DESIGN OF AN EARLY WARNING FLOOD LEVEL INDICATOR

(RESEARCH PAPER)

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AN OFFICIAL ENTRY TO THE REGIONAL SCIENCE FAIR 2012

TEAM CATEGORY (APPLIED SCIENCE)
CLUSTER 1

OCTOBER 2013

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ALFARO, DENNISE B., GENETTE S. SOLIS AND KENNETH ROWEL REYES. Design of an Early Warning Flood Level Indicator. Research Paper for the Regional Science and Technology Fair (Cluster 1, Applied Science). October 2013. Cavite National High School, Cavite City, Region IVA- CALABARZON.

ABSTRACT

Development of an early warning device that can detect increase in flood water level is the primary aim of the study. The device was developed using inexpensive and simple in structure materials. In order to provide early detection of water level rise, three different alarm systems were incorporated in the improvised equipment that detects 4-in, 8-in and 12-in increase in water level. Pilot testing of the device was done at flood prone areas of Cavite National High School. Test results from the prototype system showed that the flood alarm device achieved the design requirements. Also, the siren sound of the device can be heard up to 35 m away from the flood alarm. Using the increase in flood level measured, inside and outside the school, a flood warning system was developed as a guide for students, teachers and employees during flood events in the school vicinity.

Improvised flood alarm device is comparable to commercially available devices in terms of providing real-time flood level alerts and sensitivity to water. This early warning flood indicator is one way of saving properties and keeping individuals safe during flood disasters. The simplicity and practicality of the equipment designed was considered for future replication and modification by household, school and barangay community frequently affected by coastal floods.

INTRODUCTION

Background of the Study

Flood events are a part of nature which is caused by natural and human activities such as heavy rainfall, coastal flooding, deforestation, poor farming, poor water management, and population pressure. These causes the disasters which later on may harm, if not, kill people especially if they are unaware of it beforehand. Bongolan *et al.* (2010) stated that 80% of Metro Manila was covered in waters during rainy seasons that in some parts were nearly two meters deep, considering that it is compared to a normal August worth of rain which dumps on the city in 48 hours.

Cavite City is recurrently affected by flood because of heavy rainfall during August and September with minimal rains on June, July and October. Due to widespread flooding, Cavite was placed under a state of calamity last August 2013 with reports of death and missing people (Mangosing and Sabillo, 2013). Schools, especially Cavite National High School is more frequently dumped with flood water because it is located in a low land area and because of this, classes are always interrupted if not, suspended.

Flood forecasting and warning is a prerequisite for successful mitigation of flood damage. Also, preventive measures should be taken to reduce possible adverse effects of floods on aquatic and terrestrial ecosystems, such as water and soil pollution. Its effectiveness depends on the level of preparedness and correct response. The responsible authorities should provide timely and reliable flood warning, flood forecasting and information (The Association of State Floodplain Managers, 2003).

Flood alarms are often used by people in detecting the level of water during rainy seasons. Most of the flood alarms available in the market commend high price and complex usage. To address such problem with the lack of early warning device for floods in the community, this study is conducted to create a scrap-made flood alarm that is cheaper and effective compared to the commercially introduced ones. The main consideration is the simplicity of the device wherein anyone can simply use and manipulate it.

Statement of the Problem

After conducting this study, it is expected that an early warning device that can detect increase in flood water level rise will be developed. Furthermore, this study aims:

1. to create a flood alarm device from scrap materials;
2. to test the functionality of the device;
3. to determine how far the buzzing sound of the alarm reach;
4. to develop a flood warning system that can be used by the school in the future; and
5. to compare the created flood alarm from existing commercial flood alarms.

Significance of the Study

The use of flood alarm during rainy seasons is of great help in determining the level of flood water and informing people of various levels of water in different land areas. The created flood alarm can be used by the different members of the society:

Household. Families can build their own flood alarm for them to determine if flood water is high enough to enter their houses.

Flood-prone areas. Areas that is usually damaged by flood can produce their own alarm in order to develop their awareness especially if they already need to evacuate and secure their protection.

School. Schools can build their own flood alarms in order for the students, teachers and others to know if the flood water in their school is high for them to have a suspension of classes.

*Hydrologists***.** This study will be used as additional information about the development of scrap-made flood alarm to be widely used in our country.

Scope and Limitations

The study focuses on the creation of an alarm system for detecting increase in flood water level. The sound produced by the device in the study is only limited to its maximum range when tested.

The effectiveness of the device was assessed through placing it on flood prone area in Cavite National High School. The device has three alarm systems that alarms when the set level of water is reached such as 4-in, 8-in and 12-in. The study was conducted from July until September 2013 at Cavite National High School, Cavite City.

Review of Literature

In most places, rainfall is likely to occur irregularly and in widely different amounts from one time to another. As a result, the streams which carry the surface runoff fluctuate greatly in the amount of water they carry. Thus, floods can be expected to occur at intervals as a normal part of the cycle (Ramsey and Burckley, 1966).

