SCHOOL OF COMPUTING AND INFORMATICS

PROJECT REPORT

EARLY WARNING SYSTEM FOR FLASH FLOOD MANAGEMENT CASE OF HELL'S GATE NATIONAL PARK

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in

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AT

UNIVERSITY OF NAIROBI

JULY 2020

DECLARATION

Student

I declare that this report is my original work and has not been presented in any other institution for the purpose of academic award.

Signed ....

Date ....

P53/11640/2018

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This research project has been submitted as partial fulfilment of the requirements for the award of the Degree of Master of Science in Distributed Computing Technology at the University of Nairobi with my approval as the faculty supervisor.

Supervisor: MS Christine Ronge

Signature: ....

Date: ....

DEDICATION

I would like to dedicate this study to my wonderful family, my mother Christina, my wife Chepkirui, my son Cheruse, my daughter chepkigen my sisters and brothers.

ACKNOWLEDMENTS

I would like to thank God for the giving me good health. Secondly, I thank my supervisor Ms. Christine Ronge for having seen me through this entire process and accommodating my impromptu visits to his office and calls for guidance. I also wish to pass my warmest gratitude to my mum for their daily encouragements and inquiry and round the clock availability for financial support. I want to sincerely thank my wife Chepkirui for having to put up with my working late as I worked on this project as well as her words of encouragement. I thank Nerokas Ltd., for having provided me with the resources especially hardware equipment used in this project. Patrick won’t be forgotten. His skills with the hardware was so invaluable and I thank him for that.

ABSTRACT

Natural disasters, like flood, flash floods, earthquakes have led to destructions of properties, loss of lives around the world. Hells gate national park in recent years has experiences destructive flash floods, these situations prompted the development of flash flood early warning systems technology has been useful in mitigation of floods which causes deaths and destruction, notification and prior knowledge of the occurrence of the flash flood is critical in saving lives. The use of modern GSM and wireless technology is key in passing information, risks avoidance, preparedness, mitigation and response. Data collection of the study was based on an assessment of how early warning systems can be used effectively in ensuring safety of tourist visiting the park and specifically the gorge, and therefore primary data from the parties involved in this matter is crucial. However, secondary data from relevant publications and internet has been used to support various augments in the studies. The early warning system will be effective tool in early warning system.

ABBREVIATIONS AND ACCRONYMS

GSM	Global System for mobile Communications
WSN	Wireless Sensor Network
EWS	Early warning system
NPFDM	National Policy for Disaster Management
SMS	Short Message Service
UNEP	United Nations Environmental Program
KRC	Kenya Red Cross
API	Application Programming Interface
IoT	Internet of Things
GPRS	General Radio Packet Service
LORA	Long Range
ODK	Open Data Kit

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Definition of terms

Early warning system (EWS) is technology and associated policies and procedures designed to predict and mitigate the harm of natural and human-initiated disasters and other undesirable events.

Lead time Lead time in flood forecasting refers to the amount of time a flood takes to reach a particular downstream community from the flood measurement station upstream. The basic principle for assessing lead time is that advance warning should be given with enough time for effective preparatory action.

A Sensor is a device that responds and detects some type of input from both the physical or environmental conditions, such as pressure, heat, light. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing.

Sensor is the object used to gather information about a physical object or process, including the occurrence of events**.**

GSM it is stands for global system for mobile communication (GSM). It is widely used mobile communication system in the world. GSM is an open and digital cellular technology used for transmitting mobile voice and data services operates at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands

Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location

CHAPTER 1. INTRODUCTION.

1.1 Background research.

Kenya's disaster profile is dominated by droughts, fire, floods, terrorism, technological accidents, diseases and epidemics that disrupt people's livelihoods, destroy the infrastructure, divert planned use of resources, interrupt economic activities and retard development. (NPFDM,2009).

Natural hazards are very destructive, its occurrence cannot be anticipated on when and where. Disasters like flash floods, earthquakes and fire, happens when it's not expected and humans being have no control.

Several regions in Kenya experience the effects of flash floods. Some of such areas include the Kano plains in Nyando District and Nyatike in Migori District, Nyanza Province, Budalangi in Western Province. (P. OWOR,2015).

Flash Flooding occurs as a result of substantial rainfalls, structural failures and a large number of human factors, it relies on precipitation amounts and rates, topology, geology, land use, and antecedent moisture condition. (Daramola, Eresanya, & Ishola, 2018). It results in tremendous environmental destruction and loss of live.

Flash floods is also associated with land degradation, increased soil erosion with the consequent silting and erosion of riverbanks, which affect water intake facilities. Man-made factors have contributed also to flash floods occurrence this include desertification, poor farming practices, lack of gabions. Its affects mostly lowlands and the zones cascaded by ridges and mountains, Hell's Gate National park and Narok town falls under the category. (Kenya Red Cross)

Efforts to mitigate and respond to flash floods is complicated since responsibility for flash flood risk management is currently fragmented between agencies. Forecasting, information management, disaster mitigation, emergency response, this need clarifying particularly between central and county governments to develop a common understanding of when to use forecasts, who will take decisions about action and how these actions will be funded. (L. Weingärtner .et al .2019).

In the pursuit of reducing vulnerabilities to risks, the Kenyan Government has formulated this National Policy on Disaster Management to institutionalize mechanisms for addressing disasters. The policy emphasizes preparedness on the part of the Government, communities and other stakeholders in Disaster Risk Reduction mitigation and prevention. However, much of the efforts to reduce disaster risk in Kenya are fragmented among different stakeholders within the Government, UN, NGOs and academia. This leaves much opportunity for developing multidisciplinary approaches.

Hell's Gate National Park which is located in Naivasha Kenya, covers an area of 68.25 square kilometres. The park is at 1,900 meters above sea level, temperature ranges from 20-30degrees Celsius and rainfall ranges between 200mm to 700 mm, the climatic condition is composed of two rain seasons: Long rains occur in the period of March & April and the short rains November and December. (Kenya Wildlife Service, 2019)

The park is a tourist attraction site with Spectacular scenery including the towering cliffs, water-gouged gorges, stark rock towers, scrub clad volcanoes and belching plumes of geothermal steam and among the most visited scenery in the park is the gorge. A gorge is typically a narrow valley between hills or mountains, typically with steep rocky walls and a stream running through its 24 km long deep ravine line with sheer cliffs of varying depth, the gorge widens out as it weaves its way down. This is caused by continuous erosion from flowing water through gullies and over several decades' forms gorge.

For several years it has been a unique feature that attract tourist to explore the site, despite being a dangerous feature when flash flood happens, particularly when it rains on the upper zone. In 2012 and 2019 Hells Gate National park recorded loss of life's due to flash flood that occurred, as a result of rainfall on the upper zone of Nyandarua Hills.**(**Aljazeera.com,2019)

Gorges and canyons are prone to flash flood since it has no control from untimely water flowing to notify and warn of the impending risk since when it rains on the upper zone flowing water accumulate to form a large mass fed from the tributaries joining at Lake Naivasha. Flash water flowing through the gorge is disastrous, that it sweeps anyone walking on the flow of the gully

Early action is sometimes used broadly to mean early response to a crisis (Obrecht A. 2019). More commonly, early action refers to preventive actions that seek to avert a crisis or mitigate its impact.

Early warning is a system that provide data collection and analysis to monitor people's well-being in order to provide timely notice when an emergency threatens and trigger early and appropriate response Early warning (EW) is the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response according to the United Nations' International Strategy for Disaster Reduction (ISDR), it integrates (UN 2006). Warning thresholds vary substantially depending on the location. (Aleotti, 2004; Hong and Adler, 2007).

1.2 Problem Statement

Flash floods causes deaths and destruction. Hell's Gate National Park, has among other features are gorges that many tourist visits. In 2019, seven tourists lost their lives due to flash floods at Hell's Gate National Park. A gorge is a narrow deep gully caused by erosion over time, due to depth it has a poor visibility and cellular service. When tourists are within the gorge, they are not in a position to know what happens on the upper surface and in the event of flash flood no one can foresee the inrush of flash water. As a result, everyone is caught by surprise by flash water which is hazardous many are washed away to death. Currently, the park doesn't have safety mechanism to warn and inform in case of flash floods. Flash flood early warning system gives prior knowledge of flash flood occurrence to alert and warn about the sudden flow of rain water to gorge. Early Warning System provide lead time which is critical in safety evacuation.

The system sends the short message to alert the Hell's Gate management which is relayed to the tour guide to evacuate the tourist in the gorge.

1.3 Objectives

1.3.1 General objectives

To study the hazards caused by flash flood disaster, risks, preparedness, mitigation and response currently in the Hell's Gate National Park with the view of proving technological solution.

1.3.2 Specific objectives

To study and establish the reason why there is no prior knowledge on flash floods and challenges hindering the installation of early warning system.

To establish how communication is relayed currently to tourist in case of disaster and emergency

To find out how the park management keeps the tourist data for safety notification.

To design and implement an early warning system that provide risk knowledge, monitoring, information dissemination and warning for effective response.

Establish an effective hazard monitoring and warning service with a sound scientific and technological basis

1.4 Research question

1. What are the approaches (i.e. tools, practices, mechanisms, processes) that Hell's Gate management and national disaster-response actors have used to adapt their activities based on flash flood incident of 2012 and 2019?
2. How will deaths caused by flash flooding be avoided by the use early warning system based on Global System for Mobile communication (GSM) and short message service (SMS) in Hell's Gate National Park?
3. Will the early warning system avert the impact of flood to human lives and destruction in Hell's Gate National Park?

1.5 Justification.

While the gorges are wonderful recreation sites, they can be very dangerous in case of flash floods. The era of Information Technology has evolved to the extent of improving human safety. The aim of this research is to explore ways of enhancing environmental safety with application of technology in early warning system, using water level sensors and relaying of warning messages

1.6 Relevance of study to Science.

The use information technology concepts in hardship environments has evolved to simplify how things are done making it a lot easier to study the environment and apply. With these gadgets powered by solar panels, wind power and maintenance free battery packs, it makes it easier to deploy and remotely manage them.

GSM utilizes the use of embedded systems which makes electronic the basis, transmission of data which involves telecommunication and programming circuit board as well as data mining and analysis which is covered in computing.

1.7 Relevance of study to the safety of the tourist.

With the outcome of this study, it is important to note that there may be is an alternate solution in future which will be accurate, quick and timely in getting information about danger in the park. This system will greatly impact the lives, improve safety in the parks to tourist visiting also it will help generate more revenue to Kenya wildlife service since it be safe for visitors.

1.8 Relevance of study to the Governing authorities

The study will be of importance in formulating policies, regulation on disaster preparedness and management by the local and national government.

1.8 Scope

The research will be undertaken to find out the solution to flash floods at Hell's Gate National Park, how the implementation of the application will be off benefits to community. And relay the information to the people via GSM network to a mobile phone in a form of SMS.

1.9 Assumptions

It is assumed that all flowing water in the tributaries will reach the same level almost same time during.

2.0 Limitations

Some areas may have poor (GSM) Global System for Mobile communication networks.

Wireless devices also pose a challenge of power.

CHAPTER 2. LITERATURE REVIEW.

2.1 Introduction

Early warning is the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response. (UNEP 2012).

The sudden climate and rainfall changes, also unexpected natural phenomenon often happens. One of the problems that often occur is flash floods a natural hazard, it effects leads to human suffering and the loss of life. Although it can be avoided by being prepared and aware of how to deal with it. For this, we need to understand the nature, frequency, severity and lead time of flood.

In this decade loss of lives and investment can be avoided with use of technology because flash flood can happen within a short time of excessive rainfall alternatively can occur after a period of drought when heavy rain falls onto very dry, hard ground that the water cannot penetrate. (Hughes et al. 2006) described that damage due to flash flood is correlated to the warning time announced for a flash flood event. The most important factor to safety is Lead time in flood forecasting, it refers to the amount of time a flash flood takes to reach a particular downstream community from the flood measurement station upstream. The basic principle for assessing lead time is an advance warning given to allow enough time for effective preparatory action for safety. This depends on the need of the target community which are tourist and area which refer to gorges, type of catchment structure which forms hills, catchment size is wide, catchment response for a given rainfall and the catchment lag time which is time taken by runoff from the furthest corner of the catchment to the point of interest, which translates into longer lag times for larger catchments.

The United Nations International Strategy for Disaster Reduction (UNISDR), (2019). Platform for the promotion of Early Warning has identified four key elements for a complete and effective early warning system this include; assessments and knowledge of flood risks in the area, local hazard monitoring, warning service, flood risk dissemination and communication service, and community response capabilities.

As the risks and the costs of such natural disasters are likely to increase so are the appropriate measures for mitigating losses and providing relief to victims. (Linnerooth-Bayer and Amendola., 2003). Such prospective developments have given rise to increased emphasis on the improvement of operational flash flood forecasting and the enhancement and refinement of flood-risk management systems (Arduino et al., 2005) Among the various aspects of flood management, flood forecasting is very efficient tools for flood management. Among the tools are GSM sensors, wireless sensors, flood sensors, water level sensors

Understanding of warning information by the receiver is very important. It primarily depends on accuracy in assessing risks and its uncertainties and dissemination of risk information along with its uncertainty to the people at risk and stakeholders responsible for responding the risk information. It also depends on active participation of the communities and stakeholders in risks assessment, use of language that communities understand, the ways it is disseminated, and the ownership of information by the stakeholders and communities. Very importantly, warning information should be owned and understood

Use of GSM sensor is an evolving domain and its demand is increasing day by day due to providing solution to exceptional problems. This Sensors does not require line of sight (LoS) and may be deployed in a geographical region for short range communication. (I. Malavolta and H. Muccini,2014)

Early warning systems can be implemented in various technologies. (Jong-uk Lee et al.,2008) presented the Real-time Flood Monitoring System with Wireless Sensor Networks deployed in two volcanic islands Ulleung-do and Dok-do located in the East Sea near to the Korean Peninsula and developed for flood monitoring Real Time Flood Monitoring System Measures River and weather conditions through wireless sensor nodes equipped with different sensors.

