Faculty of Science and Engineering

Assignment front cover sheet

SECTION A – TO BE COMPLETED BY THE STUDENT

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Assignment Title	**Dissertation Thesis**	Assignment Number	
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Flood Assessment – Akurana Area

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Statement of Authorship

This is a statement that this assessment was produced by me, has not previously been published, and has not been offered for publishing elsewhere. The authors whose published data I used for the report have their names cited.

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Abstract

Akurana is situated in the central proving of Sri Lanka, where the city is one of the most widely affected city by flooding. During the monsoon season the city is subjected to flooding atleast once a year. Travelers on the Kandy to Jaffna route near Akurana along the Pinga Oya have experienced hour-to-day flooding on a regular basis since 2001. About 5 km upstream of its junction with the Mahaweli river at Katugastota, the flooding happens without prior warning. Many possible reasons for the flooding in akurana have been conducted but a proper solution to overcome this matter has not been implemented. Some officials who have done previous analysis believe that the Polgolla Barrage and/or climate change are to blame. Other potential causes include river narrowing, river dumping, and increased runoff as a result of changing land use.

In this analysis the main priority is to mitigate a proper way to overcome this matter. Therefore, at first a feasibility study was carried out a then all the previous analysis and records was observed to undergo a proper study. It was found that the best remedy here is to implement proper ways of drainage systems so that when the rainfall occurs the water has the ability to flow towards Pinga oya. This is the main water body which is crossing the area resulting in floods when water is maximized.

A survey was conducted in the city limits of Akurana, where we wanted get the opinions of the locals of Akurana city. Urban, commercial and industrial personnel were interview and surveyed who have experienced the flooding in Akurana and to get an insight on the adverse effects and experiences after/during the flooding and causes for the Akurana flooding the results were then tabulated and critically analysed to come up with a possible mitigation method for the flooding in Akurana.

Acknowledgement

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1. Chapter 01: Introduction to the study

1.1 Introduction

A temporary state of surface water (a river, lake, or the sea) is called a flood when the water level or discharge exceeds normal limits. Infrastructural expansion, commercial, industrial, and other human activity are moving closer to sensitive areas like streams, stream corridors, and flood plains resulting in massive drainage issues. The Pinga Oya catchment has experienced a significant increase of population, changes in land use, and increase of resource utilization. Floods have become more frequent, along with dengue and other water-borne illnesses, issues with water quality, and a reduction in the scenic value of streams. It is able to note that one of the greatest problems in Sri Lanka and Asia is the improper management of stream corridors in urbanizing areas.

The local authorities did not have records of development into the waterways, and there are also illegal projects where no actions have Many illegal infrastructures which have led to massive drainage blocks was the main problem which can be observed in the city. been taken yet. With accordance to previous research done by Mahaweli Authority in Sri Lanka some possible reasons which can lead to massive floods in Akurana was identified. They are namely,

(i) Construction of Polgolla dam
(ii) Changes in the rainfall
(iii) Illegal constructions which terminate drainage systems
(iv) Stream bed modifications brought on by rapid siltation
(v) Lower infiltration into the soil due to changes in land use

Residents and visitors on the A-9 main road in Akurana, which serves as the main route between Jaffna and Kandy, have experienced frequent flooding during the past 20 years. In this area, floods have just recently become a common occurrence; since 2001, there have been not less than 10 floods. There were no floods until 2001, but despite a rapid rise in river level to the point, nearly flooding on November 23, 1978 (the day of the Batticaloa storm with 263 mm of rainfall). Akurana is one of the most frequent cities in the hill capital that is subjected to flooding when compared with cities like Rathnapura, Colombo.

1.2 Problem statement

Sri Lanka is a tropical country which has monsoonal rains within a year. Many areas in Sri Lanka are subjected to natural disasters but flooding can be considered as the most affecting disaster throughout Sri Lanka. This does not only affect the society but also a massive drop to economy and other problematic situations may arise.

One of the most affected areas in Sri Lanka due to flooding is the Akurana area. Many recent cases can be seen and a large impact to the area was identified within the last 2 decades. By considering previous studies it is able to determine that the main problem which leads to flooding is the improper drainage systems. Therefore, this study is done to assess a solution for this matter by conducting a study to provide an alternative to this matter.

1.3 Aim

Conducting a survey to mitigate and improvise the drainage system in the Akurana area.

1.4 Objective

- Investigating of current impacts in the area which leads to flooding.
- Conducting a survey to analyse the alternative measures which is provided as a solution for this matter.
- Carrying out a study to analyse whether the provided solution is satisfying the mitigation method.

1.5 Scope

- Flood assessment analysis and analysing the alternative measure proposed and to provide any solutions if the implemented solution is not satisfied.

2. 2.0 Literature Review

2.1 Flood

Flooding can be identified as one of the most common natural disasters around the world. It is widely happening in tropical countries like Sri Lanka. The most common causes for flooding are heavy rainfall, cyclone which cause massive storms, damage in water retaining structures like dams, rapid snowfall, tsunami, and incorrect drainage systems etc. Floods can impact negatively across a large area, loss of life, damaging private property, and destroying vital public health facilities. More than 2 billion people worldwide were impacted by floods between 1998 and 2017 according to research which was done by the WHO. The most vulnerable people to floods are those who reside on floodplains, in non-floodproof structures, or who lack warning systems and awareness of the risk of flooding.

Floods can be categorized into 3 types. They are,

1. Flash floods – floods caused due to intense rainfall which raises the water levels at a nick of a time.
2. River floods – Floods which occur due to natural phenomena such as rain and snow which enter rivers and streams so that the capacity of those will exceed.
3. Coastal floods – Floods which occur due to storms, cyclones and tsunami.

In the last 10 years, floods, droughts, tropical cyclones, heat waves, and severe storms have been responsible for between 80 and 90% of all known disasters caused by natural hazards. Floods are becoming more frequent and more intense, and climate change is predicted to result in an increase in both extreme precipitation frequency and intensity. (WHO, 2022)

A case for which a massive flood occurred in Sri Lanka can be considered as the floods occurred in almost 14 districts in the year 2017. The death toll was gone up to 100 and more than 50,000 families was affected and more than 800 homes were destroyed in Sabaragamuwa and Western regions.

A flood will not only impact the lives of people, but it will cause a massive damage to the economy of the country and the poverty of people. After a flood the rebuilding phase is one of the hardest and time-consuming mitigation methods.

2.1.2 Flooding in Sri Lanka

Among the natural impacts of seasonal changes, flood is the natural disaster that affects Sri Lanka the most. In view of Sri Lanka's growing urbanization, flooding can be considered a serious catastrophic condition. One of the most common areas of flooding can be identified as the "Akurana" region located at the central province near to the hill capital Kandy. Therefore, the main objective of this study as mentioned above this study will show the areas that needs to be improved to minimize this disaster as much as possible. The village of Akurana is intersected by Piga Oya, one of the Mahaweli river's principal branches. When the river overflows, which happens multiple times a year, daily life, and economic activity for those who are living in the Akurana urban area collapse. Also, at that period all traffic on the A9 route is stopped. Therefore, the affected areas should also include the Akurana, Waragashinna, and Kurudugahaela areas. According to a previous study which was done by the University of Kelaniya, it was identified that the main reasons for the above flooding is due to the reasons such as the river is blocked due to soil erosion caused by construction on both sides of the area, erosion of river banks caused on by incorrect land use, clearing of forests in upper mountain regions and reclamation of banks of the Piga oya, incorrect bridge construction, and garbage discharge into the river. It was also able to conclude that due to the lack of personal habitats of the people who live in the area, all the drainage systems are also blocked, and the water has no form of flow. (Kumara, K.G.R.N, 2019, UoK). Given below are some images which has been captured in the Akurana when the area was subjected to a massive flood.

Case studies for the floods occurred in Sri Lanka is discussed below in the topic __

Figure 2.2 - Flooding in Akurana

Figure 2.1 - Flooding in Akurana

2.2 Floodplain Management and Mitigation

Flood mitigation or management is the principal key behind the reduction of floods occurring around the world. The main aim of these measures will be to reduce the structure experiencing flood damage and it will cause of massive reduction in the severity of the flood. A main mitigation method which was followed in Sri Lanka was done by the inter-agency Flood Mitigation Task Force, led by the Sri Lanka Land Development Corporation (SLLDC). They selected flood and drainage management infrastructure maintenance and enhanced that as a main priority. This component supports those efforts to lessen the effects of future floods in the Colombo Water Basin watershed, the investment packages under this component are crucial and essential.

