a flood situation.

Within the limitations of funds, drainage systems, and water storage areas should be designed and maintained for maximum rainfall events, say the 1-in-500 years or even the 1-in-1,000 years event. Warning systems should be built and maintained to alert the population of possible pluvial flooding from extreme events. Emergency supplies and resources should be kept on hand for emergency personnel to distribute to the population in times of need. The population should be educated in flood mitigation, risks, and safety. Roadways and streets should be designed and built to withstand the effects of flooding if it does happen. Building codes should be enforced to ensure that building construction complies with the mitigation of flood hazards and that buildings are designed to be flood resilient. Urban areas should be landscaped to have sufficient green and permeable areas to absorb some surface runoff to allow infiltration into the ground. This will lessen pooling and give some relief to the drainage system and lessen pluvial flooding.

IX. RECOMMENDATIONS

- There should be regular monitoring, measurement, and recording of siltation at every sluice to determine siltation cycles and scheduling for de-silting procedures. Daily measurements would be ideal, but weekly measurements might be more feasible. Lack of trained personnel and appropriate equipment, including safety gear, could be a hindrance. Equipment would be needed for measuring siltation or silt depth at sluices and pumps. Regular monitoring of siltation in the outfall channels should also be done for the same reasons.
- Sluice doors should be built an additional foot (0.30 m) higher to prevent overflow of seawater or river water during extremely high spring tides. This would help to minimize saltwater intrusion into inland cultivation areas.
- More use should be made of draglines, rather than hydraulic machine excavators, to dig and clear canals. The draglines can dig deeper and shape the channels better for more efficient flow.
- Citizens in each community need to be more aware of the drainage structures therein to be able to immediately report inefficiencies to the relevant agencies.
- More citizens need to be trained in the field of coastal engineering as this is vital to the country's current and future development needs.
- There should be close coordination between the Hydromet Service and the drainage authorities in every region to ensure efficient response of drainage infrastructure and systems to rainfall likely to result in flooding.
- The government should cease distributing house lots in flood-prone areas or build up the lots with compacted reef sand to ensure the lands are above flood levels.
- Owners of house lots already in flood-prone areas should seek to build up their lots with reef sand.Laws should be passed to make the cost tax deductible or government subsidized.

X. CONCLUSION

A modernized drainage system would be the best investment for Guyana to mitigate flooding in the rainy seasons and ensure adequate irrigation in the dry seasons. This system would integrate water level sensors and rainfall gauges with the opening and closing of motor-driven sluice doors and the operation of drainage pumps. The system would be controlled by a central computer and its networks to make optimum decisions for a drainage-irrigation area for best water control and management.

However, even a top-classdeveloped country drainage system working at maximum efficiency and in clean and clear conditions will be overwhelmed if the rainfall is high enough to exceed the drainage and storage capacity of that system and so flooding will occur as happened in sections of New York City, USA, just recently. (Offenhartz2023). To survive and prosper, we must learn to be water resilient as were our pre-historic and historic ancestors.

ACKNOWLEDGEMENT

The researcher expresses sincere gratitude to the sluice and pump operators who supplied him with the information on the operations of their structures. He salutes them for performing their duties in all weather and at all times of the day and night to keep the drainage and irrigation system in operation. The researcher also thanks Ms. Ashmini Prasad, English Teacher at Tagore Memorial Secondary School for providing constructive criticisms and corrections needed for the successful completion of this manuscript.

REFERENCES

[1]. Case, Gerald O. (1920). Coast Erosion Protection Works on the Case System in British Guiana. Breinigsville, PA: Kessinger Publishing Legacy Reprints. https://archive.org/details/coasterosionpro00casegoog/page/n32/mode/2up
[2]. Daily Rainfall Observations. (2023). Hydrometeorological Service. Ministry of Agriculture, Guyana. https://hydromet.gov.gy/
[3]. Google Earth Satellite Maps. (2021). http://www.google.com/earth/index.html.
[4]. Hackett, M. (2021 May 29). Once rainfall exceeds the maximum drainage capacity flooding will occur. Stabroek News.