2.2 Flash Floods

A flash flood is characterized by a rapid stream rise with depths of water that can reach well above the banks of the creek. Flash floods can be produced when slow moving or multiple thunder storms occur over the same area. When storms move faster, flash flooding is less likely since the rain is distributed over a broader area.

Several factors contribute to flash flooding. The two key elements are rainfall intensity and duration. Intensity is the rate of rainfall, and duration is how long the rain lasts. Topography, soil conditions, and ground cover also play an important role. Flash floods occur along small streams; you can determine your risk by knowing your proximity to streams. Flooding can be caused by rain that falls several miles upstream and then moves rapidly downstream. Floods are remarkable hydro meteorological phenomena and forceful agents of geomorphic evolution in most physical geographical belts and, from the viewpoint of human society, among the most important environmental hazards the entire physical environment influences their origin, flash floods are proper subjects for physical geographical investigations (Czigány et al., 2008). For instance, soil moisture conditions prior to the rainfall events are major hydrological controls of flash flood generation (Norbiato et al., 2008; Czigány et al., 2010). It is only with knowledge on the topography, soils and human impact on the catchment topography like steep slopes, drainage density, impermeable surfaces, saturated soils and land use influence the occurrence. No flash flood threshold can be established with some precision. Anthropogenic influences are important because some basins respond particularly rapidly to intense rainfall in the wake of disturbances in the natural drainage (stream channelization, deforestation, housing development, fire etc.) (Norbiato et al., 2008). As hydro meteorological phenomena, flash floods are best characterized by their magnitude (total amount and intensity of inducing rainfall), return interval, total runoff and similar parameters.

Flash flood in the Hells gate national park is caused by rain water that accumulate on the upper zone. The topography is the main factor.

2.3 Early warning system.

The provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response. (UNISDR, 2004).

It is a major element of disaster risk reduction. Early action can often prevent a hazard turning into a human disaster by preventing loss of life and reducing the economic and material impacts. To be effective and sustainable they must actively involve the communities at risk. Early warning systems can be set up to avoid or reduce the impact of hazards such as floods, landslides, storms, and forest fires. The significance of an effective early warning system lies in the recognition of its benefits by local people.

Early Warning Systems (EWS) are complex processes aimed at reducing the impact of natural hazards by providing timely and relevant information in a systematic way.

The key elements of early warning systems

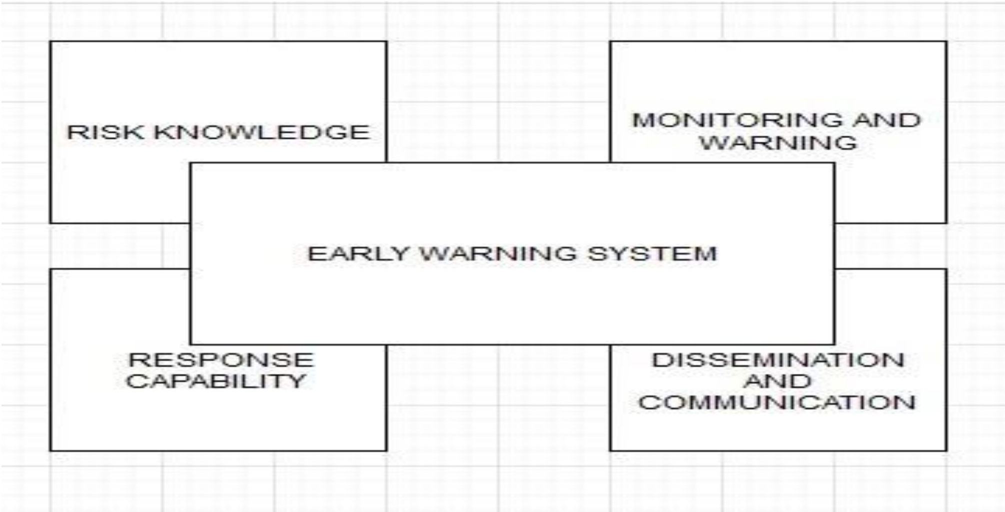

Figure 1 Source: UN/ISDR Platform for the Promotion of Early Warning

Risk Knowledge

Risk arises from the combination of hazards and vulnerabilities at a particular location. For this reason, risk knowledge is a key element of successful EWS. Risk knowledge is defined as the interplay between establishing organisational arrangements, identifying natural hazards, community vulnerability assessment, risk assessment, and information storing and sharing. Risk knowledge is the baseline needed before undertaking further action. When addressing end user through an early warning system, it is fundamental that the importance and potential of the system are well understood by the community itself. To achieve this, the public must be informed about risks, risk communication channels, and emergency plans. Risk information is continuously changing. Climate change alters hydro meteorological conditions across the world and impacts the frequency and intensity of hazards, bringing uncertainty to hazard and risk forecasting

Monitoring and Warning Services

Warning services lie at the core of the system. There must be a sound scientific basis for predicting and forecasting hazards and a reliable forecasting and warning system that operates 24 hours a day. Continuous monitoring of hazard parameters and precursors is essential to generate accurate warnings in a timely fashion. Warning services for different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication

Monitoring is the act of collecting information along with a set of proxy variables related to risk, such as rain that correlated with floods, or seismic waves which correlated with earthquakes. This can be done through direct observations, e.g. through seeing an approaching wildfire or landslide. For many other hazards, where EWS allow warnings with a considerably longer lead time such as storms, flooding, and droughts, continuous monitoring of significant proxy variables can trigger risk mitigating actions.

Dissemination and Communication

Dissemination and Communication Warnings must reach those at risk. Clear messages containing simple, useful information are critical to enable proper responses that will help safeguard lives and livelihoods. Regional, national and community level communication systems must be pre-identified and appropriate authoritative voices established. The use of multiple communication channels is necessary to ensure as many people as possible are warned, to avoid failure of any one channel, and to reinforce the warning message.

Response Capability

Response capability can be enhanced either by increasing public and institutional preparedness, or by automating emergency responses. It is essential that communities understand their risks; respect the warning service and knowhow to react. Education and preparedness programmes play a key role. It is also essential that disaster management plans are in place, well-practiced and tested. The community should be well informed on options for safe behaviour, available escape routes, and how best to avoid damage and loss to property

Response capability also needs to take into consideration the fact that all people should receive the same protection regardless of gender, age, education, or disability. An additional factor must underpin a risk-informed society in order to issue and properly respond to early warnings: institutional capacity. Capacity is the ‘ability of individuals, organizations, and systems to perform functions effectively and in a sustainable manner’ (UNDP, 1998). In the context of early warnings and disaster risk reduction, capacity is the combination of the strengths, attributes, and resources available in a community or society to issue and react to warnings to mitigate disaster impacts. This may include infrastructure, as well as human knowledge, skills, and collective attributes such as social relationships, leadership, and management

2.4 Wireless sensor networks

Wireless technologies have been developing rapidly in these years. The obvious advantage of wireless transmission is a significant reduction and simplification in wiring. (Ning,et al.,2006). Wireless sensor Network (WSN) can generally be defined as a network of nodes that sense data cooperatively and may control the environment based on different conditions, enabling interaction among computing devices, persons and surrounding environment (Broring, et al.2011)

In WSN each node is equipped with sensor to sense physical phenomena such as temperature, light, pressure, humidity etc. process data and transmit to sink or base station for further processing and analyses.

A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components. The individual nodes in a wireless sensor network (WSN) are inherently resource constrained: they have limited processing speed, storage capacity, and communication bandwidth. From that perspective (Paul et al., 2011), proposed a geometrical solution for locating the optimum sink placement for maximizing the network lifetime. Most of the time, the research on wireless sensor networks have considered homogeneous sensor nodes. But nowadays researchers have focused on heterogeneous sensor networks where the sensor nodes are unlike to each other in terms of their energy.

2.5 GSM sensor networks.

Sensor is the object used to gather information about a physical object or process, including the occurrence of events (i.e., changes in state such as a drop in temperature or pressure). These are called remote sensors. From a technical perspective, a sensor is a device that translates parameters or events in the physical world into signals that can be measured and analyzed, (Ahmed, A., et al).

Since the GSM network started its operation in 1991, the SMS has become popular as it provides cheap, convenient and a faster method of communication. (Bisandu, Desmond.,2016). In developing countries Kenya being one, have faced challenges in both flood monitoring, forecasting and warning which is very essential in early warning systems. It Causes inefficiency and real time response may not be realized due to the situation in these areas. In a bid to address those problems which require reporting and warning systems for certain physical phenomena, we can make use of smart micro-electronic objects. (GSM) global system for mobile communication (GSM) interface the physical world with computers, thereby creating a profound flexibility for awareness and remote controlling of the environment. One of the critical components in developing a Sensor in Hell's Gate National Park is to build a geospatial information infrastructure that connects the heterogeneous in situ sensors and remote sensors over the global system for mobile communication (GSM). They are characterized by their little demand for attention from human operators, their capability of self-management, operation in adverse places and near the occurrence of the actual phenomena, great accommodation of node mobility or failure, and effective node cooperation in order to carry out a distributed sensing task. The relative simplicity, smallness in size and affordable cost of GSM modem sensor permit heavy deployment in places or objects in which a sensing task is carried out.

2.6 Types of early warning sensors.

2.6.1 Seismic sensors.

Seismic sensors are the mechanical or electromechanical assemblies that convert Earth motion into electrical signals that can then be digitized and recorded for later analysis. Here, sensors are distinguished from systems, in that the latter may consist of multiple combinations of the former, coupled to a digitizing and recording apparatus.

There are two basic types of seismic sensors: inertial seismometers which measure ground motion relative to an inertial reference and Strainmeters or extensometers which measure the motion of one point of the ground relative to another. Since the motion of the ground relative to an inertial reference is in most cases much larger than the differential motion within a vault of reasonable dimensions, inertial seismometers are generally more sensitive to earthquake signals. However, at very low frequencies it becomes increasingly difficult to maintain an inertial reference, and for the observation of low-order free oscillations of the Earth, tidal motions, and quasistatic deformations, Strainmeters may outperform inertial seismometers. Strainmeters are conceptually simpler than inertial seismometers although their technical realization and installation may be more difficult. The dynamic range of the seismic spectrum extends from the level of the background ambient noise to the largest signals generated by seismic sources.

2.6.2 Smoke and fire detectors.

Smoke detectors are the most sensitive automatic means of detecting a fire and should be used wherever conditions allow. In their finding on wireless sensor networks, (Yu et al. 2005) presented a wireless sensor network for real-time forest fire detection method. The wireless sensor network can detect and forecast forest fire more perfectly and accurately than the traditional satellite-based detection approach. This method is used to minimize the loss of forests, wild animals, and people in the forest fire

There are many concerns in automatic fire detection, of which the most important ones are about different sensor combinations and appropriate techniques for quick and noise-tolerant fire detection. Researchers have been studying fires taking place in various places such as residential area (Milke and McAvoy 1995), forest (Yu, Wang et al. 2005; Bagheri 2007) and mines (Tan, Wang et al. 2007) to find some solutions for fire monitoring. Many commercial products can only detect airborne smoke by using either ionization sensors or photoelectric sensors (Brain 2000).

2.6.3 Remote Sensing and geographic information system.

Remote Sensing and geographic information system enable the collection of data about natural phenomena over very large areas and the assessment and monitoring of natural resources and the prediction of natural phenomena such as flooding. Remote Sensing enables the collection of information on natural phenomena instantaneously. Remote sensing indeed is defining a new paradigm for volcano logical observations, (Pieri and Abrams,2004).

The complexity of global flood disasters requires an integrated approach in studies that may lead to the effective management and reduction of the flash flood problem. Usually, latest information on flood plain dynamics such as flood plain characteristics, and flood duration in addition to intensive fieldwork, are required to prepare flood risk maps using hydrological and hydraulic mathematical formulae and stream geometry.

Remote sensing provides synoptic data of the area either in real-time or near real-time in different spatial or temporal resolutions for different magnitude of flood so that the flood extent can be related to the flood magnitude. The duration and recession of floodwaters can be estimated using multiple imageries of the same area for few days. GIS provides the environment for the combination of the remote sensing data and different spatial and attribute datasets to delineate the flood affected areas under different magnitudes of floods or flood scenarios such as breach in the embankment, overtopping and unprotected rivers. (Sharma, P. 2004)

In many countries, remote sensing is being applied to flood inundation management, analysis and rescue operations. For example, during the flooding in Mozambique (January – March 2000). The GIS hydrological model in China uses of satellite to read the water level and then subtracts the surface elevation to get the height of flood. (C. Shaohong, 2010)

2.7 Sensors application in other countries.

2.7.1 Flood detection in Venezuela: Wireless Sensor Network (WSN)

(Mauricio Castillo-Effen et al.,2004) presented the ongoing effort in providing the population of the Andean region of Venezuela with a flash-flood alerting system by making use of state of-the-art wireless communications and information technologies. A key component of the project is a Wireless Sensor Network (WSN) that is used for monitoring the environment and tracking the disaster while it evolves, they prepared a hybrid of local and remote sensor network. (Sunkpho et al.,2011) represented two main objectives of the developed system which serve as an information channel for flooding alert and response. To implement wireless sensing networks (Halgamuge et al., 2009) presented a comprehensive energy model for wireless sensor networks. It is based on seven key energy consumption sources namely. processing, communication, sensing, transient, logging, actuation and cluster formation.