Flood mitigation measures directly links to the protection of individual properties, protection of communities, and finally the flood risk management.

Protection of individual properties describes the improvement of areas such as shoreline developments, scour protection, better rainwater infiltration through the use of permeable paving materials and grading away from structures, and the inclusion of berms, wetlands, or drainage channels in the landscape are all examples of preventative measures that can be used to reduce flooding at the property level.

Protection of communities refers to areas that are prone to flooding. Therefore, temporary flood defenses can be built to protect against rising flood waters. Large urban development's frequently control and diverts rivers that flow through them. Flooding that spreads to neighboring waterways

and community areas when a canal's capacity is exceeded by water might lead to serious damage. Flood defenses, embankments, or walls can be used to raise the water's edge as part of long-term and short-term defenses to reduce damage. In bigger urban locations, the high expense of mitigation is frequently justified by the high population and value of infrastructure at danger.

Finally flood risk management or mitigation measures can be describes in many sections.

1. Hazard Mitigation

Flood mitigation that reduces both the chance that a structure will sustain flood damage generally and the extent of that damage should do so. Planning and zoning, managing floodplains, limiting building in high-risk flood zones, and offering education and outreach are a few examples of mitigation practices in a community. Examples of mitigation for homeowners include getting flood insurance, raising buildings, or moving out of the floodplain entirely.

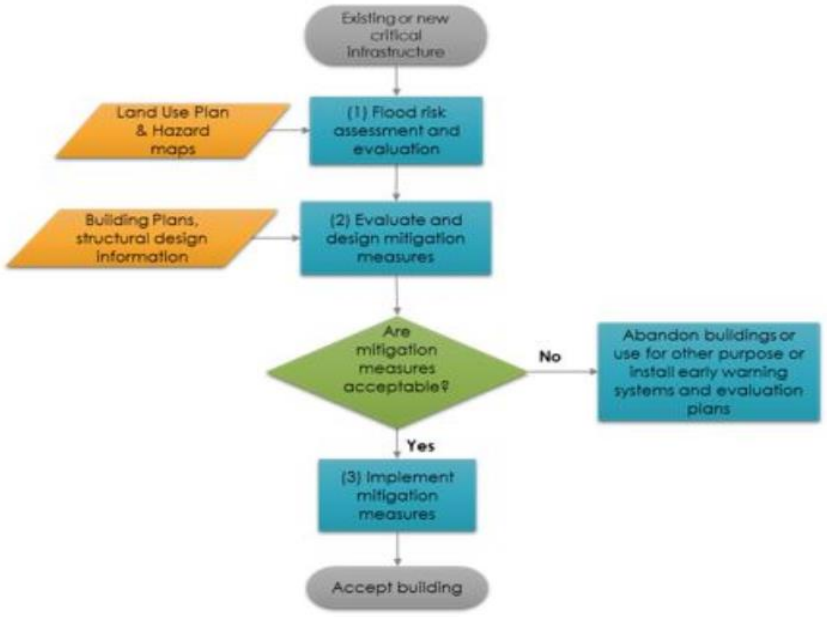
2. Structural Mitigation

Non-structural flood mitigation aims to alter how people interact with the floodplain and flood risk, as well as to remove them from places that are vulnerable to flooding. Projects could involve raising buildings, keeping floodplains as open space, or full community flood preparation.

A main example for mitigation measures taken in Sri Lanka for floods in Colombo is, flooding has been happening far too frequently. It destroys infrastructure and livelihoods, ultimately stopping the city's development and wiping out years of advancement. To ensure a high quality of life for its citizens as the city grows in size, population, and aspirations, it must overcome its vulnerability to flooding. By making wise investments in public areas, wetlands, and infrastructure, the Metro Colombo Urban Development Project is assisting in reducing the danger and effects of floods while improving the city's livability and competitiveness. It was expected that when the project is finished, 232,000 households will be more directly protected against flooding, and the quality-of-life improvements will benefit the entire city. The solution for this matter was the Metro Colombo Project has been assisting the government since 2013 in lowering floods in the Colombo Water Basin's catchment area and enhancing the ability of local governments to restore, develop, and sustain infrastructure and services through significant demonstration investments. The project has a section on managing flooding and drainage, which involves complex, integrated works including tunnels and pumping stations. Along with this, roadway and drainage infrastructure, including

canals and flood gates, is restored and managed. Also, improvements have been made to urban services and nearby public facilities. After 4 years of finishing all these mitigation activities increased the gravity system's drainage capacity by 100 cubic meters (end target has been 185 cubic meters), 2 micro drainage projects has been implemented which lowers the potential for floods in specific places, 80% of users, including Beddagana and Kotte Ramparts Parks, have expressed satisfaction with the Beira Lake Development, which has been the end goal, 39 km of roads and drainage have been constructed and restored to project specifications, and many advantages has been obtained.

Also, the Caribbean Handbook on Risk Information Management has shown a methodology for flood mitigation methods for buildings. The flow is as follows,



[Chart 2.1 – Mitigation methods for constructing flood resistance buildings]

This handbook has also given measures that should be implemented in real world situations based on the risk assessment and the inspection of the building.

Primary Flood Source	Flood risk factors	Evaluation Criteria	Structural Mitigation Measures
Flash Floods	For design level flood	Ensure structural integrity is maintained Floatation is prevented	• Anchor structure to foundations. • Sufficient embedment of foundations • Anchorage of walls to structural framing/ with each other
Back water flooding	For service level flood	Ensure living and critical service level are not inundated, building to remain operational Floatation, seepage is prevented	• Water diversion channels • Levy walls • Proper drainage • Temporary doorway blocking etc. • Use water resistant materials • Allow basements to be flooded
	For design level flood	Ensure building safety, nominal disruption of operations, prevent critical services from disruption	
	For extreme level flood	Ensure building safety, prevent floatation, access to safe zones, provide escape mechanism	
Sea-surge and wave based coastal flood	Water flow	Ensure structural integrity is maintained Floatation is prevented	• Anchor structure to foundations. • Foundation protection from scour and wave action • Sea-walls to protect building • Break water structures
Rain based flash flood	Velocity and Depth	Low velocity <less than 3 m/sec> low water depth < 1m	• Foundation protection from scour • Water diversion, and drainage
		High velocity, low water depth, velocity > 3 m/sec	• Foundation protection from scour • Water diversion, and drainage • Design walls for water pressure and debris impact • Water-flow through paths(break-away zones) to prevent building instability
		High velocity (> 3 m /sec), high water depth (> 1 m)	(Use back water flooding process)
		Low velocity, high water depth	(Use back water flooding process)

Table 2.1Mitigation measured based on the Caribbean Handbook

According to a study done by Dr.(Eng.) S.S.Sivakumaa, in 2015, Flood Mitigation Strategies Adopted in Sri Lanka A Review, has stated 3 main branches that should be implemented here in Sri Lanka in order to mitigate an area which is prine to flooding. Those are,

1. Modifying the flood
2. Reducing the susceptibility to the damage
3. Reducing the impact of flooding

Therefore, in this study these strategies have been given a priority in order to achieve a considerable flood assessment to the Akurana area.

2.2.1 Flood Mitigation Methods

Many flood mitigation methods can be seen around the world. Day by day new innovations are bought in to the construction industry in order to mitigate these disasters. But the means of knowing to apply the correct mitigation methods to respective areas must be implemented with experience and proper understanding. When it comes to the methods of flood mitigation some of the common methods that can be seen in Sri Lanka and also around the world are construction of proper water management systems, construction of well-designed water retaining structures, floodwalls, floodgates, and implementation of proper water evacuation routes etc. These measures come under the category of Structural mitigation approaches and when it comes to the non-structural mitigation approaches they are, removing people from risky areas, providing proper warnings on time, advising the society to innovate the surroundings as mitigate measures etc.

Since the Akurana town is not that much of a busy town the mitigation measures can be taken easily. It was identified that a main reason for the flooding in this area is the improper water evacuation systems and blocking of drainage systems. Therefore, the initial stage of mitigating these areas can be started by improvising the water management system in the area. Also, it should be noted that the river which runs across the town will definitely impact the town due to the high rise of water levels, therefore providing a proper mitigation method to overcome this matter is also the next challenge. According to previous study measures has been taken in the Akurana area to provide solutions for this mater.

