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Development of Early Flood Detection & Warning System

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Abstract: Flooding is a major hazard in Malaysia due to the country's proximity to the equator, which often leads to property damage and loss of life. In order to mitigate these effects, early detection and warning systems are necessary to alert the local community about evacuation plans and property protection. This project focuses on developing a prototype of such a system that uses Internet of Things technology, ultrasonic sensors, and water level sensors controlled by an Arduino microcontroller to detect flood water depths at different locations in real-time and send warning messages to users via instant mobile short message services. The prototype system also has a web-based graphic interface that allows users to access real-time information about local water levels. The system records data with a resolution of one second but displays it every minute, and takes into account local river water level thresholds from the Ministry of Energy and Natural Resources to accurately reflect the specific location. The system's performance was tested at three locations with various water level heights and was found to be effective. It is hoped that this prototype system can serve as a preventive measure against flood disasters in flood-prone areas and can be expanded into larger-scale systems that provide real-time flooding information and warnings to the local community.

Keywords: Flood, Natural Resources, Arduino Uno, Web-Based Graphic Interface

1. Introduction

As a result of global climate change, extreme weather events are expected to become more frequent and severe on a regional and local scale. In Asia, extreme rainfall is causing catastrophic flooding and significant damage to human societies, and disaster management is crucial for the region. The development of the Prototype Early Flood Detection & Warning System is flood readiness, as well as to elicit responses from multi-level emergency management agencies. This as well can reduce the disaster's risk and impacts. A weather warning is issued based on extreme weather forecasts, and a flood early warning is sent based on the projected discharge and water level, which is assessed using a hydrological model that uses numerical weather predictions and geographical circumstances as input data.[1] This EFDWS system senses the water level using the water flow sensor and water level sensor that is being used to detect the level of substances that can flow and sense the raise in the water level

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and give people early alert regarding this natural disaster. This system aims to provide helps to people by sending an early warning regarding the early flood that has been detected by the system. Because this tragedy poses a risk to human life, an effective countermeasure or alert system should be established to tell people as soon as possible so that security steps can be taken to avoid any disaster.[2] While it is difficult to completely eliminate flood risks or prevent them from occurring, it is possible to mitigate their effects and the resulting losses.[3] As soon as information on a flood occurrence is obtained and detected, the system will subsequently alert and warn humans accordingly through SMS so people could take necessary action/ evacuate themselves.

1.1 Literature Review

This section presents an in-depth examination and evaluation of the flood detection and warning system. The outline of the flood detection system presented in the previous works is discussed accordingly, along with some comparative analysis concerning the features of each work.

1.1.1 Flood Detector Sensor System

This section includes a summary and analysis of existing research on flood early warning systems and IoT technology. It begins by describing the flood detection system. Then followed by an overview of IoT technology specifically on processing and transmission network. This section generally examines specific examples of flood early warning systems that use IoT technology and analyze their effectiveness. Finally, the review discusses any limitations or gaps in the current work and suggests areas for future study.

The disadvantages and advantages of the alternatives observed throughout the subchapters are summed up in table 1 below.

Table 1: Summary of Flood Detector Sensor System

Project	Advantage	Disadvantage
Technology, E. (2021)[4]	The HC-SR04 is an ultrasonic sensor that can measure distances in a variety of environments without requiring human intervention.	The ultrasonic sensor hc-sr04 may be incompatible with certain materials that degrade the quality of the sensor's received echo.
Nevon Projects. (2020)[5]	The system has a DHT11 Digital Temperature Humidity Sensor. It is an advanced sensor module that consists of resistive humidity and temperature detection components.	The covering in which the sensor is enclosed. As it is made of plastic, so it is prone to melt due to intense heat.
Zain, Z. M., & Khalid, M. N. M. (2007)[6]	The microcontroller unit (MCV) is in one of its special modes of operation, It can do anything a normal user program can do.	ASM11 is needed because the microcontroller only can read the machine code. Program memory is not accessible and only one single accumulator is present.
Shankar, B. M., John, T. J., Karthick, S., Pattanaik, B., Pattnaik, M., & Karthikeyan, S. (2021)[7]	Embedded wireless technology that is web friendly with no use of shields or any peripherals, as is required for Arduino.	WiFi code takes a lot of CPU power.