2.7.2 Flood Detection system in Honduras.

In Honduras, flash flood sensors and application of wireless sensor network provided an effective technology to be deployed for fighting with the flood in poor and developing country. (Basha et al.,2007) presented a brief description about implementation of the sensor network in Honduras for an early detection of flood & alert the community the study highlighted the flood detection problem in Honduras and proposed a solution. Using global system for mobile, they divided the solution into four tasks namely event prediction, authority notification, community alert, and community evacuation. They have conducted different experiments to validate the proposed solution. On the communication side, they verified the usability of the 144 MHz radios. The early warning system has proved to be the effective in warning of the communities on the lower zones of Agu´an River in north-eastern Honduras.

2.7.3 Earthquake Early warning system in Japan.

Japan has been hit several times by several earthquakes.in the effort to provide solution, Japan has implemented an efficient earthquake warning system to allow residents to carryout precautionary measures. Even a 60 second warning prior to an earthquake can allow a driver to pull over to the side of the road or a student to huddle under a desk before the earthquake's ground-shaking rupture Because earthquakes are not limited to any particular region of Japan, JMA has installed over 1,000 seismographs throughout the entire country for earthquake detection (Hoshiba, et al., 2011; Talbot, 2011).

Japan's Earthquake Early Warning System is managed by the Japan Meteorological Agency and was first launched on October 1st, 2007 (JMA, 2007b). Earthquake Early Warning System is a type of front-detection system in which seismometers near the epicentre, or source of the earthquake, send warnings to more distant urban areas. The EEWS is split into two phases: earthquake detection and warning dissemination.

In order to determine when and where an earthquake has occurred, ground movement data is collected using Japan's dense seismic network. This information is then analyzed by monitoring stations to determine whether it is necessary to issue an earthquake warning. The system issues a series of warnings which alert the residents on the possible earthquake. If a warning is justified, this earthquake information is broadcasted to nearby residents through various media such as television, radio, and cellular networks. Specialized alerts are also sent to business operators and facilities in order to deploy necessary countermeasures such as the shutdown of dangerous facilities or the slowing down of commuter trains in order to mitigate any earthquake-related damage (Scientific Earthquake Studies Advisory Committee,2007). Because this type of detection issues a warning after the earthquake has released its initial seismic waves, the EEWS is most useful for regions that are located at least 100km from the earthquake's epicentre. This distance translates into an approximately 20-50second warning.

2.7.4 Early warning in Pakistan pipe network system.

(Stoianov et al.2007) describes how Pipe Network system based on wireless sensor networks which is applied to detect, localize and quantify bursts and leaks and other anomalies in water transmission pipelines such as blockages or malfunctioning control valves. The system monitors water quality in transmission, distribution water systems and the water level in sewer collectors.

2.7.5 Sensor Networks in Kenya.

(Juang, et al., 2002), proposed a system sensor system for monitoring wild zebra herds in Kenya within a 100 km square game reserve. The system measured the GPS location of each animal and communicated the information using peer-to-peer short range radios, performing little analysis of the measured data. In addition to the mobile zebra collar nodes, the base node also was mobile within the network, receiving information from whichever nodes were nearby through a long-distance radio during fixed communication windows. The test deployment of the system in 2004 consisted of 10 nodes over a 24-hour period (Zhang et al 2004).

2.7.6. Proposed flood Early Warning System, Hell's Gate National Park.

From the previous studies early warning system has proved to be the most effective technology used to predict, communicate and warn of impending danger caused by flash flood. With the situation at the Hell's Gate National Park it is evident that deployment of the early warning system in the tributaries in various points along the water path will be the most effective way of ensuring that tourist will be alerted and warned when the water level reaches a critical height to trigger alert and warning. on the increase of water hence the loss of lives can be minimized or avoided. With the availability of GSM sensors in the local market one is able to implement a real time system that will measure the water level and communicate to the control tower which in this case a Kenya wild life service office.

The Global System for Mobile Communications (GSM) module is used for sending the mobile text messages while the Arduino Uno microprocessor is used to read in the input from the pressure sensor and then calculate the height of water. This simple yet effective warning system is deemed to be one of the fastest and less costly method of alerting the relevant authorities and the vulnerable residence.

The idea of an SMS based warning system was proposed because mobile phones have become a popular communication device amongst people all over the world.

The Hell's Gate National Park which is the custodian of the system will be able to communicate to the tourist in the gorge to be evacuated. Every tourist visiting the gorge are provided with the tour guide who are equipped with a two-way radio communication commonly known as walkie talkie that are effective on the kind of terrain where cellular communication may not be available. It is effective for broadcast where multiple radios are on one channel everyone on the same channel will receive the same communication. The positioning of the sensors will be a distance away on the upper zone of the tributary that will allow the tourist or the affected person to reach safe ground, it will allow the adequate lead time. The system will be designed to use the solar or wind energy, an accumulator to provide power for sensors

Once the water reaches critical level, sensor will send the warning via short message service to the control station within the park. The sensor alert will need constant monitoring and the issuance of warning is based on the alert level since it will have 3 levels

Conceptual framework

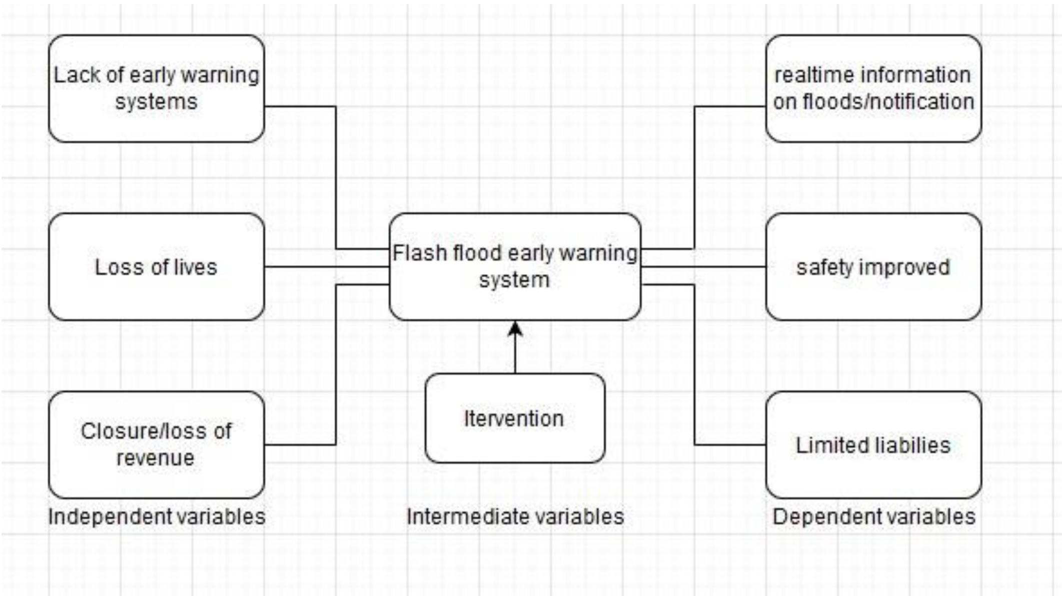

Figure 2.: conceptual frame work

CHAPTER 3. METHODOLOGY

3.1 Introduction.

The aim of this chapter is to bring into perspective the methodological choice of instruments, the exact techniques that will be used for user elicitation and system implementation and how the system will work using relevant analysis Thus, when we talk of research methodology we not only talk of the research methods but also consider the logic behind the methods researcher will use in the context of our research study and explain why we are using a particular method or technique and why we are not using others so that research results are capable of being evaluated either by the researcher himself or by others tools and users.

In research methodology, Research is simply the process of arriving as dependable solution to a problem through the planned and systematic collection, analysis and interpretation of data. It is the most important process for advancing knowledge for promoting progress and to enable man to relate more effectively to his environment to accomplish his purpose and to resolve his conflicts. Although it is not the only way, it is one of the more effective ways of solving scientific problems, (Singh, Y.K.,2006).

Methodology is the framework associated with a particular set of paradigmatic assumptions that can be used to conduct research (O'Leary,2004).

This section presents an overview of the methods and procedures used in the study. It covers research design, population, sample and sampling techniques, data collection and analysis.

3.2 System Architecture

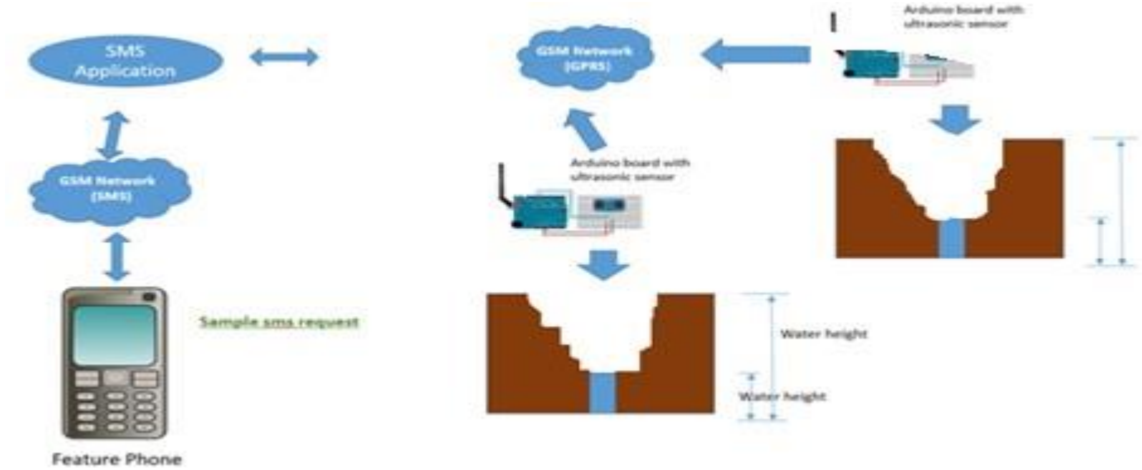

Figure 3. System Architecture landscape

3.3 Research design.

A research design is the conceptual structure within which research is conducted. It is the overall strategy that one chooses to integrate the different components of a study in a coherent and logical way, thereby, ensuring one effectively address the research problem; it constitutes the blueprint for the collection, measurement, and analysis of data.

Research design is as a framework of methods and techniques chosen by a researcher to combine various components of research in a reasonably logical manner so that the research problem is efficiently handled.

Kerlinger (1973) defined survey research as a study on large and small populations by selecting samples chosen from the desired population and to discover relative incidence, distribution and interrelations.

This study has adopted a survey research design that seeks to investigate the study variables without manipulating any of them or tampering with them in an attempt to understand, describe and explain the use of early warning systems.

3.4 Application of Descriptive research

A descriptive research study is one in which information is collected without changing the environment. It is used to obtain information concerning the current status of the given phenomena to describe" as it is" with respect to variables or conditions in a situation.

The study being conducted had its problem statement well stated. Therefore, it's prudent to describe the already available information. Currently the problem at hand is that the hells gate management had a hard time relaying warning to the tourist visiting the park and more specifically warning of flash floods. To understand this scenario, the study sought to find and implement the effective methods to availing accurate and timely information to the tourist. This study endeavoured to gather quantifiable information that was used for statistical inference on the target audience through data analysis. The research questions were majorly closed-ended questions. Though however, in some cases, observation came in handy to actually see the nature of the environment within the park.

3.5 Sampling and Sampling Technique.

To assess the effectiveness of using Early warning system at Hell's Gate National Park, the researcher contacted the selected population to help out in getting samples and to obtain views from them, which are the custodian of data and also the managers of the park, the tourist who visits the park, who are the most affected in case of flooding, and finally early warning systems experts who will give professional advice on use of early warning system. The targeted population for the study thus included:

1. Park manager
1. Information system expert

1. Early warning systems Experts
2.Tour guide

2.Safety managers

1. Security manager

3.6 Data Collection.

The focus of the study was based on an assessment of how early warning systems can be used effectively in ensuring safety of tourist visiting the park and specifically the gorge, and therefore primary data from the parties involved in this matter is crucial. However, secondary data from relevant publications and internet has been used to support various augments in the studies.

3.7 Data collection tools.

The data collection methods that has been used in this study include observation, interviews and, secondary sources of data, which will be used to collect and process data to achieve all the objectives of this study with view of complete comprehension of the problem. To aid in the collection of data requirements, the researcher focuses on the of the day-to-day business operations in the park and the rainy season within and its surrounding. The management of the organization, employees and customers will be briefed on the research and made to understand the essence of the study which will be on purely academic-based research**.**

3.7.1 Quantitative data collection method.

Quantitative data collection methods rely on random sampling and structured data collection instruments that fit diverse experiences and categories. The sample design to be used must be decided by the researcher taking into consideration the nature of the inquiry and other related factors. They produce results that are easy to summarize, compare, and generalize. Quantitative research is concerned with testing hypotheses derived from theory and/or being able to estimate the size of a phenomenon of interest. Depending on the research question, participants will be randomly assigned to different treatments. If this is not feasible, the researcher will collect data on participant and situational characteristics in order to statistically control for their influence on the dependent, or outcome, variable. If the intent is to generalize from the research participants to a larger population, the researcher will employ probability sampling to select participants.

3.7.2 Interviews

In a structured interview, the researcher asks a standard set of questions and nothing more. (Leedy and Ormrod, 2001).