2.3 Flood Forecasting

In order to control flood risk, minimize flood hazards, remove residents from flood-prone locations, set insurance rates, and manage environmental and water resource systems, accurate flood forecasting is required. The practice of predicting future phases of flows and their timing at specific locations along a river during floods is known as flood forecasting. According to "Flood Mitigation Strategies Adopted in Sri Lanka, 2015" the estimations or forecasts which generally requires are maximum discharge and time occupancy and the levels that are anticipated above a

given water level or the warning level at different times in time between rising and lowering stages of flooding in a river.

An example for flood forecasting system in Sri Lanka is the realtime rain monitor systems (Kalu basin, all rain gauge, 30 days)

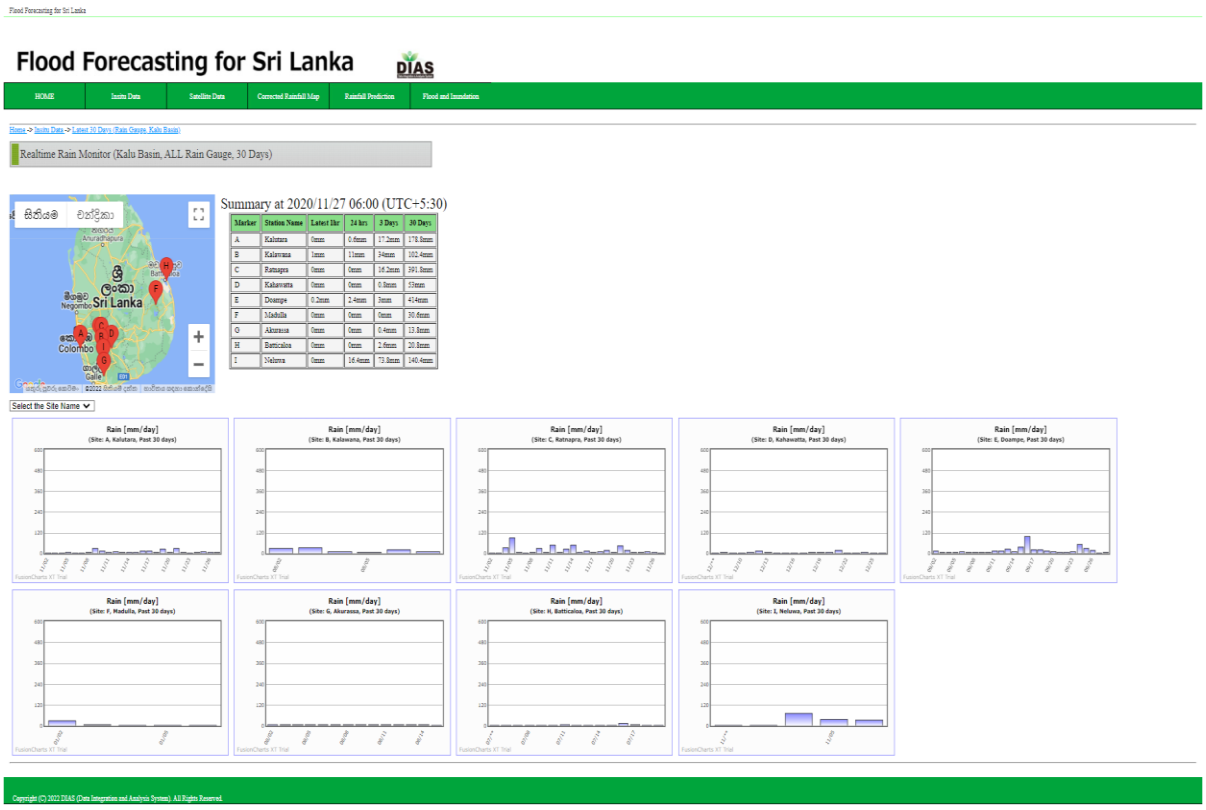


Figure 2.3 Realtime rain gauge, Sri Lanka

2.4 Previous cases of flooding in Sri Lanka

The most recent massive flooding which occurred in Sri Lanka happened on 15th October 2022 mostly on the western province. As of 16th October, 5,383 individuals from 1,660 households had relocated to 36 places where the government had designated as safe. While 207 homes were damaged, five were completely destroyed.

Since the beginning of August, Sri Lanka was experiencing flooding and landslides due to heavy rain. At least 3 deaths and 2,374 displaced individuals were reported as of August 3rd. The severe weather has had an overall impact on 12,289 persons, 2,374 of whom have been uprooted from

their homes and placed in relief facilities. More than 300 dwellings have suffered damage. Both the closure of schools and the suspension of rail service.

In 19th August 2021, according to Sri Lanka's Disaster Management Centre (DMC), around 1,500 people were evacuated from their homes in the districts of Kandy and Kegalle due to flash flooding and severe rain. The regions of Gangawata Korale and Pasbage Korale in Kandy were severely impacted by the intense rainfall that began on August 11th. According to DMC, 19 homes were severely destroyed by the floods and heavy rain that caused 1,509 individuals to be evacuated. 1,972 individuals from 426 families were impacted in total.

Finally, it is able to conclude that Sri Lanka is most likely to face flooding mostly in the areas of central and western but also in other areas as well. The reasons for which this happens is the lack of maintenance in the drainage systems, water evacuation, improper structural constructions etc. A main area in the central region which is most subjected to flooding is the Akurana region. Therefore, in this study it is much focused to assess the causes of flossing in the Akurana area and to mitigate them using previous study and survey.

3. Chapter 03: Methodology

3.1 Purpose of research

Qualitative research should be done in 3 main ways. Also, it can be considered as an exploratory investigation where it is categorized into 3 main sections based on the data analysis. They are the Review of literature review, subject discussion and focus groups or data discussion by means of a meeting. Therefore, in this study all these categories will be considered in order to implement a mitigation method to the Akurana area.

3.2 Approach of research

When it comes to research with accordance to qualitative approach, the study can be approached in 2 main ways. They are Deductive and inductive method methods which is according to Saunders et al. 2009. The inductive approach focuses mostly on creating a hypothesis after first creating one through data collection. It is widely utilized and better suited to using qualitative data when the research topic or the researchers are inexperienced with the field. Nearly the opposite of the inductive method is the deductive method. Here, the focus is on developing a theory from start and learning as much as you can about it. Although this approach leans more toward quantitative data, qualitative data is still a better solution.

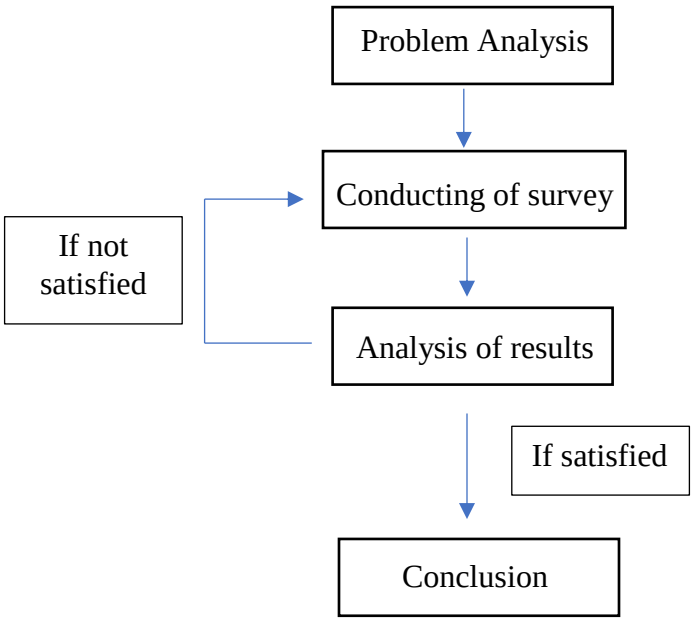
An organized way of problem-solving is a research methodology. It is a systematic method of learning how to conduct research. A methodology is a framework that shows how a scientific approach can be used to represent, explore, interpret, forecast, and research reality. A research methodology, in other words, is a strategy for highlighting the limitations of methodologies and emphasizing their origins, underlying assumptions, and consequences. Research methodology is the study of understanding strategies with the aim of developing a strategy simultaneously with the research. Research methodology refer to a variety of procedures, schemes, and formulas used in the study. They are typically organized, analytical, and value-free.