Daud, E., Mohd, & Bakar, I. (2021)[8]	Voltage sensor can be used for the voltage calculation and monitoring of an object	The voltage sensor doesn't waterproof which caused the system equipment to be damaged and not functioning well when facing water

1.1.2 IoT Technology (Processing and Transmission Sensor Network)

Based on table 2 below, the sensor component of Wireless Sensor Networking (WSN) observes the environment. To guarantee that the output is accurate, a system's sensor selection is critical. For flood monitoring and alerting, various factors need to be observed. Data must be delivered from a node installed at a remote site to the end user, which necessitates processing and transmission. WSN is the communication technology utilized in the flood monitoring and alert system. WSN is commonly utilized in flood-prone areas due to its low cost and ability to transmit data quickly and accurately. Wireless sensor networks are becoming increasingly prevalent in human life and throughout the planet. All human activity can be observed within a set timeframe with this technology. Wireless communication standard types include 3G, Bluetooth, GSM, ZigBee, and Wi-Fi.

Table 2 : Summary of Processing and Transmission

Authors	Advantages	Disadvantages
Asmara, W. A. H. W. M., & Aziz, N. H. A. (2011). [9]	Alarm system that would detect the escalation level of water in the drainage or riverbanks and send an SMS alarm to the user's mobile phone.	Electronic interference. Because GSM uses a pulse-transmission technology, it is known to interfere with electronics
Vinothini, K., & Jayanthy, S. (2019)[10]	The detected sensor values are processed using PIC Microcontroller and it is transmitted to IOT through Wi-Fi module.	It will not forecast the values or use previous data for classification using any machine learning algorithm.
Aziz, I. A., Hamizan, I. A., Haron, N. S., & Mehat, M. (2008). [11]	The advantages of utilizing a wireless sensor network for early warning include its ability to provide a redundant and resilient system that can give a precise assessment of a specific situation. Additionally, a Sensor Network offers dependable and robust information about the physical infrastructure or status of any element due to its wireless and computational capabilities. It can be easily deployed in the physical location where it is required.	Wireless sensor networks are designed for low-speed applications, they cannot be used for high-speed communication.
Yuliandoko, H., & Rohman, A. (2019).[12]	Using mesh networks and ZigBee takes advantage of being implemented in the remote area. Sensors would detect the indication of flooding and send the data through ZigBee. ZigBee is a unique	The distance between XBee need to be considered because It influence to the percentage of data success received.

	wireless device where this device is used in sending small data with low power consumption and low cost. With low power consumption, ZigBee works with just using a battery so that it is more flexible to use.	
Baharum, M. S., Awang, R. A., & Baba, N. H. (2011)[13]	MyFMS are easy to assemble and disassemble, real-time update features for users or local authorities, and also easy to update SMS database. In terms of computer security, this system is low virus and hacking vulnerability. The use of freeware and no licensed software make this system cheaper than others in the market.	This system is limited to monitoring and sending an alert message only. Local area network (LAN) also is required to link between the monitoring side and the warning/alert side. Therefore, without a LAN connection the system will not operate properly.

1.2 Location of Flood Detection Installation from previous work

The location of a flood detection system, such as a remote water level monitoring system, is crucial for its effectiveness. Factors to consider include the likelihood of flooding, access to hydrological data, proximity to at-risk communities, physical accessibility, and cost. These systems consist of a network of sensors and data loggers placed near drainage areas like rivers, creeks, canals, coastal areas, and other bodies of water at a higher risk of flooding.