McDaniel (2012) stated that floods are the second-most widespread natural disaster on Earth. It happens when water overflows or soaks land that is normally dry. There are few places on Earth where people don’t need to be concerned about flooding. Generally, floods take hours or even days to develop, giving residents time to prepare or evacuate. Sometimes, floods develop quickly and with little warning.

Flooding may result from the volume of water within a body of water, such as a river or lake, which overflows or breaks levees, with the result that some of the water escapes its usual boundaries, or may be due to accumulation of rainwater on saturated ground in an area flood. It can also arise from abnormal heavy precipitation, dam failures, rapid snow melts, river blockages (Mwape, 2009).

Impacts of Flood Events. Floods are among the most dramatic forms of interaction between man and its environment. They are always associated with heavy loses of life and property, misery hardship disease and at times, famine. There are two main causes of flood which are natural and man-made.

Some examples of natural causes are heavy rainfall and overflowing of river banks which usually results to perennial flooding. Also, heavy rainfall accompanied by flooding cannot only cause tremendous damage to buildings and homes, but also kill woody and herbaceous plants (Devalsam, 2011).

Lu (2012) opined that significant amount of topsoil were removed from a large area of farm land. Whereas some parts of the landscape have lost significant amounts of topsoil both due to sheet erosion as rain falls on wet soils and heavy flooding. However, the removal of topsoil is always a loss to agricultural productivity for topsoil is that part of the soil horizon having higher level of organic matter and nutrients which generally has better structure. Some effects of flood caused by natural causes depend on rainfall duration, heights of water level, topography, and use of flood plains.

The most significant impact of flooding arises from man-made causes like urbanization because it involves deforestation, land use changes, temperature modification of soil's physical properties and structures and the exposure of bare soil surfaces especially of construction sites all of which bring about changes in the morphological and hydrological state of water (Khalekuzzaman, 2004).

Usage of Flood Alarm Systems. Among all natural disasters in the world, flooding constitutes the most costly and prevalent. Simonovic (2012) opined that there are a lot of strategies and methods nowadays used in addressing flood hazards and disasters. Flood Alarm Systems or Flood Warning Systems (FWS) have been introduced in many countries to minimize life and chattel losses by warning people in flood prone areas to evacuate and protect their property, albeit some damage still occurs (Goodwin, 2012).

Molino (2002) stated that sirens are designed to provide a very rapid alert to potentially threatened populations. They are currently the only reliable means of alerting outdoor populations. Some sirens are used in making an effective FWS.

Furthermore, a local flood warning system helps in increasing lead time for watches and warnings at locations subject to flood risk. The information can be used to predict whether a flood is about to occur, when it will arrive, and how severe it will be.

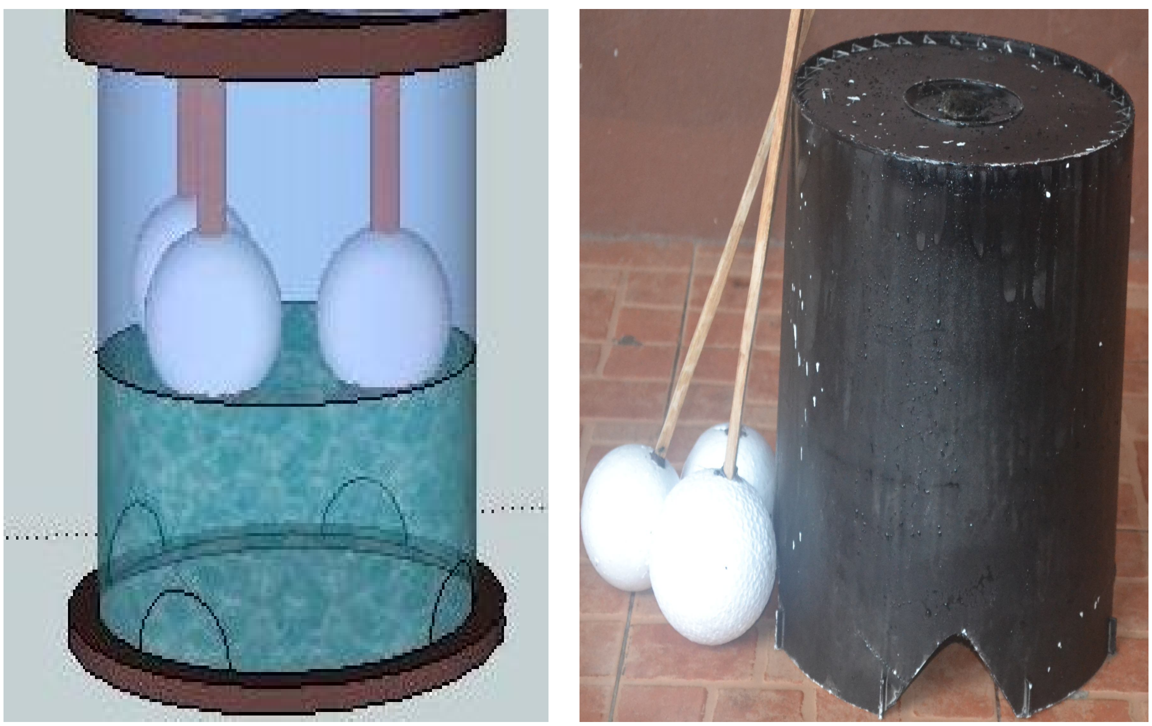
Organizations and individuals are given notice by the system so they can protect themselves and their property.