The topic of this research directly means about "Assessment". Therefore, assessing of collected data has been utilized and then an output for the collected data will be the implementation of a mitigation method to overcome flooding in Akurana area. Therefore, in this research a qualitative approach has been used from the start to the end of this research.

3.3 Methodology of the research

The methodology of this research consists of 3 main areas where first of all a feasibility study was carried out in the city limits of Akurana, where all the previous records and required data for the analysis was collected. After analysing the problem, an alternative (the mitigation of drainage systems) was implemented and then a survey was carried out finally to ensure that the mitigation method has satisfied the requirements so that it can be implemented in the Akurana area.

The flow of the analysis is shown below in chart 3.1



[Chart 3.1 – Methodology]

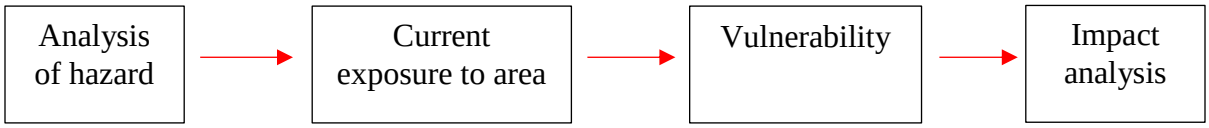
At first the analysis of problem will be carried out using the statistical data on the literature reviews, field survey and proposed mitigation methods. As it is known the main problem here is the recurring of flooding in the Akurana area due to many manmade and natural factors, the problem

analysis proved that the main requirement here is to overcome all the drainage issues in the specific area.

Then a survey was carried out in order to assess the amount of population which was affected and to satisfy the requirements to implement the above-mentioned alternative.

Finally, the data collected using the survey will be analysed and then it will be confirmed whether the alternative proposed will be satisfied or not.

All the above-mentioned scenario will undergo 4 main stages of approach. They are Analysis of Hazard, current exposure to the area, vulnerability, and impact analysis. The main purpose of carrying out these steps is to ensure that the mitigation method which will be applied to overcome this matter will give a positive output at the end of this research.



A rapid onset hazard's severity and related likelihood at a location of interest are described by the term "Analysis of hazard."

The term "current exposure to area" refers to valuable assets that may be exposed to a hazard. These resources can be physical (structures, items, essential infrastructure), social (people and social systems), commercial (companies, regional scale economic activity), or environmental (structures, items, critical infrastructure).

Vulnerability explains how susceptible assets are to hazard exposure and shows how building loss and risk intensity, such as floods, are connected. Building vulnerability can be evaluated using three main methods: analytical/computational, empirical, and expert judgment.

Impact refers to the monetary losses brought on by a building's damage during an event.

These analysis before implementing the mitigation method will give a thorough understanding on how to apply the most acceptable way of implementation

3.4 Study area and general details

The main water source which affects the flooding in the Akurana region is the Pinga Oya. It consists of a large area of 14,467 Ha. In addition, Hunnan Oya, Owissa Oya, Balapitiya Oya, Kurugoda Oya, and Wahagalla Oya make up the majority of its sub tributaries. The Pinga Oya is the principal stream that links Hunnan Oya, Owissa Oya, and Kurugoda Oya. It flows into the Mahaweli river in Katugastota. Home gardens and paddy fields cover over 75% of the Pinga Oya catchment. Tea lands cover the upper catchment, and scrub areas occupy the northwest corner.

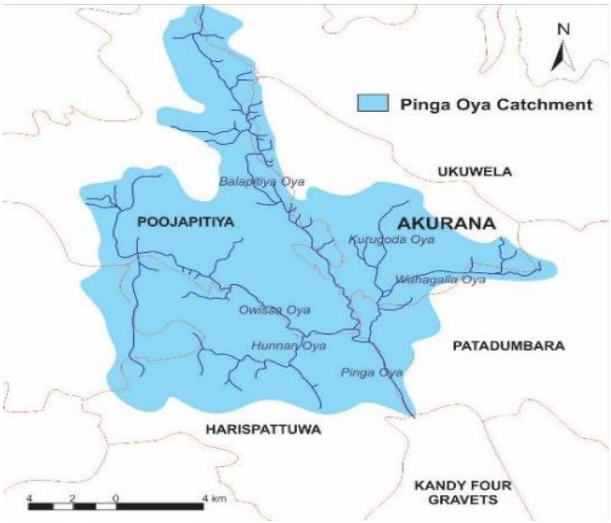
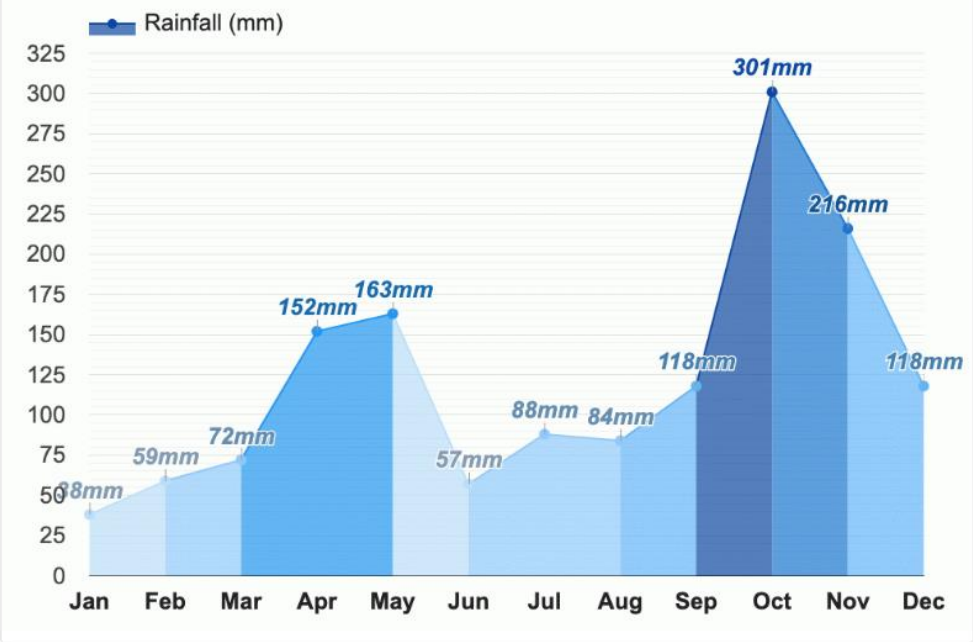


Figure 3.1 Pinga Oya Catchment

According to the analysis the previous rainfall was found in order to identify the times of the year where flooding can occur at peak.



Average rainfall in January: **38mm**
Average rainfall in February: **59mm**
Average rainfall in March: **72mm**
Average rainfall in April: **152mm**
Average rainfall in May: **163mm**
Average rainfall in June: **57mm**
Average rainfall in July: **88mm**
Average rainfall in August: **84mm**
Average rainfall in September: **118mm**
Average rainfall in October: **301mm**
Average rainfall in November: **216mm**
Average rainfall in December: **118mm**

Figure 3.2 Average Rainfall in Akurana in a year

According to the satellite details, the general details of the area could be taken only for a certain an amount of time. The below mentioned data set was the most important areas which was analysed in order to provide a solution to this matter.

1. Data on annual rainfall of the area was collected from Sri Lanka department of Meteorology and using internet-based material.
2. Satellite details of observed previous rainfall
3. Flood occurrence previous data was collected from social media news and other journal articles including the future forecasts
4. The number of bridges and water retaining structures in the specific area was noted to ease the mitigation methods

3.5 Data collection methods

The collection of data for this research is conducted in 3 main ways. They are (i) using previous literature reviews, (ii) sampling method and (iii) Survey/Questionnaire methods. The reasons for using these sources are to satisfy the conditions for a qualitative approach to the study.

3.5.1 Literature review

Any research project should start with a thorough analysis of the literature. This enables the needs of the research issue and the development of the study subjects. The individual researcher surveys and assesses the relevant intellectual region. The conceptual framework and research strategy were built on a thorough analysis of the literature. As the first attempt in collecting information were based on the previous studies and the previous flood affects occurred in Akurana using articles and other sources of literature. It was able to conclude many reasons for these massive floods to occur and also the past remedies which has taken at present to overcome these matters using many alternatives. Also, the reasons for the flooding including many illegal activities were also obtained using these literatures. Finally, it was able to conclude that the best remedy for mitigating this issue is to uplift the drainage issues in the Akurana area which will lead to a massive comeback to this matter.