1.2.1 Riverside Location

When installed in a river, the Libelium sensor platform can be used to monitor a wide range of parameters, such as water level, flow rate, temperature, conductivity, pH, and dissolved oxygen. [14]

Figure 1: Early flood detection and warning system in Argentina developed with Libelium sensors technology. [14]

1.2.2 Drainage Location

The monitoring panels were placed in the drainage and equipped with a monitoring device, battery, and water level sensor. [15]

Figure 2 : Linkwise Technology provide a flood monitoring system in Singapore [15]

1.2.3 Coasts Area Location

The flood detector is placed at The City of Newport News, Virginia, located on the east coast of the USA, alongside the Atlantic Ocean. [16]

Figure 3 : The City of Newport News, Virginia, is located on the east coast of the USA, alongside the Atlantic Ocean. [16]

2. Methodology

This project includes a description of the prototype design, data collection methods, and performance evaluation techniques used in this work. Details on the operational principles of the system are also explained accordingly, along with the circuit and software elements.

2.2 Block Diagram of System

The project uses a hardware-based system, as shown in the block diagram in Figure 4. It employs an Arduino Uno R3 to develop the sensor system. Ultrasonic Sensor 1 (SONAR1) detects the water level at Location A and an LED indicator shows if the water level is safe, cautious, or dangerous. Similarly, Ultrasonic Sensor 2 (SONAR2) and Ultrasonic Sensor 3 (SONAR3) detect the water level at Location B and Location C respectively. After measuring the water level in all three locations, the system sends SMS alerts via a GSM module to notify people of the current safety level in their location. The water level data is also sent to a platform called ThinkSpeak, where it can be accessed and viewed by users.

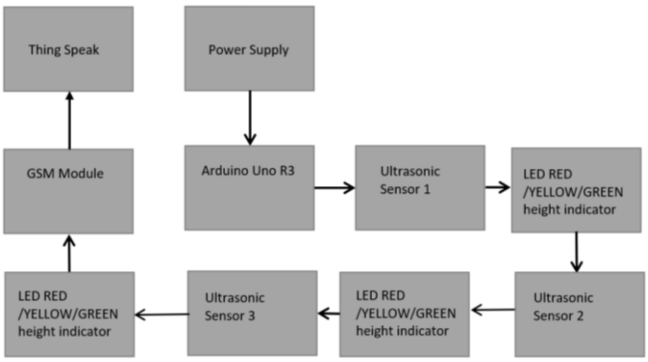

Figure 4 : Block Diagram of the system

2.3 Schematics Diagram of Final Product Prototype

Figure 5 shows the circuit of the project diagram detailed representation of the electrical connections and a layout of the various components in the prototype.

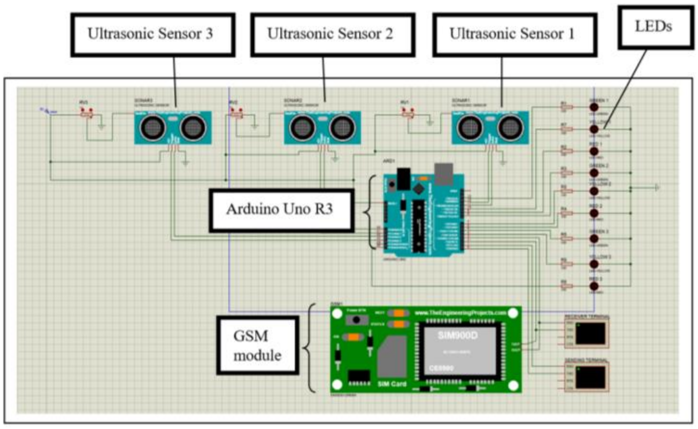

Figure 5 : Diagram of the project's diagram

2.4 System Program Algorithm Design

The Flowchart shown below in Figure 6 of this project Early Flood Detection & Warning System represents the outline of the operating flow that shows the sequence of steps and decisions that are developed by a project.