Floods impact on both individuals and communities and have social, economic, and environmental punishment. The consequences of floods, both negative and positive, vary greatly depending on the location and scope of flooding, and the susceptibility and value of the natural and constructed environments they affect. Floods can also traumatize victims and their families for long periods of time. The loss of loved ones has deep impacts, especially on children. Displacement from one's home, loss of property and disruption to business and social affairs can cause continuing stress. For some people the psychological impacts can be long lasting.

METHODOLOGY

The procedures in creating and testing of the flood alarm device are as follows:

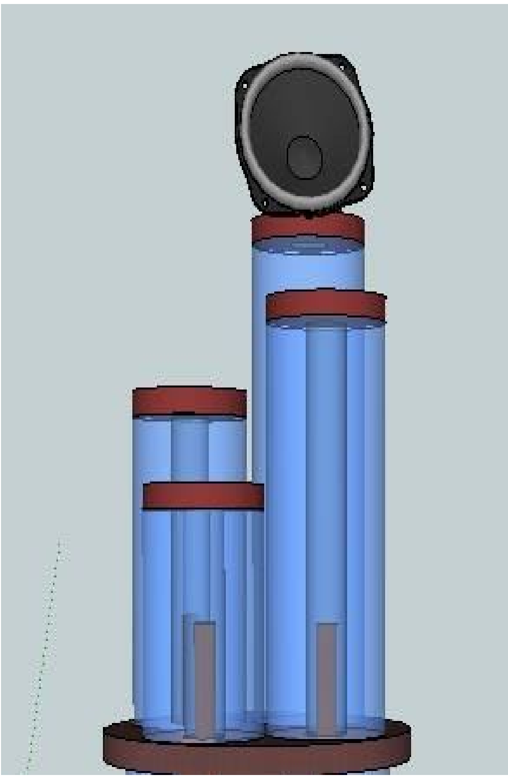
Creation of the Base Part. A base for the device was created using a used pail covered with cement for additional weight. Three holes similar to the form of a five peso coin was drilled on the base of the created cemented pail. A glue stick was used to attach a 12-inch high wood vertically at the styro ball. Three styro ball sensors was created and installed inside the base part of the device. It will serve as the improvised sensor for the increase in flood water. Figure 1 shows the diagrammatical sketch of the device.



(a) (b)

Figure 1. Base part of the flood alarm device. (a) diagrammatical sketch of the base with the styro ball installed inside (b) actual base part of the flood alarm device.

*Creation of the Siren System***.** Three siren systems was created and attached on the created base part of the device. The siren system will respond to the three different flood water rise—4-inch, 8-inch and 12-inch. In creating the siren system, a 12-inch high PVC pipe with 0.75 in diameter was housed inside a 3-in (diameter) PVC pipe which is 12 inches in height by cementing it. This will assure the wood's passageway towards hitting the button of the siren. The siren is connected to the pipe by means of its wires with its button attached inside the hole made on the center top cover of the PVC pipe. The same procedure was performed in creating the other two sirens with varying height of pipes such as four and eight inches. The three siren systems were connected to a speaker which is operated by eight 1.5-volts double A batteries attached on top of the PVC pipe.



(a)

(b)

Figure 2. Siren system of the flood alarm device. (a) diagrammatical sketch of the base with the styro ball installed inside (b) actual base part of the flood alarm device.

Initial Testing of the Device. The created flood alarm parts was assembled by attaching the siren system on top of the cemented base part. Initial testing for the functionality of the device was carried out under controlled condition. The assembled device was placed inside a larger water container. Using running water from the faucet, effectivity of the device in alarming at three different identified water levels was determined.

Testing of the Device on Actual Flood. Once the three alarms are functioning at the three different water levels during the initial testing, the device is now ready for testing in the field. Actual testing of the device was done at Cavite National High School. The device was installed outside the school vicinity reported to have the highest flood water rise for the past few weeks. Aside from the identified location for the device installation, three flood prone areas inside the school was determined.

Once the flood alarm device buzzed the first warning, 4-in water rise outside the school, the increase in water level on the identified flood prone areas inside the school was measured using a 12-in ruler. The same procedure was performed once the alarm buzzed the second alarm (8-in water rise outside the school) and the third alarm (12-in water rise outside the school). This testing was carried out three times at different dates. The obtained measurements for the increase in flood water inside the school was used as a reference in creating the flood warning system or guide for students, teachers and school employees.