ISSN No:-2456-2165

[5]. https://www.stabroeknews.com/2021/05/29/opinion/letters/once-rainfall-exceeds-the-maximum-drainage-capacity-flooding-will-occur/

[6]. Heavy rains swamp Georgetown, Coastland. (2015 June 1). Kaieteur News. https://www.kaieteurnewsonline.com/2015/06/01/heavy-rains-swamp-georgetown-coastland/

[7]. Hoppie, S. (2015 July 17). Georgetown not designed for this magnitude of rainfall – Authorities. Kaieteur News.

[8]. http://www.kaieteurnewsonline.com/2015/07/17/gtown-not-designed-for-this-magnitude-of-rainfall-authorities/

[9]. Hydromet Weather Briefs. (2014 – 2021.) Hydrometeorological Service.Ministry of Agriculture, Guyana. https://hydromet.gov.gy/weather/weather-brief/

[10]. Lacey, Gerald. (1953). Report on the Drainage and Irrigation Problems of British Guiana. Appendix B Notes on the Discharging Capacity of Drains and Pumping Installations. Gov't of British Guiana. Georgetown.

[11]. Liu, N.C. (2014 October 9). There needs to be a technical analysis of the drainage system of Georgetown and the East Coast. Stabroek News Letter.

[12]. https://www.stabroeknews.com/2014/10/09/opinion/letters/needs-technical-analysis-rainage-system-georgetown-east-coast/

[13]. Merrill, Tim. (1993). Guyana and Belize Country Studies. Federal Research Division. Library of Congress.

[14]. https://tile.loc.gov/storage-services/master/frd/frdcstdy/gu/guyanabelizecoun00merr_0/guyanabelizecoun00merr_0.pdf

[15]. Offenhartz, Jake et al. (2023 Sept. 29). New York City area gets one of its wettest days in decades, as rain swamps subways and streets.https://apnews.com/article/northeast-storm-rain-new-york-flooding-subway-a16ad4720eddd6c0f7ea3b761f414e80

[16]. Potter, Merle C. (2009). Fluid Mechanics Demystified. McGraw Hill, New York.

[17]. Preliminary report on Guyana's drainage due in six months – Patterson. (2015 July 23). Kaieteur News. https://www.kaieteurnewsonline.com/2015/07/23/preliminary-report-on-guyanas-drainage-due-in-six-months-patterson/

[18]. Proceedings 1st National Conference on Engineering & Architecture Education in Guyana.(2007). Faculty of Technology. University of Guyana.

[19]. http://uog.edu.gy/faculties/fot/files/National_Conference_on_Engineering_and_Architecture.doc

[20]. Ramraj, R. (1990). Rainfall Distribution along coastal Guyana, 1901-1980. https://www.gammathetaupsilon.org/the-geographical-bulletin/1990s/volume38-1/article3.pdf

[21]. Rowe, W. D. (1970). A Report on Declared Drainage and Irrigation Areas in Guyana. Land Use Study. Supplemental Paper No. 2. Ministry of Works, Hydraulics and Supply.

[22]. Suseran, L. (2014 May 19). Ramotar commissions $37M drainage pump at Rose Hall Town. Kaieteur News. https://www.kaieteurnewsonline.com/2014/05/19/ramotar-commissions-37m-drainage-pump-at-rose-hall-town/

[23]. Thompson, Alvin. (1987). Colonialism and Underdevelopment in Guyana 1580 – 1803. Carib Research & Publications Inc. Bridgetown, Barbados. pp 2-3

[24]. U.S. Army Corp of Engineers Mobile District & Topographic Engineering Center. (1998). Water Resources Assessment of Guyana. U.S. Southern Command Engineer's Office.

[25]. https://www.sam.usace.army.mil/Portals/46/docs/military/engineering/docs/WRA/Guyana/Guyana%20WRA.pdf

[26]. $183M drainage pump commissioned at Eversham. (2015 Oct. 29). Guyana Chronicle.

[27]. https://guyanachronicle.com/2015/10/29/183m-drainage-pump-commissioned-at-eversham/

[28]. $587M Berbice drainage pumps commissioned. (2015 Dec. 30). Kaieteur News.

[29]. https://www.kaieteurnewsonline.com/2015/12/30/587m-berbice-drainage-pumps-commissioned/