3.5.2 Sampling method

Because of the specific needs mentioned throughout the thesis and the proposed research topic, the researchers have chosen to employ a non-random sampling method to collect data. The decision to apply an interpretive approach by the researchers' restricted conclusions about the entire population and restricted statistical analysis of the data. In an interpretive approach with a large population, a sample is sufficient. As the researchers have chosen to conduct an exploratory study, specialists or people experienced with environmental procedures and quality assurance should be consulted in order for the data gathered to be valid and useful for making conclusions.

3.5.3 Survey/Questionnaire method

A questionnaire was required to analyze the data for assessing the current situation and finding possible solutions for mitigation. A questionnaire consisting of 3 sections was created. Each section was designed to gather specific information about the current and past experiences the people of Akurana had faced with floods.

1. ***SECTION A*** - assessed the eligibility of the participants and gathered information about the number of occurrences and the severity of the floods that the participants had encountered.
2. ***SECTION B*** - assessed the impact of the floods (cost and effect of damages, time to return to normal working condition), the type and efficiency of the current warning systems, an effective warning time to minimize damages, the responsibility of the affected body, and if the flooding caused any waterborne diseases.
3. ***SECTION C*** - focused on gathering information about current flood protection methods, availability of an evacuation plan, and participants' opinions on possible mitigation methods. It also assessed the knowledge of the participants on the causes of the Akurana Flooding.

The survey was conducted in Akurana city and physical copies were handed out to the general public with the focus on:

- The general community members to gather first-hand accounts of the flood event and its impact on their livelihood and wellbeing.
- Business owners in Akurana to gather information about the economic impact of the flood on their businesses.
- Institutes located in the vicinity of Akurana city.

Most of the surveys were handed out to the general community members had each question explained in Sinhala/Tamil as some of the participants were having a tough time understanding the question.

The responses of the participants which can be quantified (as shown in Table 3.1) which was rated on a three point rating scale, where “1 = minimal effect, 2= moderate effect, 3= major effect”

Table 3.1Rating on conditions

Rating	**1**	**2**	**3**
Factor			
Section A (rating depends on selected answer)			
Have you experienced flooding in Akurana	Yes		No
How often flood occurs	a	b	c
Duration of flood	a	b	c
Level of water	a	b	c
Section B (rated depending on given answer)			
How long participant has lived in Akurana (years)	>3	1 – 3	<3
Age of building (years)	>5	5 – 10	<10
How many times participant has encountered flood (times)	>1	1-3	<3
How high the level of water of experienced flood (feet)	>1	1-5	<5
Cost of repairs (damage to building and other owned properties i.e.; cars, gates etc…) for damages caused by flood (total cost = LKR $x10^3$)	>10	10–30	<30
Time taken for the flood to reach participants property after being informed (hours)	>1	1 – 5	<5
Property that could've potentially be saved if informed earlier (%)	>33	33- 66	66-100
Minimum warning time needed to prepare for the flood (hours)	>8	8 – 16	< 24
How far the Pinga Oya is from participants property (km)	>1	1 – 3	>3
How long it took participant to get back to normal (days)	>1	1 – 3	>3
Amount of extra expenses (food, transportation, inconveniences apart from cost of repairs) (total cost = LKR $x10^3$)	>10	10-30	<30
Did an outbreak of waterborne diseases occur after the flooding	No		Yes
Section C (rated depending on given answer)			
Are there any flood protection measure in place	a	b	c
Are there any evacuation plan in place in case of a flood	a	b	c
Are you satisfied with current flood management practices	a	b	c

SURVEY QUESTIONNAIR

Section A: General Info

I. Survey date - ……..
II. Survey area - ……..
III. Name of applicant - ……..
IV. Age - ……..
V. Occupation - ……..
VI. Have you experienced flooding in Akurana - YES □ NO □

1. How often do floods occur in your area?
   - Rarely (once a year)
   - Occasionally (once every 4 months)
   - Frequently (at least once a month)

2. What is the typical duration of a flood event in your area?
   - Less than 1 day
   - 1-3 days
   - More than 3 days

3. How high does the water typically rise during a flood event?
   - Less than 1 foot
   - 1-3 feet
   - More than 3 feet

Section B: Damages

Urban/Residential Damage

I. How Long have you been living here?…….. Years
II. Age of the building (year of construction)?…….. Years
III. Type of construction material □ Wooden structure

□ Concrete structure

□ Mixed structure

IV. How many times did you experience the flood while residing at current building, if you have; what was the maximum water level of experienced flood?

…… times

…….feet

V. If applicable, what are the costs of repairs to the damage that was caused by the flood for

1.Your building - …….

2.Contents in building - …….

3.Damage to properties outside the building - …….

VI. How were you made aware of the flood before it reached your property?

1.TV

2.Radio

3.Siren

4.Observing rise of water level

5.None

6.Other - ……..

VII. How long did you have before the flooding reached your property after being informed?

…… hours

VIII. Were you able to potentially prevent a percentage any damages done to your property due to earlier warning?

…….. %

IX. What is the minimum warning time you would have needed to move all your contents to a safe place?

……. Hours

X. Have you insured the property that was affected by the flooding? If so have you insured,

1.Building □

2.Contents □

3.People □

XI. How long is the affected water body (Ping Oya) from your property?
…….. (m/km)

XII. How long did it take for your property to get back to your normal daily routine?

……. Hours/days

XIII. Do you have any sources of income except your salary?
YES □ NO □

XIV. Do you have any savings in case of an emergency?

YES □ NO □

XV. Does the flooding effect living conditions due to additional cost or interruption? If so how roughly how much?
1.Additional money for transportation - ……
2.Additional money for food - ……
3.Did you have an interruption in electricity or water?
……

XVI. Did an outbreak of waterborne diseases occur after the flooding?
YES □ NO □

XVII. Would you want to keep living with the floods? ……

Institutional Damage

I. How Long have you been working here?…….. Years
II. Name of company/institute - …….
III. Age of the building (year of construction)?…….. Years
IV. Type of construction material □ Wooden structure

□ Concrete structure

□ Mixed structure

V. How many times did you experience the flood while residing at current building, if you have; what was the maximum water level of experienced flood?
…… times
…….m

VI. If applicable, what are the costs of repairs to the damage that was caused by the flood for

1.Your company/institute - …….

2.Contents in company/institute - …….

3.Damage to properties outside the company/institute -

…….

VII. How were you made aware of the flood before it reached your company/institute?

1.TV

2.Radio

3.Siren

4.Observing rise of water level

5.None

6.Other - ……..

VIII. How long did you have before the flooding reached your company/institute after being informed?

…… hours

IX. Were you able to potentially prevent a percentage any damages done to your company/institute due to earlier warning?

…….. %

X. What is the minimum warning time you would have needed to move all your contents to a safe place? ……. Hours

XI. Has the company/institute been insured?

1.Building □

2.Contents □

3.People □

XII. How long is the affected water body (Ping Oya) from your company/institute?

…….. (M/km)

XIII. How long did it take for your company/institute to get back to your normal daily routine?

……. Hours/days

XIV. Were preventative measure taken to avoid the flooding of your company/institute?
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……

XV. Briefly explain the purpose of this company/institute and how many workers are currently employed.
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……

Commercial Damage

I. How Long have you been working here?…….. Years
II. Name of shop/industry - …….
III. Age of the building (year of construction)?…….. Years
IV. Type of construction material □ Wooden structure

□ Concrete structure

□ Mixed structure

V. How many times did you experience the flood while residing at current building, if you have; what was the maximum water level of experienced flood?
…… times
…….m

VI. If applicable, what are the costs of repairs to the damage that was caused by the flood for
1.Your shop/industry - …….
2.Contents in shop/industry - …….
3.Damage to properties outside the shop/industry - …….

VII. How were you made aware of the flood before it reached your shop/industry shop/industry?
1.TV
2.Radio
3.Siren
4.Observing rise of water level
5.None
6.Other - …….