Testing the Buzzing Sound. The buzzing sound of the device was assessed using the following scale:

Verbal description		Score
Not Heard (NH)	=	1
Slightly Heard (SH)	=	2
Faintly Heard (FH)	=	3
Loudly Heard (LH)	=	4

Three individuals assessed the buzzing sound of the device at three different distances of the device from the respondents such as 15 m, 25 m, 35 m and 45 m.

Development of a Flood Warning Guide. A guide on the usage of the flood warning system was developed for the use of the students, teachers and employees of the school. The guide will introduce the users to the background of the flood alarm device such as its purpose and usage. Using the data obtained from the actual testing, a flood warning system guide was created including the following:

1. Flood condition outside the school
2. Flood condition inside the school
3. Appropriate student, teacher and employee response

Comparison of the Created Device to Commercially Available Flood Alarm. Using the specifications of commercial flood detecting device published online, the created device was compared. Three main factors were considered such as real-time water level alerts, power source and cost.

*Data Analysis***.** Qualitative data obtained during the testing of the buzzing sound was transformed and converted into a quantitative distribution. Mean was used for all the obtained data in the three trials performed. Figure 3 summarizes the steps involved in conducting the study.

(a) Test for the Buzzing Sound
(b) Development of a Flood Warning Guide
(c) Comparison of the Created Device to Commercially Available Flood Alarm
(d) Data Analysis

Figure 3. Summary of the procedures involved in the creation and testing of the flood alarm device.

RESULTS AND DISCUSSION

Specification, Installation and Operation of the Flood Warning Device

The completed flood alarm device is composed of two parts—body and siren system. The body is made of cemented pail with holes at the bottom for the entry of water. Inside the body are three improvised sensors made of styro balls with wooden sticks directly passing through the siren system. After several modifications done to the body base of the device, it was observed that the greater the number of holes, the faster the detection of flood water rise. From a single passageway of water, it was increased into four. Table 1 summarizes the specification, installation and operation of the created equipment. Figure 4 shows the complete form of the flood alarm device.

Table 1. Specification, installation and operation of the flood warning device.

Specifications	Body- cemented pail (16 in diameter and 12.5 in height)
	Improvised sensor- styro ball (11 in circumference) with 12-in wooden stick
	Siren System- (a) three alarm systems housed in three PVC pipes (3-in diameter) of varying heights such as 4 in, 8 in and 12 in; (b) speaker; and (c) power source with eight 1.5-volts double A batteries
Installation	The body and the siren system are installed outdoors. The speaker of the alarm may be installed indoors.
Operation	During heavy rain, once the styro sensor increased by 4 inches in height from the ground, indicative of 4-in water level rise, first buzzing sound will alarm due to the wood stick attached to the ball touching the button of the siren system. The same process happens as the other styro sensors increases by 8-in and 12-in, respectively, due to water level rise.