The sample interview questions are.

1. Do you prefer to use early warning system in the park?
2. Do you like to rely on early warning system to get notification when you visit the gorge?
3. Have you ever used early warning system before?
4. Do you trust flood and flash flood management system?

3.7.3 Observation

The researcher participated in the research by immerse herself in the setting where her respondents are, while taking notes. This include visiting the gorges and taking notes on the observed situation using own understanding.

3.7.4 Document review

Document review is a way of collecting data by reviewing existing documents. The documents may be internal to a program or organization or may be external.

3.8 Data processing and analysis.

The study used the convenience sampling and purposive sampling techniques. population were sampled using a convenience sampling technique because they are easily spotted and readily available for the study.

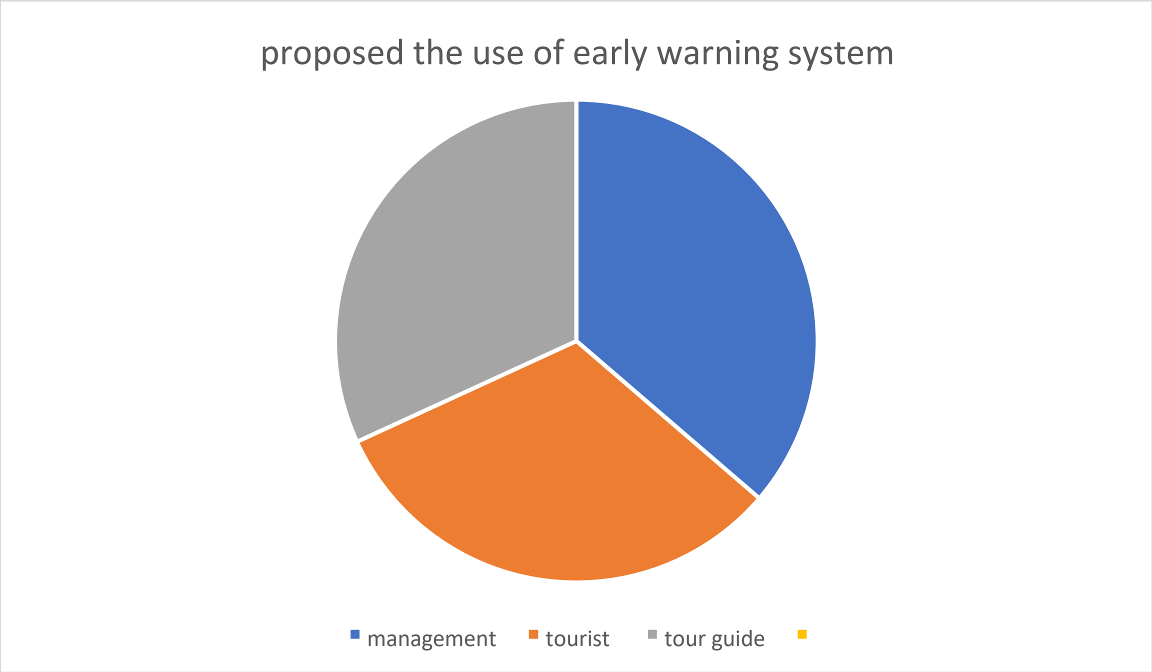

Figure 4. proposed use of early warning

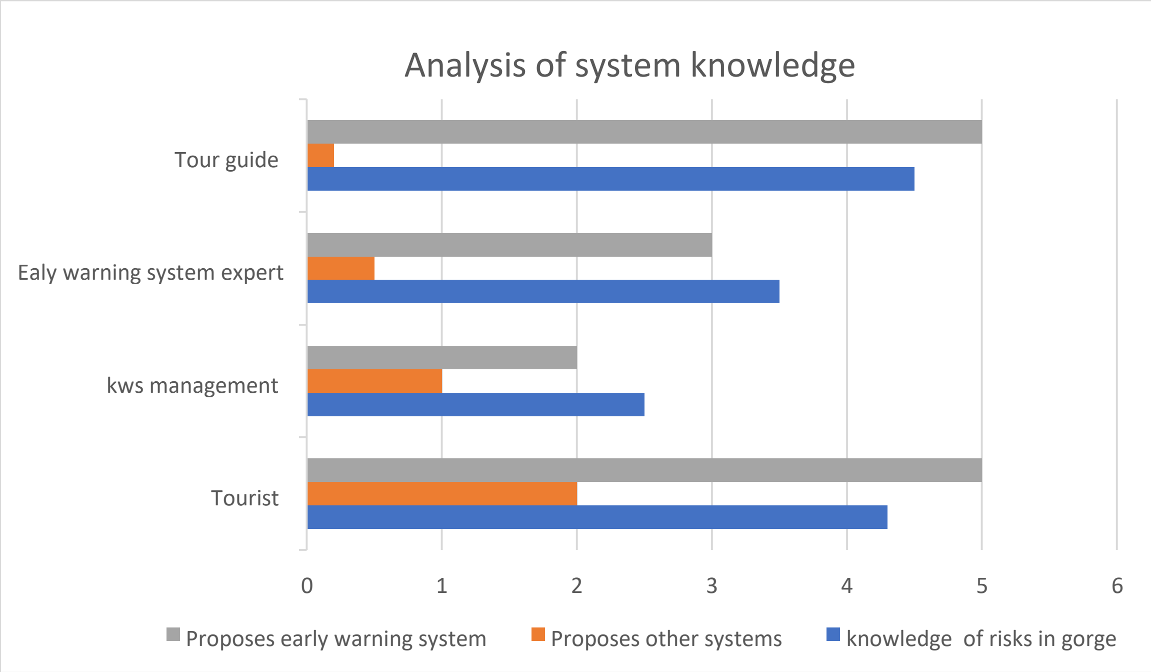

Figure 5. Graph of System analysis knowledge

3.9 Data presentation.

Quantitative data collection will use closed-ended questions that will be analyzed using statistical methods. Microsoft Excel will be used to analyse the data and obtain percentages, mean and frequencies. The findings will be presented in form of tables, pie charts and bar graphs.

4.0Summary of methodologies used.

Quantitative and qualitative research methods investigate and explore the different claims to knowledge and both methods are designed to address a specific type of research question. While the quantitative method provides an objective measure of reality, the qualitative method allows the researcher to explore and better understand the complexity of a phenomenon. This paper presented a clear statement of what constitutes quantitative and qualitative research designs and summarized techniques used to conduct studies for both research approaches. This paper also presented statements of what constitutes the mixed methods approach when conducting research. Although each approach seeks to validate sensory knowledge as truth, neither is absolute in its form.

CHAPTER 4: SYSTEM ANALYSIS.

4.1 Development methodology

Software development process as a framework for the activities, actions, and tasks that are required to build high-quality software. More important, software engineering is performed by creative, knowledgeable people who should adapt a mature software process so that it is appropriate for the products that they build and the demands of their marketplace. (Pressman, R.S 2010)

4.1.1 Waterfall software development

The most suitable method for the proposed early warning system is waterfall**,** because the model develops systematically from one phase to another in a downward fashion. The waterfall approach is ideal for projects that have specific documentation, fixed requirements, ample resources, an established timeline and well understood technology. This model is divided into different phases and the output of one phase is used as the input of the next phase. Every phase has to be completed before the next phase starts and there is no overlapping of the phases. Proposal writing; it involves generating the ideas. Requirement elicitation, this involves data collection to identify the need and expectation of the user. Requirement analysis involves working on data collected to provide meaningful output. System Designing of database and interface involves logical and physical design of the expected system. Coding is the actualization of the ideas generated to provide a desired output. Implementation, Programmer will code the program to implement the hardware functions. The language will be C programming which is mainly used by machines. Testing include Functional test will be used done to ascertain the effectiveness of the system to generate alert and warning.in waterfall model documentation is a continuous process from the inception to competition

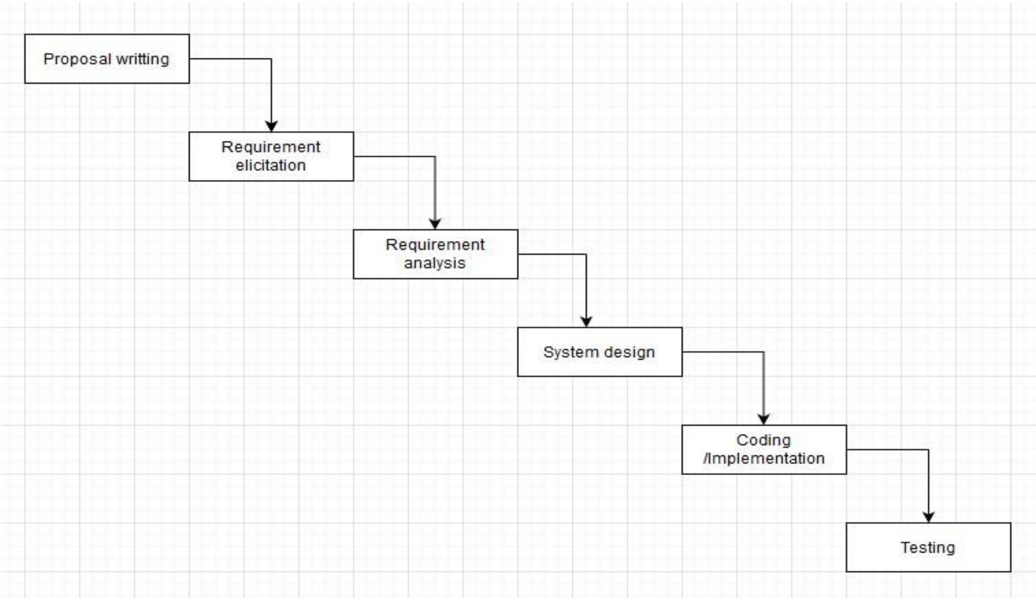

Figure 6: Waterfall methodology.

4.1.2 System analysis

This analysis encompasses those tasks that go into determining the needs or conditions to meet for a new project, taking account of the possibly conflicting requirements of the various stakeholders, analysing, documenting, validating and managing software or system requirements. Requirement Analysis, is the process of defining user expectations for a new software being built, at this stage researcher capture the requirements.

The case of flash flood sensor will be to detect rising water level and send SMS to the recipient about water levels a different location.

4.1.3 Analysis of the existing system

The hells gate national park does not have an early warning system. The current form of data collection is done by tourist filling of manual forms which enables the capturing of the individual data, which include; name, address, telephone number, residence and nationality. The current system does not employ the use of early warning technology in warning of foods hence it only the known weather pattern and observation from the locals who are the tour guide. The limitation of this kind of data collection is that in the event of need to provide emergency support, there is no established means of communication.it lacks an efficient data collection data and information sharing.

4.1.4 Model of the existing system.

The current system at Hells Gate National Park id done on book entry of data, the visitor input their personal data, the name, citizenship status and contacts. main source of information is provided by weather forecasting agents on rain occurrence around and within the environs. During rainy seasons no tourist are allowed to visit the gorges in the Hells Gate National park.

4.2 Solution

The most effective and reliable solution is to develop early warning system that will provide early warning on the occurrence of flash flood.

4.2.1 Requirements analysis of the new system.

Eliciting requirements: Requirements analysis is an effort that demands a combination of hardware, software and human factors to Identify customer's needs, evaluate system for feasibility, perform economic and technical analysis, allocate functions to system elements, Establish schedule and constraints. Requirements analysis includes four types of activity: the task of communicating with KWS and users to determine what their requirements.

Analysing requirements: determining whether the stated requirements are unclear, incomplete, ambiguous, or contradictory, and then resolving these issues.

This include tasks like how will the hardware

Requirements modelling: Requirements might be documented in various forms, such as natural-language documents, use cases, user stories, or process specifications.

Review and retrospective: Team members reflect on what happened in the iteration and identifies actions for improvement going forward.

4.2.2 Feasibility Study

It is a preliminary investigation that helps the user to take decision about whether study of system should be workable for development or not. The main objective of a feasibility study is to acquire problem scope instead of solving the problem.

Financial Feasibility: It is evaluating the effectiveness of candidate system by using cost/benefit analysis method. The initial cost of the early warning system, flash flood sensor is minimal compared to danger associated with deaths caused by flash floods.

Technical Feasibility: It analyses and determines whether the solution can be supported by existing technology or not. The technology of Arduino has the ability to be integrated with other technologies appropriate responses to what extent it can support the technical enhancement.

Operational Feasibility: It determines whether the system is operating effectively once it is developed and implemented. It ensures that the management should support the proposed system and its working feasible in the current organizational environment.

4.2.3 Functional requirement

The system should be able to sense raindrops and activate the lower level flood sensor, as the water level increase to the mid-level flood sensor is activated and finally flooding level is attained by triggering the high-level flood sensor at the top of the measurement gauge.

The system should be able to effectively notify and warn of flooding by sending short message service as each level is being attained. The massage also indicates the height of water. The system should be able to send SMS to the intended recipients

4.2.4 Non-functional requirements

This include parameters that are no measurable but they are key to the system being developed.

Accuracy, the alert should be precise and accurate

Speed, the response speed and lead time should be enough for evacuation from the danger

4.3 Parameters of analysis

Performance analysis, it provides feedback between the logical and the functional architecture decisions, flood system answers the question whether a given functional behaviour can be realized with the selected resources in terms of throughput, latency and the required resources. Vice versa, it helps in designing appropriate functional algorithms for achieving the required performance with the selected resources optimum resource utilization Hence performance analysis and architecture/algorithm design and exploration are closely related.