VIII. How long did you have before the flooding reached your shop/industry after being informed?…… hours

IX. Were you able to potentially prevent a percentage any damages done to your shop/industry due to earlier warning?
…….. %

X. What is the minimum warning time you would have needed to move all your contents to a safe place? ……. Hours

XI. Has the shop/industry been insured?
1.Building □
2.Contents □
3.People □

XII. How long is the affected water body (Ping Oya) from your shop/industry?
…….. (m/km)

XIII. How long did it take for your shop/industry to get back to your normal daily routine?

……. Hours/days

XIV. Were preventative measure taken to avoid the flooding of your shop/industry?
……..……..……..……..……..……
……..……..……..……..……..……..…

XV. Briefly explain the purpose of this shop/industry and how many workers are currently employed.

……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……
……..……..……..……..……..……

Agricultural Damage

I. What type of Agriculture? ……..

II. How many times did you experience the flooding in your fields/farms?
……

III. What was the maximum water level you encountered in your fields/farm?
……

IV. How much has the flooding cost you due to the losses in your product?
……

V. How were you made aware of the flood before it reached your fields/farm?
1.TV
2.Radio
3.Siren
4.Observing rise of water level
5.None
6.Other - ……..

VI. How long did you have before the flooding reached your fields/farm after being informed? …… hours

VII. Were you able to potentially prevent a percentage any damages done to your fields/farm due to earlier warning?
…….. %

VIII. What is the minimum warning time you would have needed to move all your contents to a safe place?…… hours

IX. Has the fields/farm been insured? YES □ NO □

X. How long did it take for your farm/ fields to get back to your normal daily routine?

……. Hours/days.

XI. How much future profits have you lost due to effects of the floods?
…….

Section C: Preventative Measures

I. Are there any flood protection measures in place in your community?
- Yes, levees or flood walls
- Yes, floodgates or pump stations
- No, not that I know of

II. Are there any evacuation plans in place in your community in case of a flood?
- Yes, there is an evacuation plan
- No, not that I know of

III. How satisfied are you with the current flood management practices in your community?
- Very satisfied
- Somewhat satisfied
- Not satisfied
- Don't know/No opinion

IV. 10. Do you have any suggestions or ideas for improving flood management in your community?
……
……
……

V. If you were to choose, which below mentioned method would be an ideal solution for the flooding in Akurana?

1. Floodplain zoning □
2. Flood forecasting and warning systems □
3. River channel improvements □
4. Community education and awareness □
5. Land use planning □
6. Better methods of water drainage □
7. Improvements to be made to Pinga Oya catchment □

VI. What is the main cause of flooding in Akurana?

1. Heavy rainfall □
2. Poor drainage system □
3. Deforestation □
4. Soil erosion □
5. Overdevelopment □
6. Blockage of water bodies □
7. Rising Sea Levels □

VII. Has deforestation impacted flooding in Akurana?

YES □ NO □

VIII. Is the drainage system in Akurana adequate to handle heavy rainfall?

YES □ NO □

IX. Have you observed any blockage in water bodies or streams in Akurana?

YES □ NO □

X. If yes, do you believe that the blockage is contributing to the floods happening in Akurana?

YES □ NO □

XI. Has the development of infrastructure in Akurana impact flooding?

YES □ NO □

XII. Are there any measures in place to prevent soil erosion in Akurana?

4. Chapter 04: Results and Discussion

4.1 Results

65 people were interview for this research, the answers provided by these participants have been tabulated as percentages calculated with set criteria which is shown in the below table 4.1. (All percentages have been rounded off to the closest 1%)

Out of the 65 interviewed;

- 40 of them were community members of Akurana
- 10 of them were owners of business run in Akurana
- 10 participants were members of institutes
- 5 participants were involved in agriculture

Rating	**1**	**2**	**3**
Factor			
Section A (rating depends on selected answer)			
Have you experienced flooding in Akurana	100%		0%
How often flood occurs	92%	8%	0%
Duration of flood	56%	34%	10%
Level of water	23%	42%	35%
Section B (rated depending on given answer)			
How long participant has lived in Akurana (years)	28%	13%	59%
Age of building (years)	10%	38%	52%
How many times participant has encountered flood (times)	20%	58%	22%
How high the level of water of experienced flood (feet)	23%	48%	29%
Cost of repairs (damage to building and other owned properties i.e.; cars, gates etc…) for damages caused by flood (total cost per participant = LKR $x10^3$)	15%	39%	46%
Time taken for the flood to reach participants property after being informed (hours)	23%	59%	18%

Property that could've potentially be saved if informed earlier (%)	10%	66%	24%
Minimum warning time needed to prepare for the flood (hours)	18%	49%	33%
How far the Pinga Oya is from participants property (km)	21%	59%	20%
How long it took participant to get back to normal (days)	18%	72%	10%
Amount of extra expenses (food, transportation, inconveniences apart from cost of repairs) (total cost = LKR $x10^3$)	32%	36%	37%
Did an outbreak of waterborne diseases occur after the flooding	14%		86%
Section C (rated depending on given answer)			
Are there any flood protection measure in place	8%	0%	92%
Are there any evacuation plan in place in case of a flood	0%	18%	82%
Are you satisfied with current flood management practices	0%	2%	98%

Table 4.1results on quantifiable questions that had conditions

Below listed in tables are the total cost of damages caused to buildings due to the recurring floods in Akurana according to the survey. Tables 4.2 shows the cost as extra expenses the participants had to endure after the floods.

- Residential Damage – below table shows the total amount of damage caused to urban/residential participants who faced the floods, these have been categorized as below,
    - Building/structural damage (structural integrity, paint, building reconstruction)
    - Content damage (furniture, equipment, clothes)
    - Damage to property outside the building (vehicles, lawns, car parks etc.)

Damage type	**Cost of damage**
Building/structural damage	LKR 689,000
Content damage	LKR 498,000
Damage to property outside the building	LKR 5, 658, 000
Total Cost	LKR 6, 845, 000

Table 4.2 Cost of damage on urban/residential property

Expense	**Cost of Expense**
Transport and food	LKR 120, 000

- Institutional damage –below table shows the total amount of damage caused to participants from institutes who faced the floods, these have been categorized as below,
    - Building/structural damage (structural integrity, paint, building reconstruction)
    - Content damage (furniture, equipment, clothes)
    - Damage to property outside the building (vehicles, lawns, car parks etc.)

Damage type	**Cost of damage**
Building/structural damage	LKR 460, 000
Content damage	LKR 160, 000
Damage to property outside the building	LKR 240, 000
Total Cost	LKR 860, 000

Table 4.3 Cost of damage on Institutional property

We had also asked the participants as to how to floods had affected them as a business, all their responses were (as all 10 institutes who partook in the survey were involved in the educational sector), they had a tough time getting back on schedule as most of the classes or seminars that took place in these institutes were put on hold due to effects of the flood and most students were unable to attend online sessions as well due to the power cuts that were going on in Sri Lanka in the recent year.

- Commercial damage - below table shows the total amount of damage caused to participants from the commercial sector who faced the floods, these have been categorized as below,
    - Building/structural damage (structural integrity, paint, building reconstruction)
    - Content damage (furniture, equipment, clothes)
    - Damage to property outside the building (vehicles, lawns, car parks etc.)

Damage type	**Cost of damage**
Building/structural damage	LKR 320, 000
Content damage	LKR 180, 000
Damage to property outside the building	LKR 320, 000
Total Cost	LKR 820, 000

Table 4.4 - Cost of damage on Commercial property

- Agricultural damage - below table shows the total amount of damage caused to participants from the agricultural sector who faced the floods, these have been categorized as below,
    - Damage caused on crops/harvest
    - Estimated losses on future profits

Damage and Expense	**Cost of damage**
Crops, fields and harvest	LKR 89, 000
Losses on future profits	LKR 260, 000
Total Cost	LKR 820, 000

Table 4.5- Cost of damage on Agricultural property

The results when asked the surveyed participants as to what the optimal solution they would propose as a mitigation method for the recurring floods in Akurana have been shown below as percentages out of the 65 participants.

Mitigation Method	**Percentage**
Floodplain zoning	4%
Flood forecasting and warning systems	49%
River channel improvements	13%
Community education and awareness	10%
Land use planning	2%
Better methods of water drainage	11%
Improvements to be made to Pinga Oya catchment	11%

According to the survey, below tables show the percentages of the participant's responses on the causes of the floods in Akurana.

Cause	**%**
Heavy rainfall	22
Poor drainage system	23
Deforestation	8
Soil erosion	15
Overdevelopment	20
Blockage of water bodies	12
Rising sea levels	0

Table 4.6survey results on possible causes for flooding

	Yes	**No**
Has deforestation impacted flooding in Akurana	36%	64%
Is the drainage system in Akurana adequate to handle heavy rainfall	18%	82%
Have you observed any blockage in water bodies or streams in Akurana	68%	32%
Do you believe that the blockage is contributing to the floods happening in Akurana	59%	41%
Has the development of infrastructure in Akurana impact flooding	72%	28%
Are there any measures in place to prevent soil erosion in Akurana	25%	75%

Table 4.7 survey results on factors affecting the flooding

4.3 Analysis and Discussion

4.3.1 Fundamental effects for Akurana Flooding

At first, it was able to know many issues which has led to this sort of flooding in the Akurana area.