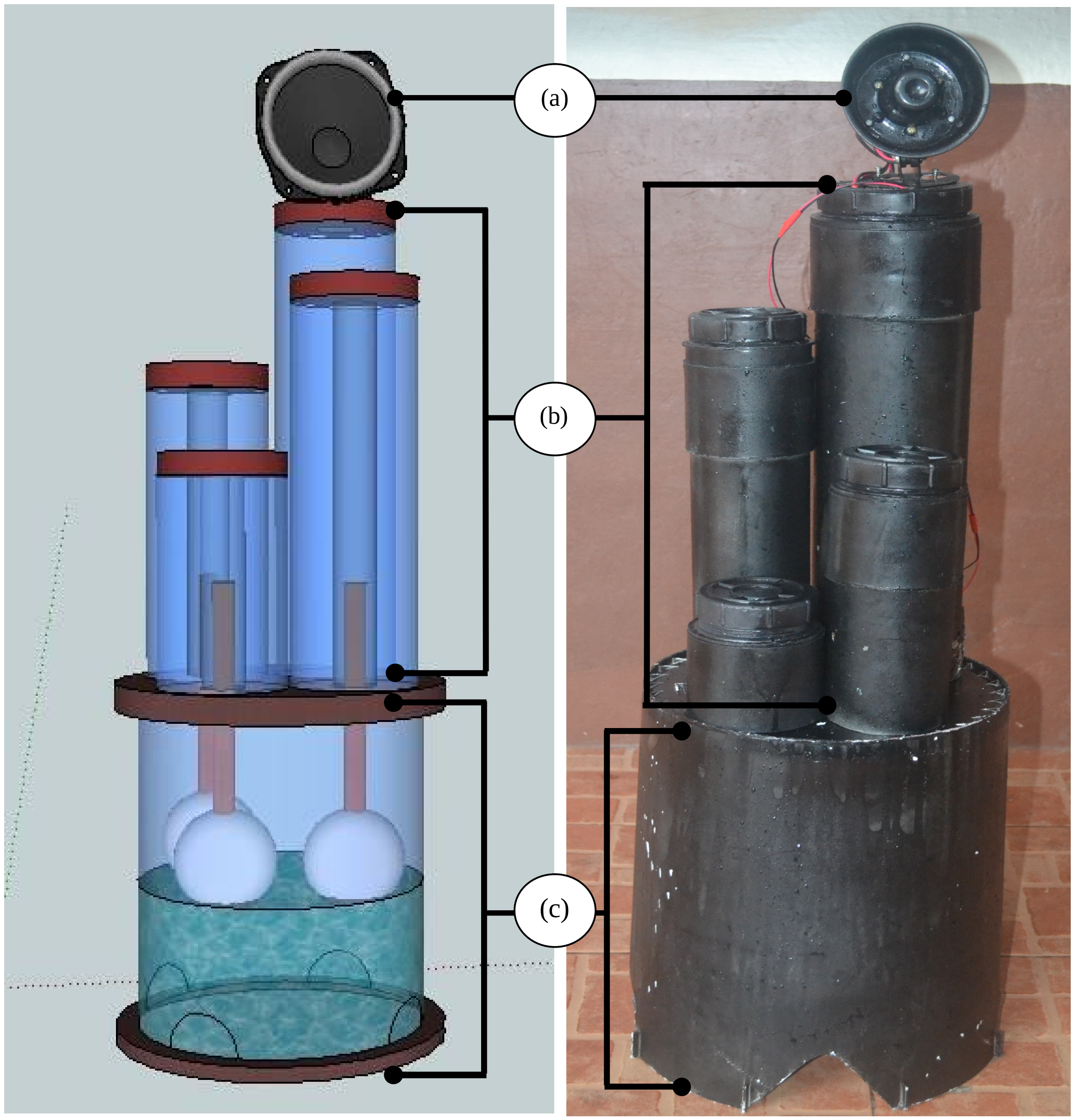


Figure 4. Completed flood alarm device compared to the blueprint. (a) Speaker (b) Three siren systems for three different flood water levels (4 in, 8 in and 12 in). A button is attached on top of each pillar that will trigger the alarming sound. (c) Base part with four entry holes for water and inside are styro balls that serve as the improvised water level sensor.

Functionality of the Flood Warning Device

The pilot testing of the device inside a large water container and running water from the faucet showed that the created flood alarm device gives signal in varying rise in water level. The three warning systems installed functioned properly.

On September 7, 2013, the device was installed near the school gate at Chief E. Martin Street, Caridad, Cavite City wherein the highest flood water rise was observed for the past few weeks. Three other flood prone areas inside the school were also determined such as: (1) quadrangle in front of Gabaldon Building; (2) side of the Science Building; and (3) entrance of the Two-Storey Building. Figure 5 is the map of the school including the location where the device was installed and the flood prone areas monitored.