The eventual goal is to demonstrate the system SMS alert from a performance point of view

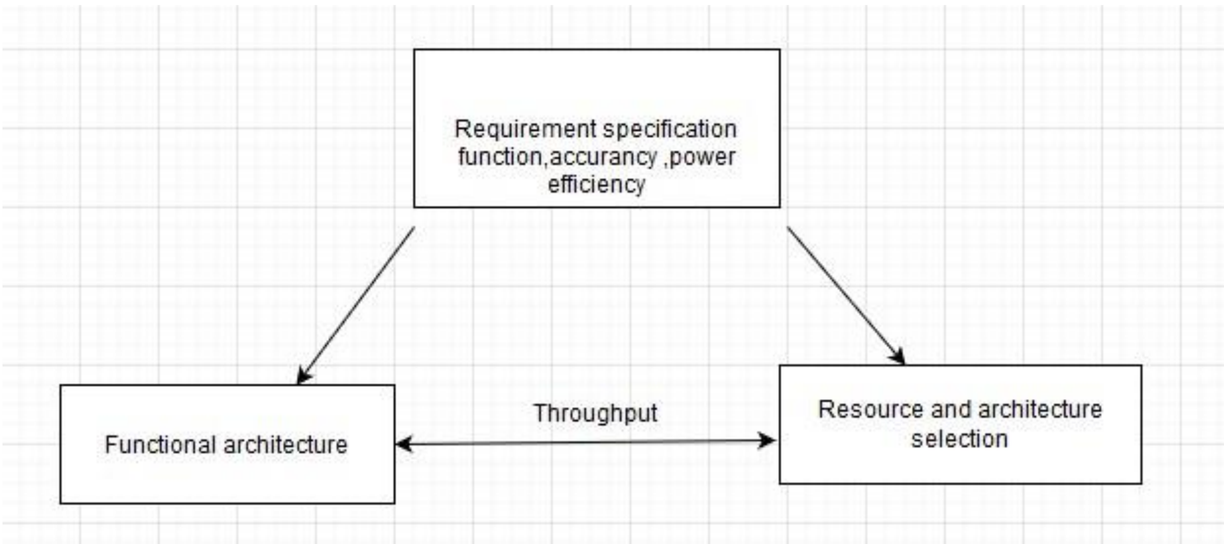

Figure 7. performance analysis

Scalability. The Arduino system will allow the addition of users when the alert will be required to reach a large population, the use of GSM is the most appropriate system to broadcast short messages Efficiency the Arduino is the most efficient system, it does not require to access the network resources until the sensor is activated, the use of power resources is utilized, it goes to sleep mode when no raindrops are detected, and only activate when it senses sustained raindrops

Effectiveness is measured by the ability to give real-time notification, send SMS at all levels. The flash flood sensor has the ability to notify the base station of occurrence of rain and the dangerous level which means the tourist must be evacuated from the gorges.

Adaptability, is the ability of the system to be integrated with other existing systems, flash flood sensor system has a GSM module that can be replaced or adapted to GPRS and internet TCP/IP Security, the system is secure from intrusion, since the system code is encrypted any distributed system is vulnerable to intrusion, which may alter the warning signals to give false or altered signal

4.4 Analysis tools

4.4.1 Simulation

Simulation, the simulation model describes the operation of the system in terms of individual events of the individual components of the system. In particular, the system is divided into elements whose behaviour can be predicted, at least in terms of probability distributions, for each of the various possible states of the system and its inputs. The inter-relationships between the elements also are built into the model. Thus, simulation provides a means of dividing the model building job into smaller component parts and then combining these parts in their natural order and allowing the computer to present the effect of their interaction on each other. After constructing the model, it is then activated in order to simulate the actual operation of the system and record its aggregate behaviour. Thus, simulation typically is nothing more or less than the technique of performing sampling experiments on the model of the system. The experiments are done on the model rather than on the real system itself only because the experiments on the real system would be too inconvenient, expensive and time consuming

4.4.2 System Flow Chart

A system flow chart is a diagram or pictorial representation of the logical flow of operations and information in an organisation. It depicts the relationship between input processing and output considering the entire system. A standard set of symbols is generally used for construction of system flow charts.

The flow chart of flash flood sensor has sequence of activities, raindrop sensor and water level sensors. The input is a water level rising the microprocessor will communicate to GSM which send SMS to the recipients specified by the hardware system.

Start the system is powered raindrop sensor sense rain drops, if sustained it activate level sensors

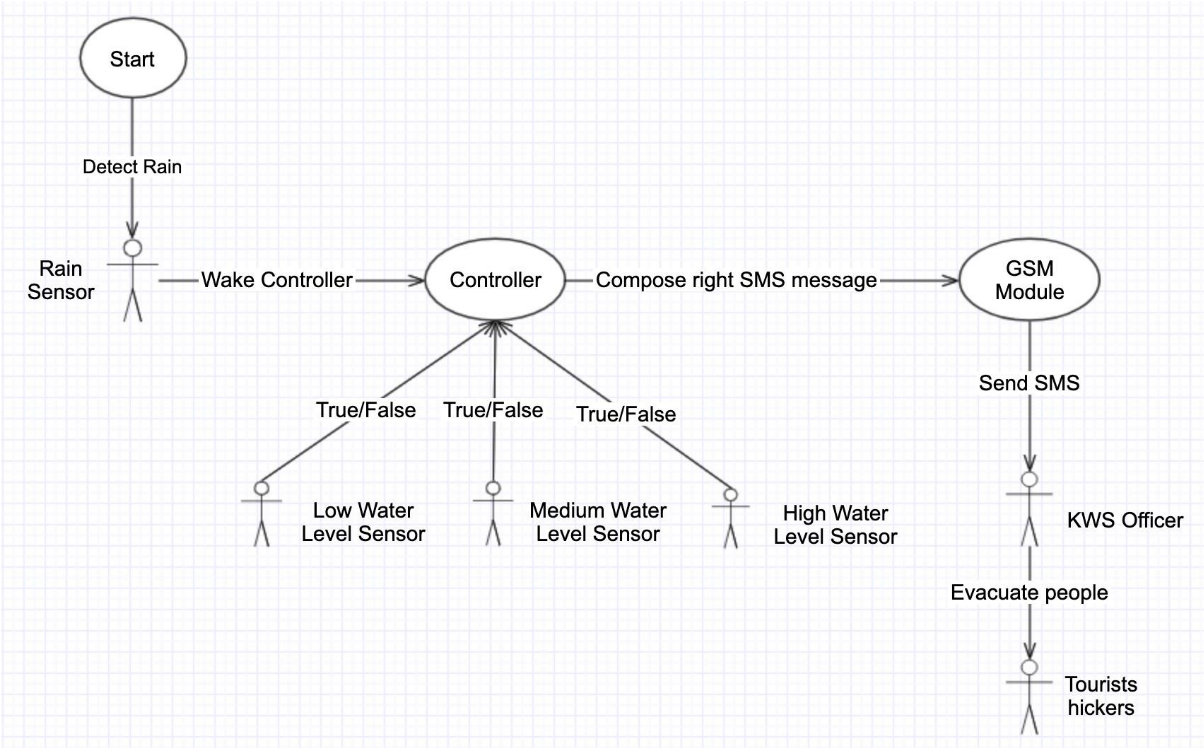

Figure 8. Data flow diagram

4.4.3 Decision tree

A decision tree is a flowchart-like structure in which each internal node represents a "test" on an attribute each branch represents the outcome of the test, and each leaf node represents a class label. The decision will first activate the Arduino processor if it sense raindrop, it checks if the raindrops is sustained then level sensor is woken, low level sensor checks the volume once the volume increase middle level sensor is activated and SMS is sent to the KWS at hells gate of warning on possible flood

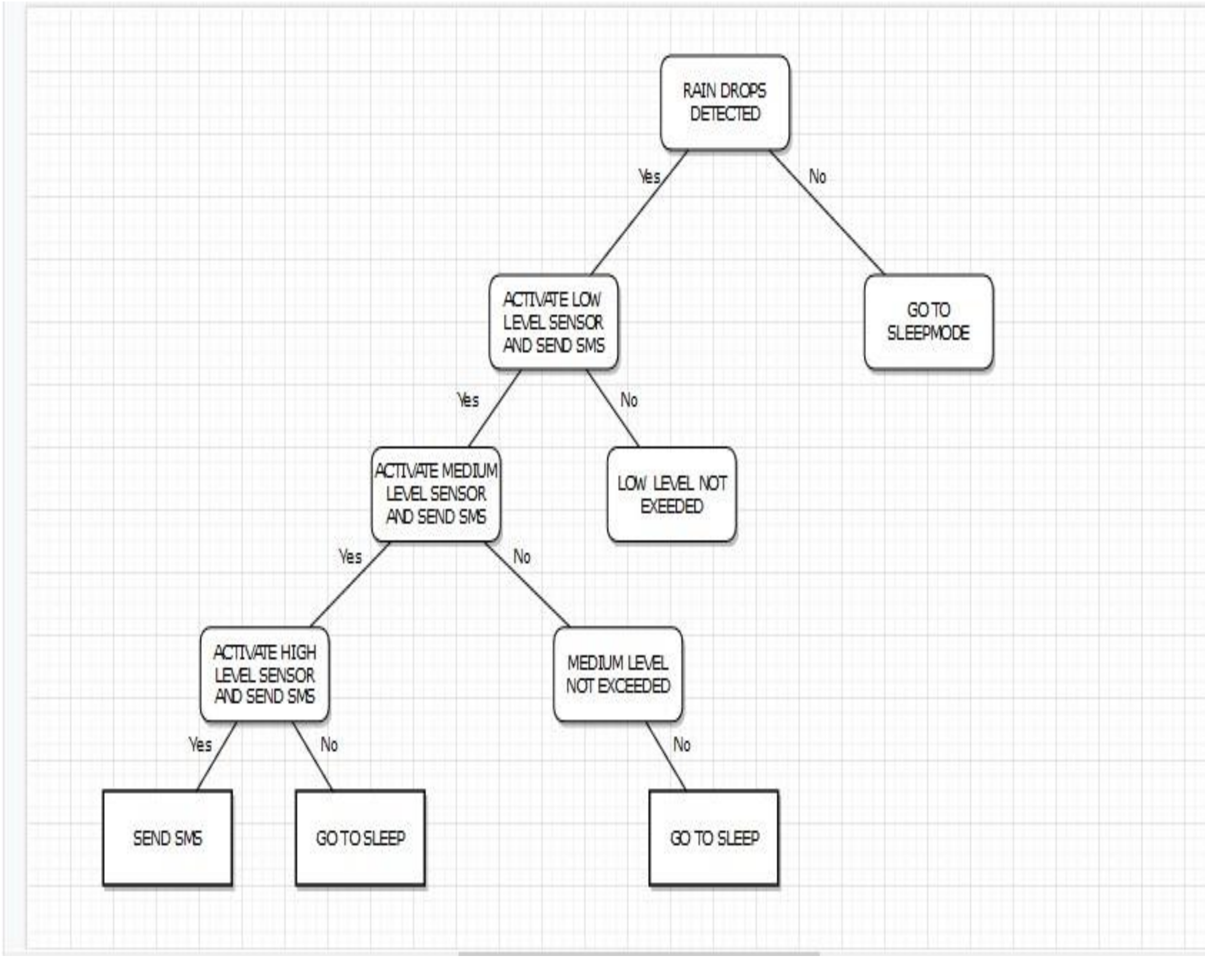

Figure 9. Decision tree

CHAPTER 5. SYSTEM DESIGN

System design is the process of defining architecture, components, module, interfaces and data that is needed for the system to satisfy the optimal requirement of the system (Yen, 2014). It is the process of defining, developing and designing systems which satisfies the specific needs and requirements of a business or organization. The logical system design arrived at as a result of system analysis and is converted into physical system design

The system will measure water level and send short message service, to the prescribed recipient, as the level increase the new level is attained SMS is send

5.1 System Design

conceptual design Typical flash flood warning sensor

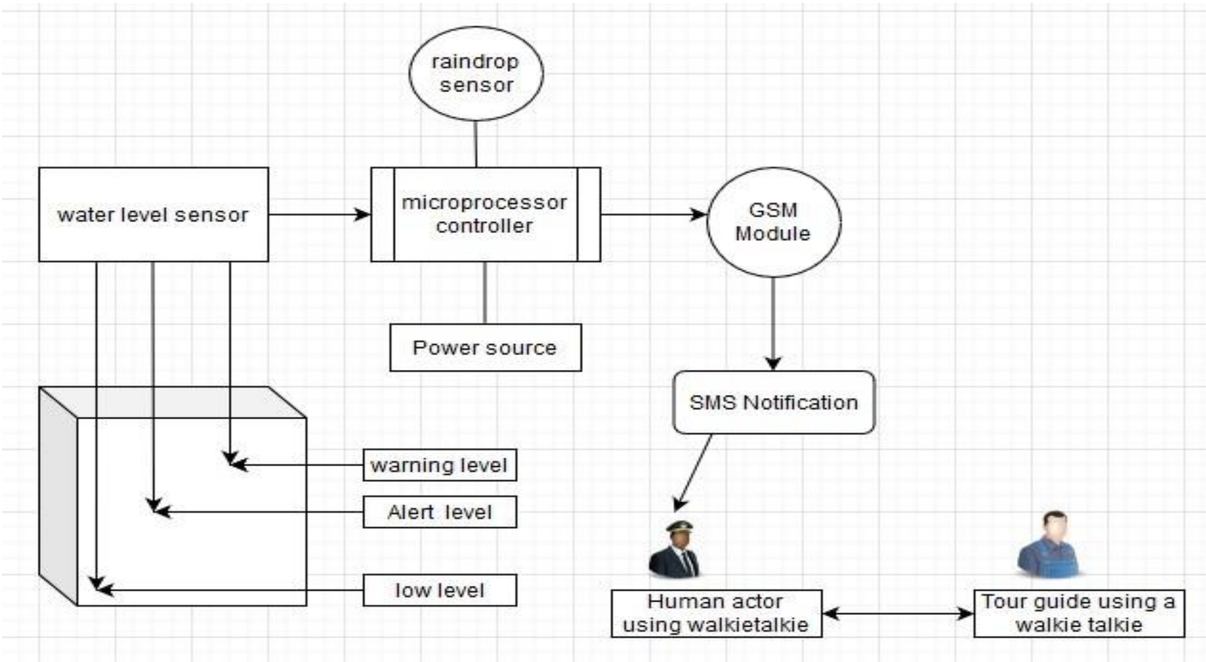

Figure 10: Conceptual design of flash flood system

5.2 Architectural Design

It defines the structure and relationship between various modules of system development process It is also known as high level design that focuses on the design of system architecture. It describes the structure and behaviour of the system. It follows Architectural design and focuses on development of each module.