(i) Upstream impact of Polgolla dam

Some people think that the recent flooding is a result of the 1972 construction of the Polgolla barrage. Akurana cannot flood even if the water level in the Polgolla barrage is kept at maximum to full supply levels since Akurana is at least 10 meters above the spill away. At 2.7 kilometers from Katugastota Bridge, the full supply level of the Polgolla barrage is equal to the stream's bed level.

Figure 4.1Polgolla Dam

(ii) Variation of rainfall

The month with the highest relative humidity is November (87.53 %). The month with the lowest relative humidity is March (74.09 %). The month with the highest number of rainy days is October (23.03 days). The month with the lowest number of rainy days is March (10.97 days).Tropical weather prevails here. The city of Kandy receives a lot of rain each year. Even in the wettest month, this is true. Kandy's yearly mean temperature is 23.5 °C (74.3 °F). There is approximately 1773 mm | 69.8 inches of precipitation annually.

According to previous research the rainfall and flood events occurred at Akurana (Katugastota) region from1978 -2016 was discovered. It is shown in figure 4.1.

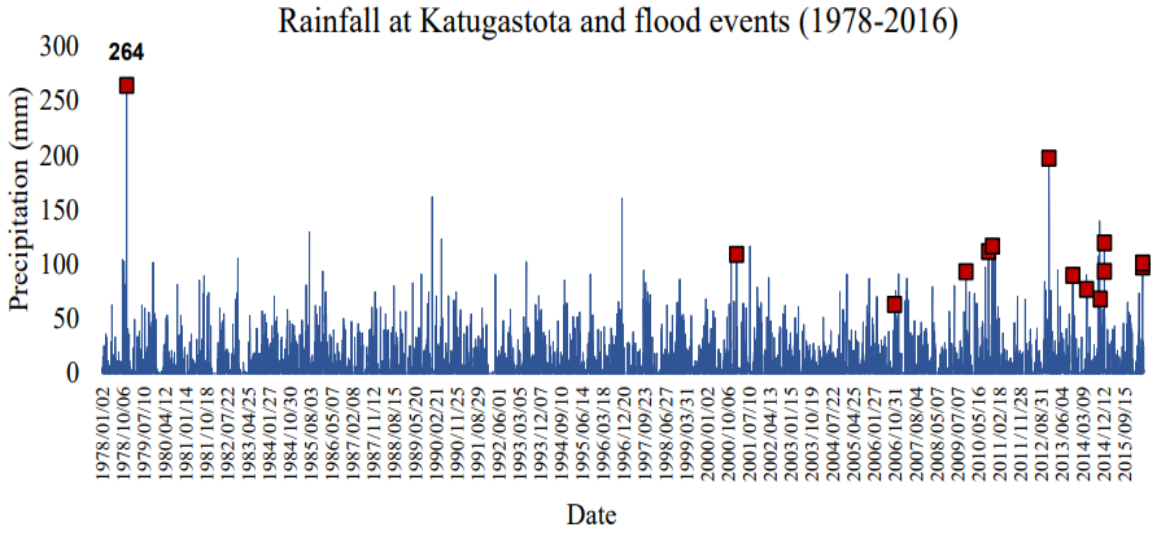


Figure 4.2 Rainfall at Katugastota region and flood events

Before 2001, there had only ever been one flood reported (1978), despite the fact that there had been 162mm and 161mm of rain, respectively. Flooding in Akurana was caused by rainfall totals of 68 mm (2014) and 63 mm (2006) even after 2001. The lowest rainfall that resulted in flooding was 63 mm on 2006.10.26. The flood limit changed from 263mm in 1978 to 109mm in 2001.

Between 1978 and 2001, the flood limit decreased by 154mm. Even though the patterns of rainfall have not changed over the past 15 years (2001–2016), frequent flood occurrences have been seen.

(iii) Narrowing of Pinga oya

Due to the development of retaining walls, buildings, and short-span road bridges, the stream's width has been reduced with time. Numerous substantial structures have been constructed in the stream reservation, some of which are on the stream bed some of which are illegal as well. The number of bridges built can be used as a measure for development along river margins. In 2010, there were 28 bridges seen in satellite imagery; in 2016, there are 43. The rise in flood levels and the expansion of river crossings are related.

(iv) Changes in land use

According to previous study a massive difference in the land use can be observed within years from 2003 – 2017. According to Mr. Dissanayake's Vegetation Transect Survey, the stream section in Pinga Oya from the rural to the urban region, together with the vegetation covers and the vegetation diversity, are in bad condition. We will conduct a quantitative study of these satellite photos in the future. In this analysis, shifting land use patterns may play a significant role.

4.3.2 Survey Analysis and discussion

This survey was done in the city of Akurana where copies of surveys were handed out the individuals in the city limits, out of these 65 set of questionnaires were obtained, where;

- 40 of them were community members of Akurana
- 10 of them were owners of business run in Akurana
- 10 participants were members of institutes
- 5 participants were involved in agriculture

This questionnaire was split into 3 sections with each section has a number of questions to assess specific data required for the study,

Section A - was used to determine the eligibility of the participant and to confirm if they have in fact faced the Akurana flood, and a basic outlook on the severity of the flood they had faced.

As shown in table 4.1, all the surveyed participants had experienced the flooding in Akurana, and 82% of them had said they experience the flood for at least once a year, which is usually during the annual monsoon season.

56% have had to deal with the floods that lasted a whole day, where they had to deal with the overflown water even after the floods had ceased. A question in *Section B* was to see how far the participants affected were from the Pinga Oya, and almost 70% of them were less them 3km from the affected water body, hence the conclusion as to why 44% of the surveyed had to endure the floods for more a day with 35% of the affected had to deal with flood levels with more than 3 feet!

Section B –

- ¤ A purpose of the set of questions in section B, was to analyze the number of people affected by the flooding in Akurana, and how long it takes he flood to reach them.

Based on the results of the survey conducted on flooding in Akurana, Sri Lanka, it appears that 80% of the respondents have experienced a flood event. The majority of these individuals (77%) reported that the flood levels were more than a foot. It's also noteworthy that a significant portion of the respondents (23%) reported that the flood occurred within an hour, while 59% reported that it took between 1 to 5 hours. Only 18% of respondents reported that the flood occurred 5 hours after they were informed. These results suggest that the majority of flood events in Akurana are

sudden and happen quickly which leads to a conclusion that Akurana might be facing a possibility recurring flash floods. Thus potentially leading to more significant impacts and requiring a prompt response.

- Another set of questions were made to assess the distance of the Pinga Oya from the participants and what prior notice was given to them and how much of their belongings could have been saved if proper notice was given to them.

The survey results suggest that a significant portion of the respondents (70%) lived within close proximity (1-3 km) to the affected water body, Pinga Oya. This highlights the need for effective early warning systems to minimize the impact of potential floods.

In terms of preferred warning time, the majority (49%) preferred a warning between 8-16 hours, while a significant portion (33%) wanted a warning at least 24 hours ahead. This suggests a preference for longer lead time for evacuation and preparation for potential floods

It is important to note that a proper early warning system could potentially help reduce the damage caused by floods. The survey results indicate that a large portion (66%) of the respondents believed they could have saved 33-66% of their property if they had been given proper notice whilst 24% of them believe they would have been able to save more than 66%. Thus, effective early warning systems could play a crucial role in reducing the impact of floods in the area.

- Another purpose of section B was to get an estimate cost on the damages that was caused by the floods, and the results obtained show that there is a significant impact on Akurana due to the floods.

Note, the cost of damage on properties outside the building was significantly higher on residential compared to commercial and institutional was because of the fact that one of the respondents had lost his entire car to the floods, were the repair cost him close to LKR 4, 000,000. But overall the most damage cost had been outside the building premises on vehicles and garages that did not have enough time to be vacated before the floods came in.