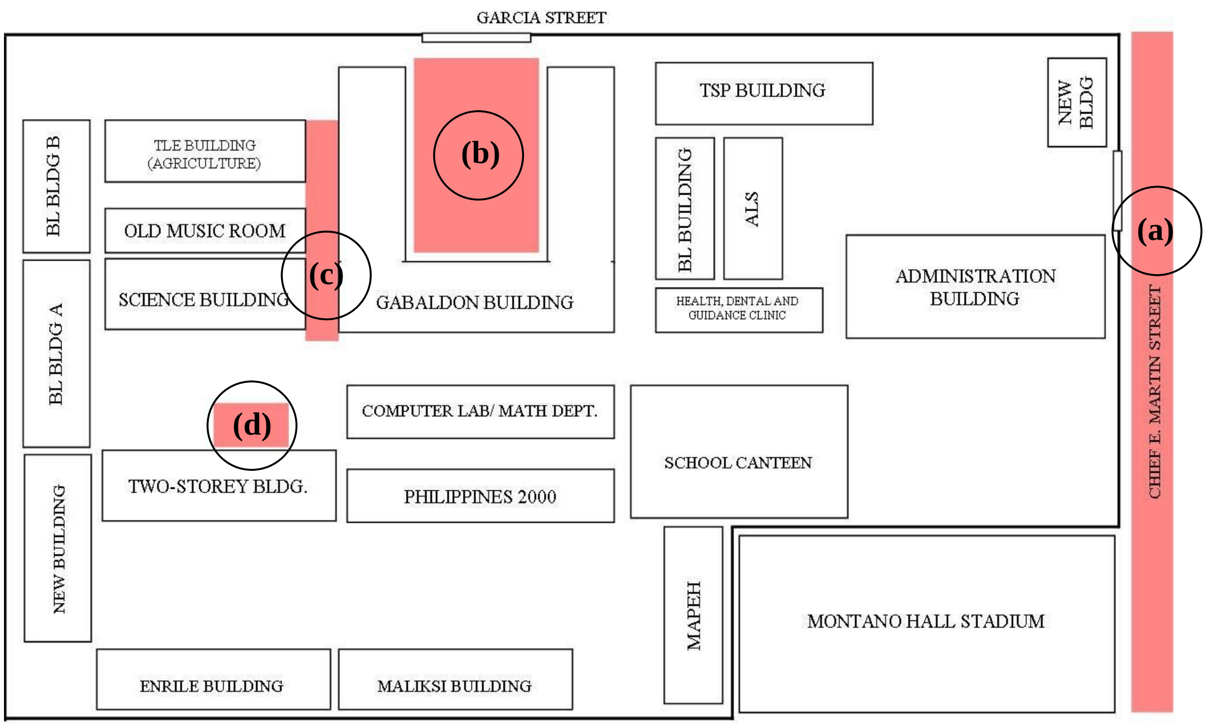


Figure 5. Map of Cavite National High School. Areas in red are the identified flood-prone areas. (a) Location of the flood warning device (b) Quadrangle in front of Gabaldon Building (c) Side of Science Building (d) Front of Two-storey Building.

Once the flood alarm device signaled the 4-inch water level rise outside the school, the increase in height of the flood water in the three flood-prone areas inside the school were measured. The same procedure was done when the alarm signaled the 8-inch and 12-inch water level rise. The testing of the device was repeated on September 12 and September 15. Results are summarized in Table 2.

Table 2. Flood water levels inside and outside the school.

Flood Alarm Signal	**Flood water level outside the school (in)**	**Flood water level inside the school (in)**											
		Gabaldon Building				Side of Science Building				Two-Storey Building			
		1	2	3	*Ave*	1	2	3	*Ave*	1	2	3	*Ave*
1	4.00	2.50	2.60	2.80	*2.63*	1.00	1.20	1.25	*1.15*	1.20	1.20	1.50	*1.30*
2	8.00	3.70	4.40	4.40	*4.17*	1.50	2.70	2.90	*2.37*	1.50	2.50	3.40	*2.47*
3	12.00	4.80	5.90	7.80	*6.17*	3.30	5.20	6.60	*5.03*	4.35	4.25	4.90	*4.50*

Note: Trial 1- September 7, 2013; Trial 2- September 12, 2013; and Trial 3- September 15, 2013

From the testing done, the device responded based from its specifications. The amount of rainfall, during the above date of testing, is enough to increase the water level in the testing site up to 12 inches. The increase in water level outside the school has a corresponding increase in water level on the flood-prone areas identified inside the school. The highest recorded increase in water level inside the school was at the Quadrangle in front of the Gabaldon Building last September 15, 2013 (7.80 inches high). In the average, increase in water level on the side of Science Building (5.03 inches high) and entrance of the Two-Storey Building (4.50 inches high) is lower compared to that in the Gabaldon Building (6.17 inches high). This recorded increase in the water level inside the school is highly dependent on the amount of rainfall during the testing date.

Buzzing Sound of the Flood Warning Device

Three individuals went on various experimental ranges to test the buzzing sound of the alarm. The buzzing sound results of the device were as follows: (SH= Slightly Heard, FH= Faintly Heard, LH= Loudly Heard and NH= Not Heard). The verbal description was given the following scores:

Verbal description		Score
Not Heard (NH)	=	1
Slightly Heard (SH)	=	2
Faintly Heard (FH)	=	3
Loudly Heard (LH)	=	4

After getting the average of the three ratings for every experimental range, the score was then translated using the following scale:

Scale		Interpretation
3.25-4.00	=	Loudly Heard
2.50-3.24	=	Faintly Heard
1.75-2.49	=	Slightly Heard
1.00-2.49	=	Not Heard

The obtained scores were tallied and shown in Table 3.

Table 3. Buzzing sound scale of the flood alarm system.

Distance of the respondent from the flood warning device (m)	**Buzzing sound rating of the respondents**				**Description**
	1	2	3	*Average*	
15	4	4	4	*4.00*	Loudly Heard
25	4	3	4	*3.67*	Loudly Heard
35	3	3	1	*2.33*	Slightly Heard
45	1	1	1	*1.00*	Not Heard

On a distance of 15 m away from the alarm system, the average result is 4 which mean that it is loudly heard. 25 m away has an average result of 3.67 which can also be classified as loudly heard. 35 m away has an average result of 2.33 which is slightly heard and 45 m away which has an average result of 1 which is not heard.

The buzzing sound of an alarm can be loudly heard if one is near the testing area. In opposite, the chance of hearing its sound lessens because the distance is far from the testing area (Association of State Floodplain Managers, 2003).

Development of a Flood Warning Guide

Using the data obtained from the testing done, a flood warning guide was developed. Figure 6 shows the proposed warning system that will serve as a guide for students, teachers and employees during heavy rains.