System Architecture

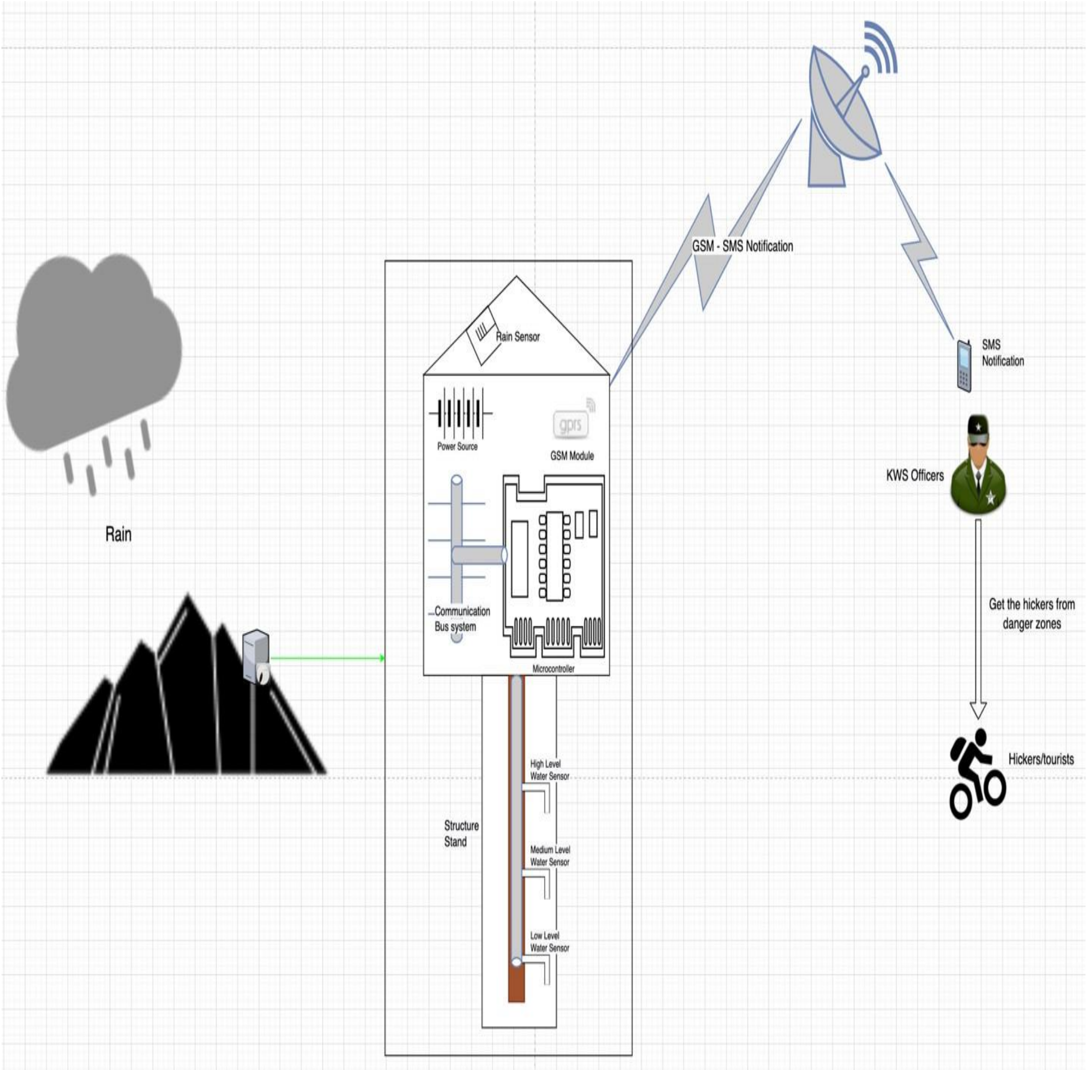

Figure 11. System Architecture Diagram

Level sensor will be positioned along the water path, where it will detect the various levels of water flowing along the channel, it will use 3 level indication, the low level indicating safe position, middle level indicating the increase in water level and the high level indicating the flood position

5.3 System flow diagram.

The system flow diagram depicts how components interacts how sensors responds as the volume of water increase the sensor is activated from low risk safe level to medium level and warning level which triggers the sensor to send a warning message to the control tower of the impending flash flood. Sensors send short message service at any level

System Flow Diagram:

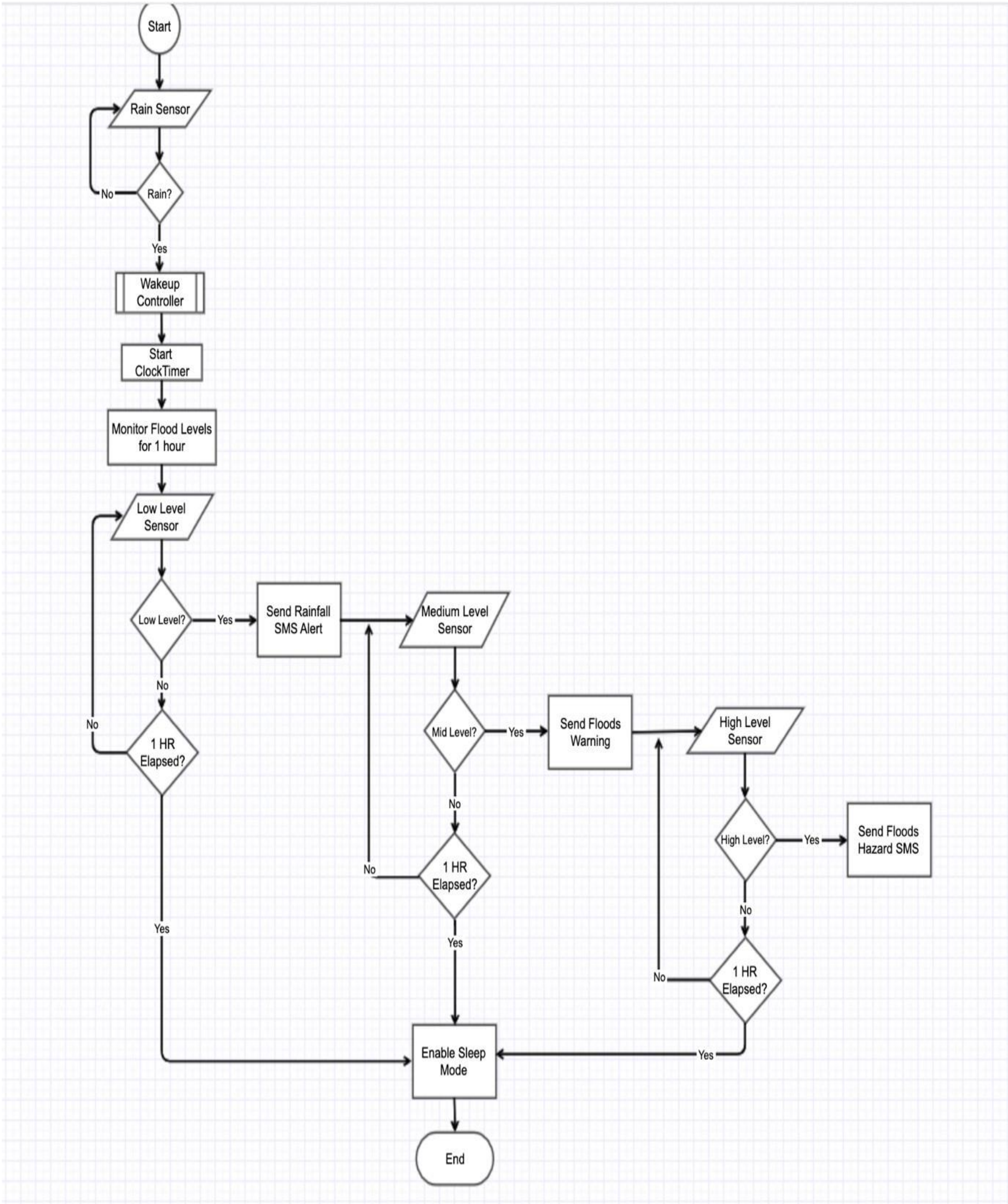

Figure 12. System flow diagram

CHAPTER 6: IMPLEMENTATION AND TESTING

6.0 Hardware requirements

1. Arduino UNO R3 board
2. Prototyping board-microprocessor
3. Float level sensor:
4. GSM/GPRS shield
5. Rain sensor
6. 9V Battery case
7. 9v Battery
8. Connection/jumper wire
9. Computer

6.1.2 Hardware System components

A9 and A9G GSM GPRS development board has been used to provide GSM services like sending SMS notification to the KWS office's phone number. A rain sensor is composed of a rain detection plate with a comparator who manages intelligence. It acts as a variable resistance that will change status: the resistance increases when the sensor is wet and the resistance is lower when the sensor is dry. A float switch is a mechanical device being used to sense the level of ground run-off water to determine magnitude of flooding downstream. Power source is 9v battery but it can be powered by solar. Arduino microcontroller is an open-source prototyping platform used for building electronics projects. It consists of both a physical programmable circuit board and a software, or IDE (Integrated Development Environment) that runs on your computer, where you can write and upload the computer code to the physical board

6.1.2 Software environments.

The Arduino Integrated Development Environment or Arduino Software (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and hardware to upload programs and communicate with them. Arduino Environment with the programming language C language with some and SMS Application – JAVA with smslib library for the SMS functionality.

The analysis of the system helps to establish the feasibility from different angles. The system should satisfy the technical, economic and operational feasibility

A whole network of devices is knit together to form a transparent system to the user. Flash Flood Sensors were placed at strategic positions in a mimicked flowing water path. This sensor will be connected to an Arduino board. An Arduino board is a microcontroller-based kits for building digital devices and interactive objects such as sensors. This device has the capacity to get readings from a water level sensor and sending to communication module connected to GSM. The Arduino board is powered by various sources e.g. a battery cell, a solar panel or USB shield Once the Arduino board received the reading, data is transmitted via SMS application.

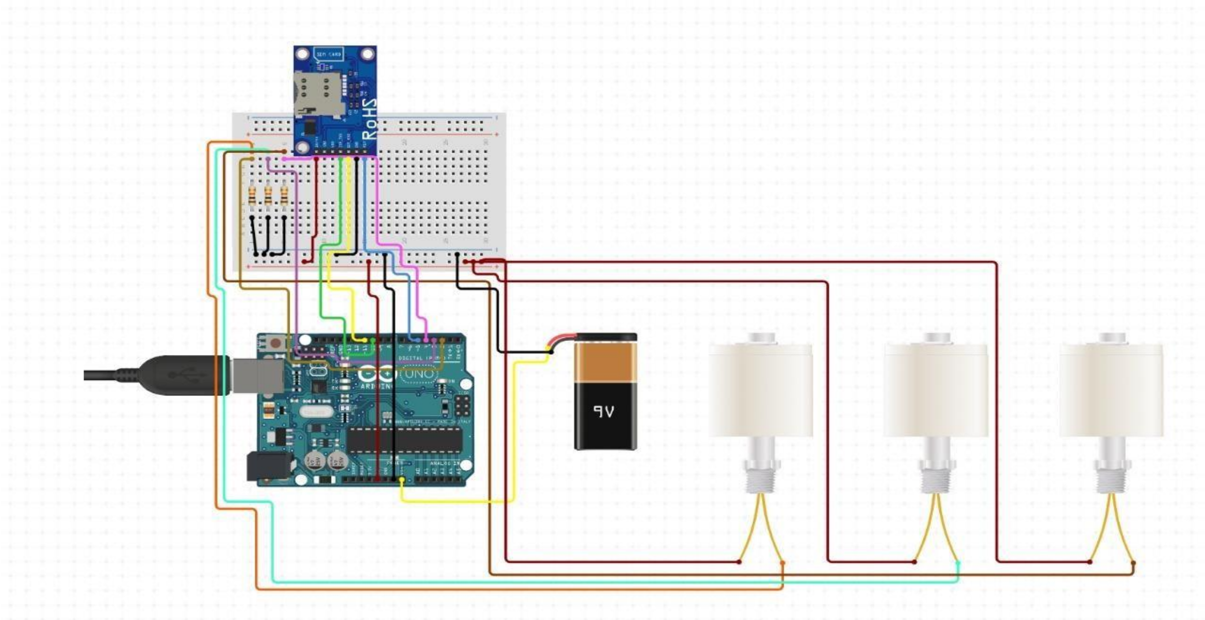

Figure 12. Hardware components integration

Low Level sensor eliminate false triggers where something triggers the mid-level sensor and the low sensor isn't triggered, by ensuring only the low-level sensor can lead in being actuated

6.2 Testing

Software testing is a process, to evaluate the functionality of a software application with an intent to find whether the developed software met the specified requirements or not and to identify the defects to ensure that the product is defect free in order to produce the quality product.