The survey results indicate that a significant number of residents in Akurana, Sri Lanka have been affected by flooding and incurred substantial costs for repairs. The majority (46%) of respondents incurred repair costs exceeding 30,000, mostly due to damages to gates and vehicles. A slightly

smaller proportion (39%) incurred losses in the range of 10,000 - 30,000. Only 15% reported repair costs of up to 10,000. These findings suggest that flooding is a major concern for the residents of Akurana and highlights the need for effective measures to mitigate the impact of floods in the future.

The results of the survey on flooding assessment in Akurana also suggest that the majority of people, 82%, took more than a day to recover from the flood. Additionally, 86% of respondents reported an increase in waterborne diseases following the flooding especially with the on-going epidemic of dengue in Sri Lanka. These findings highlight the significant impact that flooding can have on communities, including long-term recovery times and potential health consequences.

Section C – was used to assess the current preliminary methods of flood warning systems in place for the residents of the Akurana area. The results of the survey on flood assessment in Akurana, Sri Lanka, indicate that there is a significant gap in community awareness and preparedness for floods. With 92% of the community being unaware of any flood protection methods in place and nearly 100% being unaware of evacuation plans, it is clear that there is a need for increased education and outreach efforts to ensure that the community is better prepared for potential flood events. The high level of dissatisfaction (98%) with current flood management practices also suggests that there may be opportunities for improvement in the existing flood management infrastructure and processes.

It is possible that the lack of awareness and satisfaction with current practices may be due to a lack of effective communication and engagement between the relevant authorities and the community. Addressing this issue could involve increasing the frequency and quality of communication and consultation with the community, as well as involving them in the development and implementation of flood management strategies.

Additionally, there may be a need for investment in physical infrastructure and technology to better protect the community from floods. This could include the construction of flood protection structures, such as levees or flood walls, as well as the implementation of early warning systems and evacuation plans.

The survey on flood assessment in Akurana, Sri Lanka, highlights that the cause of the floods is multi-faceted, with heavy rainfall, poor drainage systems, and overdevelopment all contributing

to the issue. 22% of respondents believe that heavy rainfall is the primary cause, while 23% attribute it to poor drainage systems, and 20% to overdevelopment. These results suggest that addressing one issue alone may not fully resolve the flooding problem in Akurana and a comprehensive approach, addressing all three factors, should be considered. It's important to note that the opinion of the survey participants may not always align with the actual cause of the floods, further investigation and analysis may be necessary to determine the root cause.

In conclusion, the results of the survey indicate that there is an urgent need for improvements in the flood management infrastructure and processes in Akurana.

A clear understanding of the underlying causes of flooding is important for the development of effective flood management plans. The effectiveness of these measures will be dependent on the effectiveness of communication between all relevant stakeholders in flood management, including local residents, the local authorities and government agencies. It is therefore essential that all stakeholders are engaged and involved at all stages of the process to ensure that their needs are addressed and that their opinions are respected.

In addition, it is essential that the authorities invest in improvements to the existing flood management systems. This includes investment in physical infrastructure, such as levees and flood walls, as well as the implementation of early warning

- Flood resilience must be pursued across all sectors of development in order to mitigate against future disasters and improve the standard of living. Climate change is likely to worsen future flood risk by increasing the frequency of extreme weather events and increasing the likelihood of extreme rainfall events in some places. Therefore, it is crucial that decision-makers work closely with disaster risk management experts to develop resilient communities which are better equipped to respond to future flood events.

5. Chapter 05: Conclusion

In conclusion, the survey on Flood Assessment in Akurana, Sri Lanka, showed that the majority of respondents (82%) experienced the floods at least once a year and 56% had to deal with floods that lasted a whole day. The results indicated that the majority of flood events in Akurana are sudden and happen quickly, leading to the possibility of recurring flash floods. The majority of respondents (70%) lived within 1-3 km of the affected water body, Pinga Oya, emphasizing the need for effective early warning systems. The results showed a preference for a warning between 8-16 hours and that a proper early warning system could potentially help reduce the damage caused by floods. The survey results also indicated that the majority of residents incurred substantial repair costs due to flooding and that a significant number of residents took more than a day to recover, with an increase in waterborne diseases reported. These findings highlight the significant impact that flooding can have on communities and the need for effective measures to mitigate the impact of floods in the future.

Furthermore, the Polgolla barrage being 10 meters below Akurana cannot be the cause of the changes in the river. The rainfall extremes before and after 2001 are also found to be no different. The main causes of the changes in the river are due to construction and debris dumping in the river and its margins, which has narrowed the river cross-sections in critical locations. Siltation and debris dumping has filled up the stream bed but its impact is modest except at the confluence of the tributary from Dunuwilla at Akurana. Significant changes in land-use, paving of roads, drains and building construction also contribute to the changes in the river.

Possible mitigation methods on the Akurana flooding can be:
Mitigation methods for flooding in Akurana, Sri Lanka based on the survey results:

1. Stormwater management: Implementing systems to manage, treat and store rainwater to reduce runoff and reduce flooding.
2. Floodplain zoning: Regulating development in flood-prone areas to prevent new buildings from being constructed in flood-prone areas.
3. Levees and floodwalls: Constructing barriers along rivers or coastal areas to prevent floodwaters from reaching populated areas.

4. Elevating structures: Raising the elevation of homes and buildings to reduce the risk of flooding.
5. Wetlands restoration: Restoring wetlands to absorb and store excess water, reducing the risk of downstream flooding.
6. Channel improvements: Improving the channelization of streams and rivers to increase their capacity to carry water during heavy rainfall events.
7. Early warning systems: Implementing early warning systems to alert residents of approaching floods, allowing them to take necessary precautions.
8. Disaster preparedness planning: Developing plans for evacuation, shelter and relief efforts in the event of a flood.

6. Future Scope

The future scope based on the research the conducted can be branched out as below,

- Climate change impacts: Study the potential future impacts of climate change on flooding in Akurana, including changes in rainfall patterns and sea level rise.

- Hydrological modelling: Develop more advanced hydrological models to better understand the dynamics of flooding in Akurana and make more accurate predictions of future floods.

- Community engagement: Engage local communities in the flood assessment process to improve understanding and increase awareness of flood risks, as well as to gather local knowledge and perspectives.

- Integrated flood management: Study the feasibility of implementing an integrated flood management approach in Akurana, combining structural and non-structural measures to reduce flood risk.

- Flood risk mapping: Develop updated flood risk maps for Akurana, incorporating new data and updated models to provide a more accurate picture of flood risk.

- Adaptation measures: Evaluate the effectiveness of existing adaptation measures and identify potential new measures to reduce flood risk in Akurana.

- Multi-hazard approach: Consider the potential for multi-hazard approaches that address multiple hazards, such as landslides and flash floods, in addition to riverine floods.

7. References

Farook, N. (2013). Water quality and health of Pinga Oya. *ir.lib.seu.ac.lk*. [online] Available at: http://ir.lib.seu.ac.lk/handle/123456789/635 [Accessed 21 Nov. 2022].

Dissanayake, L. (2020). Stream corridor encroachment and its consequences: the case of Pinga Oya tributary in the upper Mahaweli River in Sri Lanka. *Modeling Earth Systems and Environment*, 7(3), pp.1907–1916. doi:10.1007/s40808-020-00918-3.

Kumara, K.G.R.N. and Rathnasekara, S.R.L.S. (2020). *A study of how floods affect urban land use based on Akurana urban area*. [online] *repository.kln.ac.lk*. Department of Geography, University of Kelaniya, Sri Lanka. Available at: http://repository.kln.ac.lk/handle/123456789/22452 [Accessed 10 Nov. 2022].

www.climate.lk. (n.d.). *Pinga Oya Symposium*. [online] Available at: http://www.climate.lk/pinga-oya/index.html [Accessed 26 Nov. 2022].

Of Sri Lanka, D., Village, Rajawella, K. and Zubair (2017). *Analysis of Historical Flooding Incident in Akurana*. [online] Available at: http://www.climate.lk/drought_climate/reports/Analysis_of_Historical_Floddings_in_Akurana.pdf [Accessed 24 Nov. 2022].

www.ft.lk. (n.d.). *Akurana suffers worst floods in 20 years | Daily FT*. [online] Available at: https://www.ft.lk/News/Akurana-suffers-worst-floods-in-20-years/56-663823 [Accessed 13 Nov. 2022].

Disaster Services. (n.d.). *Pinga Oya Floods*. [online] Available at: https://disaster.lk/pinga-oya-floods/ [Accessed 15 Nov. 2022].