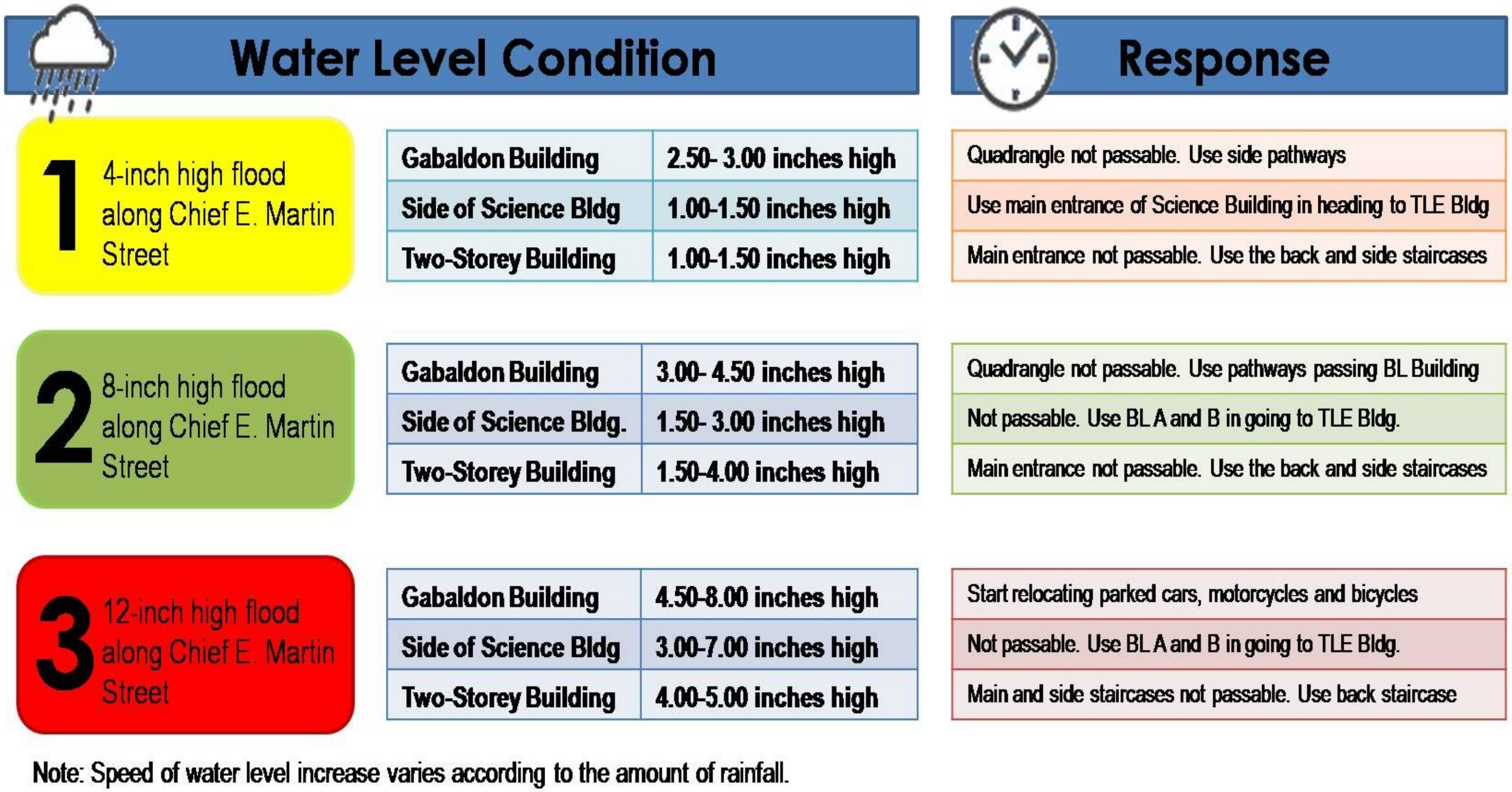


Figure 6. Proposed flood warning systems for the students, teachers and employees during flood events. It includes description of the condition outside the school, inside the school and possible response for the flood scenario.

The warning system is composed of two parts. The first part describes the water level condition outside and inside the school while the second part provides possible actions for the individuals inside the school.

The flood warning system suggests that as soon as the flood alarm device buzzed on the first level, Chief E. Martin Street is already covered with water which is 4-in high. Students are suggested not to pass by the gate on that street and use instead the Main Gate along Garcia Street. However, students heading to their MAPEH classes at Montano Hall Stadium should pass by Chief E. Martin. Students should be cautious on passing by the flood area. On the other hand, condition of the water level inside the school is described for every level of flood alarm signal. Suggested routes that the students, teachers and employees may pass by are detailed. It must also taken into consideration that the guide created is not providing information on amount of rainfall during the day. Thus, the speed of increase in water level may vary according to how heavy or intense the rain is.

Comparison of the Created Device to Commercially Available Flood Alarm

The created device was compared to commercial flood alarms available online. Table 4 summarizes the key features of the created device and commercially available device online.