Unit testing

It is done for each module to eliminate error and to make sure each module is working as desired and are error free

Black-box testing

It is carried out to test functionality of the program. The tester in this case, has a set of input values and respective desired results. Its achieved by increasing the level of water in the container as input and the SMS will be sent on the level of water

Integration testing

Is a level of system testing where individual units are combined and tested as a group. The purpose of this level of testing is to expose faults in the interaction between integrated units. Test drivers and test stubs are used to assist in Integration Testing.

System Testing

This is achieved by testing on the functionality as per the requirement, Performance which proves how efficient the software is. It tests the effectiveness and average time taken by the software to do desired task. Performance testing is done by means of load testing and stress testing where the software is put under high user and data load under various environment conditions. Security & Portability - These tests are done when the software is meant to work on various platforms and accessed by number of persons.

Acceptance testing

Is a level of software testing where a system is tested for the acceptability. The purpose of this test is to evaluate the system's compliance with the business requirements and assess whether it is acceptable for delivery.

CHAPTER 7: RESULTS AND DISCUSSIONS.

The results have been tabulated by Thingspeak is the open IoT platform with MATLAB analytics for analysis

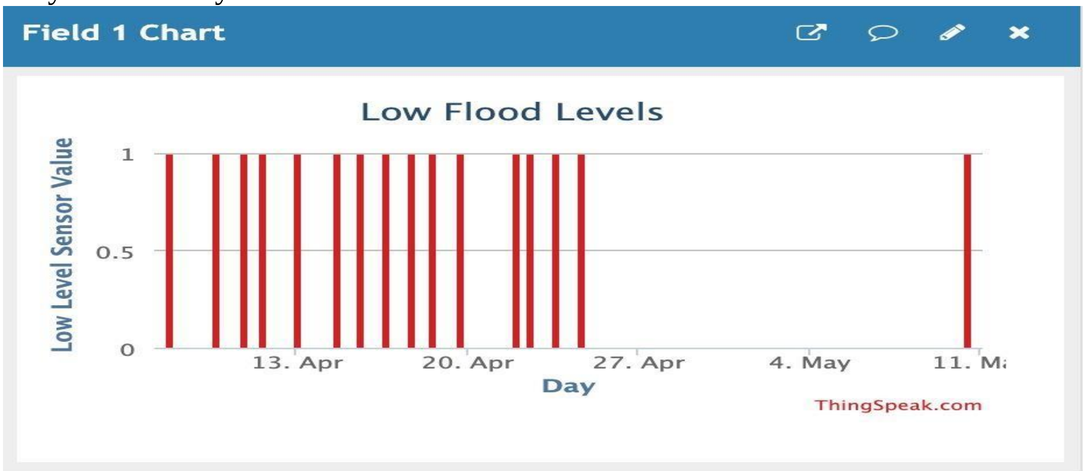

Figure 14: Low level sensor.

The low level sensor is activated several times when the water is detected, if the volume of water won't increase but does not activate the mid-level sensor and therefore it goes to sleep. Low level alert is activated to send an SMS of the alert in all the instances.

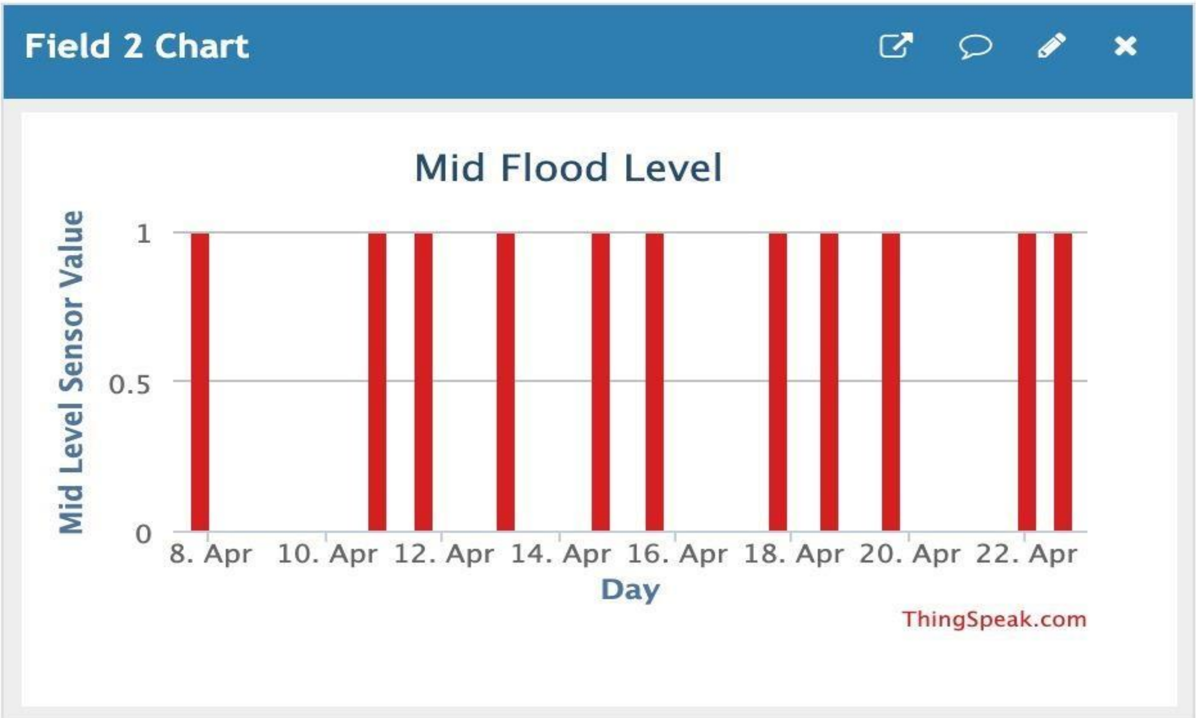

Figure 15: Mid-level sensor

The mid-level is activated once the low level sensor has been activated as the volume of water increase it triggers the system to send an SMS for moderate level warning alert

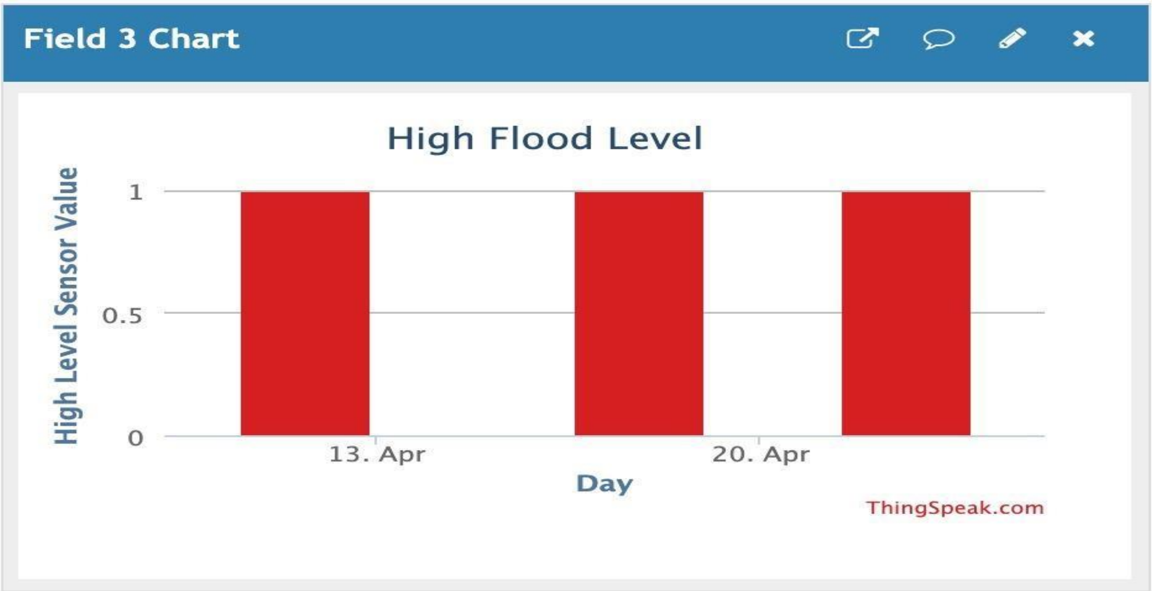

Figure 16: High level sensor

The low level sensor is triggered, it then sends SMS once the volume of water attains a sensor level, as the volume increase it attains the mid-level which sends an alert via SMS as the volume of water increase it switches the high level sensor which triggers the high level warning which means the risk is fatal. High level notification calls for action of evacuation

Notification

Lead time Lead time in flood forecasting refers to the amount of time a flood takes to reach a particular downstream community from the flood measurement station upstream. The basic principle for assessing lead time is that advance warning should be given with enough time for effective preparatory action. The alert will allow enough lead time for evacuation after the flood warning

According to Poiseuille's Law states that flow rate F is given by $F = \pi(P1-P2)r4 \div 8\eta L$, where r is the pipe radius, L is the pipe length, η is the fluid viscosity and P1-P2 is the pressure difference from one end of the pipe to the other. (Makihara et al.1993)

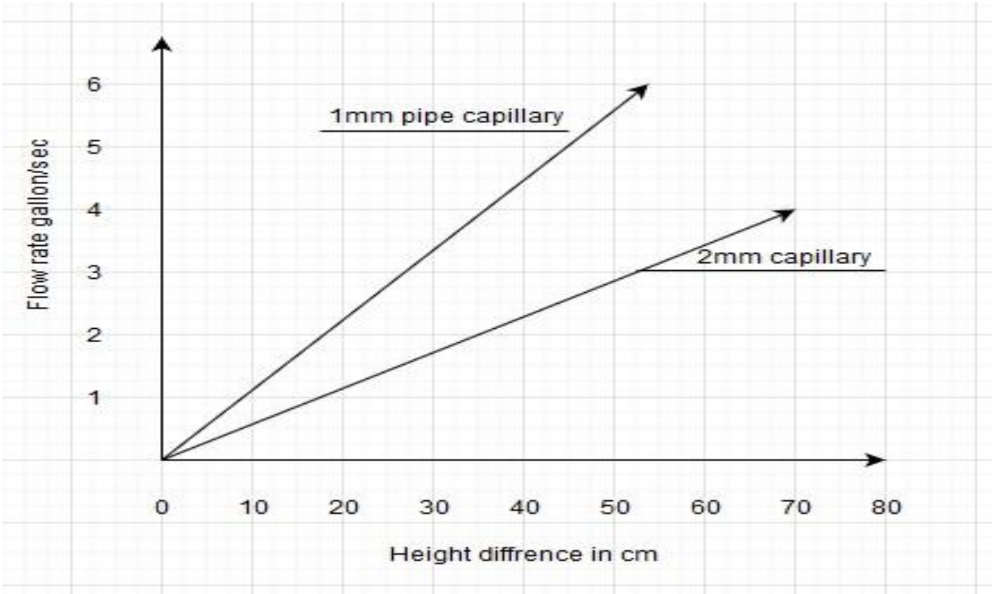

Figure 17: Linear dependence of flow rate

flow rate=volume /time

$q=\frac{VOLUME}{TIME}$ **Determining Success on rate of data submission**

The main objective of this exercise was to find out if the people After full implementation and testing of the system, evaluation of the prototype was done with the aim to determine if the developed system is delivering the expected results. The following areas were evaluated to provide answers to the research questions set at the feasibility study of the project, which are in line with the project objectives and requirements.

Determining Success on rate of data submission

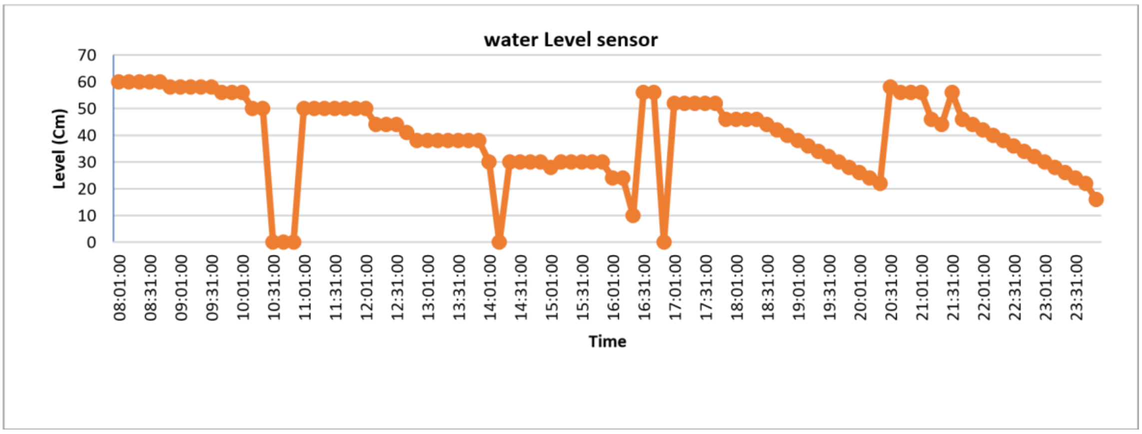

Figure 18: Sensor data submitted for the flowing water

The above figure shows data streamed in every 10 minutes from flash flood sensors mounted along the water path that simulated.0 cm means that the board failed to submit the reading which is shown in the next tabulation in Figure 6.