Table 4. Features of the created flood alarm device in comparison to commercial flood alarm.

Parameters	Commercial Flood Alarm	Improvised Flood Alarm
Provides real-time water level alerts	*yes*	*yes*
Sensitivity to water	*very sensitive (once the water touches the alarm)*	*sensitive (once the wood touches the button)*
Buzzing sound	*beep*	*siren*
Controllable water level rise	*yes*	*yes*
Number of water level that can be detected	*one*	*three*
Power Source	*3v battery*	*8 double a (1.5 volts) batteries*
Cost	*923 PhP – 7,000 PhP (depending on the quality/ size of the device)*	*250 PhP*

Source: ABUS Security Check Germany (http://www. philippines.rs-online.com/)

Both of the flood alarm devices compared provides real-time water level alerts. Commercial flood warning device operates through an electronic sensor installed inside which is very sensitive to water even in little amount. On the other hand, the improvised flood warning device operates through a manually operated sensor using a styro ball responding to the increase in water level. It is essential for a flood warning device to have an effective way of informing the user of the water level in the testing sites. The improvised flood warning device has this feature and the sound varies for every increase in height of water in the testing site. Desired water level that the device can be detected can be predetermined in the commercial device by adjusting its settings. On the other hand, the height that the improvised device can detect may be set by adjusting the length of the PVC pipes and the wooden stick attached to the styro ball.

In terms of power source, commercial and improvised devices are both battery-operated. It is a suggestion to include a solar panel to the flood warning device so that it will be having a use during non-rainy days as energy storage. One disadvantage of this device is its size. It is necessary that a strategic location should be identified for the installation of it. Also, this device is only suggested to be used in areas wherein coastal floods are the major cause of the increase in water level. This device is not yet tested in areas wherein flashfloods happen wherein there is a stronger current and different water type.

The major lead of the improvised device against the commercially available is its cost. The cost of the device was spent on the siren however there are still options of using the switches in electric fans as a connector for the three siren systems of the device. The cost of creating this improvised flood warning device is less than half of the cost of the commercial waning system.

As a summary, the improvised flood alarm device has the necessary features of an effective early flood warning device which is of low cost and can easily be created by common household.

CONCLUSIONS

An early warning device that can detect increase in flood water level was created using scrap materials. The flood warning device is designed to be an intelligent equipment which is capable of providing real-time water level alerts such as 4-inch, 8-inch and 12-inch increase in water height through a siren system. Functionality of the device was tested at flood-prone areas in Cavite National High School, Cavite City. From the testing done, the device responded based from its specifications. The amount of rainfall, during the date of testing, is enough to increase the water level in the testing site up to 12 inches. The increase in water level outside the school has a corresponding increase in water level on the flood-prone areas identified inside the school. The highest recorded increase in water level inside the school was at the Quadrangle in front of the Gabaldon Building which is 7.80 inches high. In the average, increase in water level on the side of Science Building (5.03 inches high) and entrance of the Two-Storey Building (4.50 inches high) is lower compared to that in the Gabaldon Building (6.17 inches high). This recorded increase in the water level inside the school is highly dependent on the amount of rainfall during the testing date.

Since the device works through a siren system, strength of the buzzing sound produced by the device was assessed. Based from the ratings done by three respondents, the buzzing sound can be heard up to 35 m away from the device. It is suggested that using a larger speaker unit for the siren system can increase the range of the buzzing sound.

Using the measurements obtained from the three trials of testing of the device under actual flood condition, a flood warning system was designed. This flood warning system will serve as a guide for the students, teachers and employees in cases that the flood alarm device will signal first, second and third warning. The flood warning guide includes description of the water level outside and inside of the school and suggested response that the individuals may perform during the flood warning events.

The developed device was compared to commercially available flood alarm. The improvised flood alarm device has the necessary features of an effective early flood warning device such as real-time water level alerts, sensitivity to water level increase and adjustable water level alert. The major lead of this device is its low cost.

One can improve the device by incorporating a wireless sensor network which uses GPRS or SMS whenever flood water is rising. The locale can improve the device by making it higher and larger so that whenever a huge flood occurs in the whole barangay is conversant that the flood water level is rising.

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ACKNOWLEDGMENTS

We, the researchers, would like to articulate our deepest appreciation to all individuals who helped us for the conduct of this study and the completion of this paper.

First and foremost, to the Creator who guided us throughout the completion of this study. Second, to our parents who supported us financially and understood our tight and hectic schedule in order to finish this study. Third, to our Research educator Mr. Joald G. Calpo who has the outlook and the substance of a genius. He continually and convincingly conveyed a spirit of adventure with regards to research and an enthusiasm with regards to teaching. Without his supervision and persistent help, this study would not be a success. Fourth, to all science teachers who gave and provided us ideas towards the progress and development of our study. Lastly, our classmates and friends who offered a helping hand during our most stressful times.