Submissions	Total Submissions	Failed Submissions	Success Rate
Water path	96	5	94.7%

Figure 19: Submission rate

As seen from the test results above, it's evident that this approach has a high reliability to read submit data with very low rates of failure. This portrays the fact that IoT can be reliable and trusted to create complex systems that can solve common man's problems. Determining Response of system to SMS sent to it

Test Case	Example entry	Response
SMS notification	alert Low level	Warning) Low Flood Hazard! Surface water is above altimetry level 5cm
SMS notification	Mid-level	Moderate Flood Hazard! Surface water is above altimetry level 10cm
SMS notification	Warning level	High Flood Hazard! Surface water is above altimetry level 20cm

Figure 20: Responses by the system to various queries

Some requests that users sent over to the system and their corresponding responses. Any request that was not understood or not found had a specified message with relevant information.

User test results

Tests were conducted to determine what the users thought after testing the system. From five respondents two respondents had same idea that it would make the system more usable 1-Strongly disagree 2- Disagree 3-Fair 4-Agree 5 – Strongly Agree

User	Usability	Functionality	Reliability	Notes
User 1	3	5	5	System may delay in relaying information
User 2	4	4	3	Weather may affect source of power
User 3	3	4	5	Need to broadcast to many users
User 4	4	2	4	Need to handle more requests from SMS
User 5	2	4	5	Need to install many alert stations

Figure 21: User test results

CHAPTER 8: CONCLUSIONS AND RECOMMENDATION.

8.1 Conclusions

The objective of the study was to investigate the risks, impact and mitigation of flash floods at Hells gate national park. The study seeks to answer three research questions. Mechanisms to avert flash flood risks, how to minimise deaths caused by flash flood, approaches to risk and disaster management. The researcher adopted a descriptive research design, which was appropriate for the capturing the situation as it is.

With regard to the first objective the study sought to determine human risks arising as a result of flash floods at hells gate national park. The occurrence of flash floods has led to deaths in the park, the vulnerability has been caused by lack of early warning system. The tour guide relies on their experience of the understanding of weather patterns which are not accurate. The observation was true and in agreement with the respondents.

The second objective is to established mechanism, approaches used to adapt their daily activities to enhance safety of the tourist visiting the Hells gate national park. The park doesn't have the existing safety mechanist as it has been found in the research, management did not have the data or records of visitors to the park. Respondents also agreed that there is limited knowledge on the technological aspects in safety provision social factors and limited extent of embracing new technology skills in daily operation.

The third objective is to established the effective way of monitoring hazard and warning. There is great use of modern technology's service proved to be the most effective and reliable means respondents agreed that on the effectiveness of SMS service to provide notification.

8.2 Limitation and challenges of the study

The covid 19

The visit to the Hells gate national park to test and analyse the system was hindered by the current outbreak of the viral disease, lockdown that could not allow movement in and out of the Nairobi county.

Government bureaucracy

The procedure of government to follow set guides on acquisition of software has be left to the specific departments falling under department of information which they don't carry out research and development

Availability and compatibility of hardware

Arduino board specifically needed to carry out the development of the software was not compatible with various GPRS which blew out two times during the integration of the hardware

Poor cellular network coverage

Gorges are deep gullies which have limited connectivity, hence cannot allow the sending of SMS or calls hence the flash flood early warning system will not achieve full automation.

8.3 Risk and challenges involved in the research

As with the case of first objective of why there is no early warning system in the park to mitigate the flash floods, the respondents majorly rely on the institutional model on propositions of projects to be undertaken. Respondents focused on cost benefit analysis and the feasibility of the project. Once the system is installed it provide the notification and alert about the occurrence of flood. The mode of communication as in second objective is majorly cellular which is not effective especially in gorges due to poor signal and connectivity which calls for use of walkie talkie for effective passing of the information due their broadcast nature. The third objective has been attained by use of the flash flood early warning system which sends the short massage to the control station then its relayed to the tour guide via a walkie talkie.

8.4 Recommendation.

Application Wide range technologies.

Further research into this study can include engaging more technologies like LoRA to better help in coverage of connectivity of these data that they can be deployed even on areas without telco presence. Also, the utilization of gadgets like BRCK which connects internet to remote locations.

The BRCK is a rugged, self-powered, mobile Wi-Fi device that provides internet connectivity in areas of the world with poor infrastructure. With a data enabled SIM card, existing wifi or Ethernet cord or with the BRCK vMNO, the BRCK provides a shareable Wi-Fi signal for up to 20 devices

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Appendix A

```
#include <SoftwareSerial.h>
#include <avr/sleep.h>                  //this AVR library contains the methods that controls the sleep
modes
#include "millisDelay.h"
#define interruptPin 3                  //Pin we are going to use to wake up the Arduino

#define PIN_TX    0                     //Use Arduino UNO TX digital pin 0
#define PIN_RX    1                     //Use Arduino UNO TX digital pin 1
#define BAUDRATE  9600

int LowLevelSensor=6;
int MidLevelSensor=7; int
HighLevelSensor=8;

int lowLevel;                           //reads LowLevelSensor status int
midLevel;                               //reads LowLevelSensor status int
highLevel;                              //reads LowLevelSensor status

// Status flags for preventing system from sending multiple SMS for event
int sentLowLevelWarning = 0; int sentMidLevelAlert = 0; int
sentHighLevelAlert = 0;

millisDelay waitForAnyLevelSensors;            //Used for monitoring duration in (milliseconds) before
concluding there is no rain millisDelay monitoringFloods;

//Create software serial object to communicate with SIM800L
SoftwareSerial gprsSerial(0, 1);        //SIM800L Tx & Rx is connected to Arduino #0 & #1

void setup() {
  Serial.begin(9600);                   //Start Serial Comunication
  gprsSerial.begin(96000);              //Start Serial Communication with Arduino and GSM Module
Serial.println("Initializing...");   delay(1000);
```

```
  gprsSerial.println("AT");              //Once the handshake test is successful, it will back to OK
updateSerial();
  gprsSerial.println("AT+CSQ");           //Signal quality test, value range is 0-31 , 31 is the best
updateSerial();
  gprsSerial.println("AT+CCID");          //Read SIM information to confirm whether the SIM is plugged
updateSerial();
  gprsSerial.println("AT+CREG?");         //Check whether it has registered in the network
updateSerial();

  waitForAnyLevelSensors.start(30000);     //start a 30sec timer
  pinMode(LED_BUILTIN,OUTPUT);            //We use the led on pin 13 to indicate when Arduino is
asleep
  digitalWrite(LED_BUILTIN,HIGH);         //turning LED on
  pinMode(interruptPin,INPUT_PULLUP);      //Set pin d3 to input using the built-in pullup resistor
pinMode(LowLevelSensor, INPUT_PULLUP);    //Arduino Internal Resistor 10K for LevelSensors
pinMode(MidLevelSensor, INPUT_PULLUP);    pinMode(HighLevelSensor, INPUT_PULLUP);
}

void loop() {
  lowLevel = digitalRead(LowLevelSensor);

  if(waitForAnyLevelSensors.justFinished()) {
if(lowLevel == HIGH) {
    Serial.println("No floods detected, going into Power Saving mode!");
    goToSleep();                        //If duration elapsed and the Low Level Sensor is not actuated
   }
  }

  if (lowLevel == LOW) {                   //If the Low level sensor actuated, there's some flooding.
   monitorFloods();
  }
}

void updateSerial() {
delay(500);
```

```
  while(gprsSerial.available()) {
    Serial.write(gprsSerial.read());            //Forward what Software Serial received to Serial Port
  }
}

void monitorFloods() {
  // Low level sensor is already actuated!   if(sentLowLevelWarning == 0) {              //if flag is
set to 1 don't send data for this event again     sendFloodsData(1);                        //Send data
for Low Level Floods.
  }
  midLevel = digitalRead(MidLevelSensor);   if (midLevel == LOW) {
if(sentMidLevelAlert == 0) {      sendFloodsData(2);
//Send data for Low Level Floods.
    }

    highLevel = digitalRead(HighLevelSensor);     if (highLevel == LOW) {
if(sentHighLevelAlert == 0) {        sendFloodsData(3);
//Send data for Low Level Floods.
      }
    }
  }
}

void sendFloodsData(int level) {
if(level == 1) {
    Serial.println("Low Flood Hazard sensor data!");
sendSMSWarning(1);     logDataToServer(1, 1);
sentLowLevelWarning = 1;
  } else if(level == 2) {
    Serial.println("Moderate Flood Hazard sensor data!");
sendSMSWarning(2);     logDataToServer(2, 1);
sentMidLevelAlert = 1;
  } else {
```

```
   Serial.println("High Flood Hazard sensor data!");
sendSMSWarning(3);     logDataToServer(3, 1);
sentHighLevelAlert = 1;
  }
}

void sendSMSWarning(int level) {
  Serial.println("start sending SMS message ...");
  gprsSerial.println("AT+CMGF=1");                  // Configuring TEXT mode
updateSerial();

  if(level == 1) {                                 // lowLevelSensor
    Serial.print("Sending floods notification to 0771394127");
gprsSerial.println("AT+CMGS=\"0771394127\"");     updateSerial();
    gprsSerial.print("(Warning) Low Flood Hazard! Surface water is above altimetric level 5cm.");
updateSerial();
    gprsSerial.write(26);                           // The text message entered followed by a ‘Ctrl+z’ character is
treated as SMS.

  } else if(level == 2) {                          // midLevelSensor
    Serial.println("Sending moderately heavy floods warning to 0771394127");
gprsSerial.println("AT+CMGS=\"0771394127\"");     updateSerial();
    gprsSerial.print("Moderate Flood Hazard! Surface water is above altimetric level 10cm.");
updateSerial();     gprsSerial.write(26);
  } else {                                         // highLevelSensor
    Serial.println("Sending heavy flooding alert to 0771394127");
gprsSerial.println("AT+CMGS=\"0771394127\"");     updateSerial();
    gprsSerial.print("High Flood Hazard! Surface water is above altimetric level 20cm.");
updateSerial();     gprsSerial.write(26);
  }
}

void logDataToServer(int level, int sensorValue) {
```

```
 if(level == 1) {                              // lowLevelSensor
Serial.println("Logging floods notification data");     thingSpeakLog(level,
sensorValue);
 } else if(level == 2) {                          // midLevelSensor
   Serial.println("Logging moderately heavy floods warning data");
thingSpeakLog(level, sensorValue);
 } else {                                         // highLevelSensor
   Serial.println("Logging heavy flooding alert data");
thingSpeakLog(level, sensorValue);
 }
}

void thingSpeakLog(int level, int sensorValue) {
gprsSerial.println("AT+CGATT?");   delay(1000);
 gprsSerial.println("AT+CIPSHUT");
delay(1000);
 gprsSerial.println("AT+CIPSTATUS");
delay(2000);
 gprsSerial.println("AT+CIPMUX=0");
delay(2000);   updateSerial();
 gprsSerial.println("AT+CSTT=\"safaricom\", \"saf\", \"data\"");    //start task and setting the APN,
delay(1000);
 updateSerial();
 gprsSerial.println("AT+CIICR");                  //bring up wireless connection
delay(3000);   updateSerial();
 gprsSerial.println("AT+CIFSR");                  //get local IP adress
delay(2000);   updateSerial();
 gprsSerial.println("AT+CIPSPRT=0");
delay(3000);   updateSerial();
 gprsSerial.println("AT+CIPSTART=\"TCP\",\"api.thingspeak.com\",\"80\"");                    //start   up
       the connection   delay(6000);   updateSerial();
 gprsSerial.println("AT+CIPSEND");                 //begin send data to remote server
delay(4000);   updateSerial();
 String      str="GET      https://api.thingspeak.com/update?api_key=YVVP3R458L5U41ID&field"      +
```

```
String(level) + "=" + String(sensorValue);
Serial.println(str);
  gprsSerial.println(str);                        //begin send data to remote server
delay(4000);   updateSerial();
  gprsSerial.println((char)26);                   //sending
  delay(5000);                                    //waitting for reply, important! the time is base on the condition
of internet    gprsSerial.println();   updateSerial();
  gprsSerial.println("AT+CIPSHUT");               //close the connection
delay(100);   updateSerial();
};

void goToSleep() {
  Serial.println("Enabling power saving mode");
  sleep_enable();                                          //Enabling sleep mode
  attachInterrupt(digitalPinToInterrupt(interruptPin), wakeUp, FALLING);
  set_sleep_mode(SLEEP_MODE_PWR_DOWN);                              //Setting the sleep mode, in our
case full sleep
  digitalWrite(LED_BUILTIN,LOW);                                //turning LED off
  delay(1000);                                          //wait a second to allow the led to be turned off
before going to sleep
  sleep_cpu();                                          //activating sleep mode
  Serial.println("System Resume!");                           //next line of code executed after the interrupt
digitalWrite(LED_BUILTIN,HIGH);                                                        //turning  LED  on
waitForAnyLevelSensors.restart();                           //Set monitoring Flood level sensors timespan.
  sentLowLevelWarning = 0;
sentMidLevelAlert = 0;   sentHighLevelAlert
= 0;
}

void wakeUp() {
  Serial.println("The controller resumed from power saving mode");       //Print message to serial
monitor
  sleep_disable();                                         //Disable sleep mode
  detachInterrupt(digitalPinToInterrupt(interruptPin));                //Removes the interrupt from pin 3;
}
```