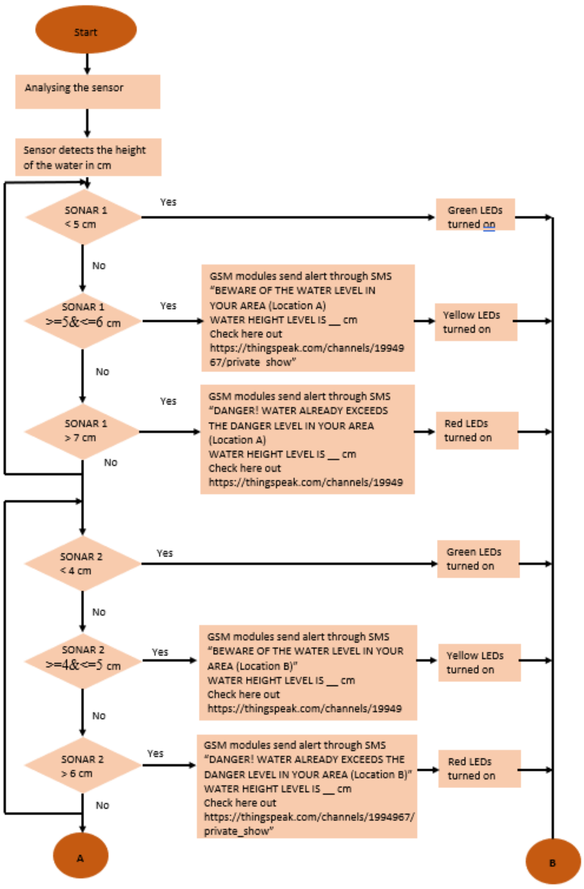

Figure 6 : Flowchart of the System Algorithm

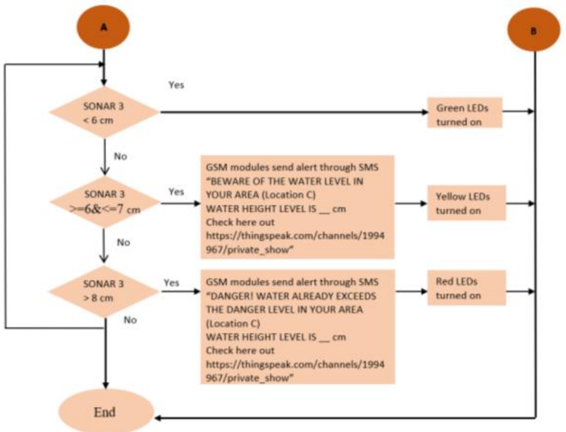

Figure 6 : Flowchart of the System Algorithm (continued)

2.5 Overview of the Project Location

The project design in Figure 7 below is created based on the objectives and scope that are meant to be achieved. There are three different places that are implemented in this project design to show that the prototype can detect different places with the same system.

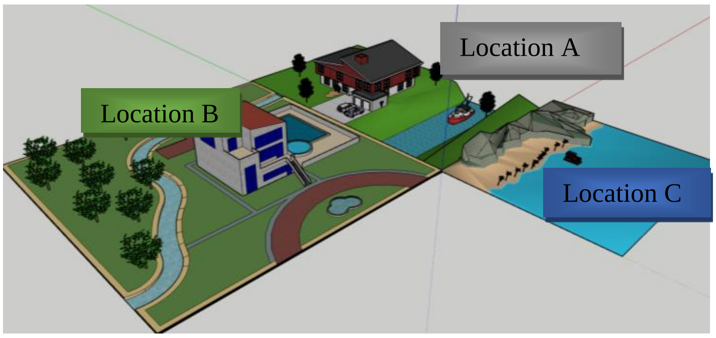

Figure 7 : Design of three location of places

3. Results and Discussion

This chapter presents the outcome of the developed prototype system. This includes performance validation of the system.

3.1 Overview of the Developed Prototype System

After successfully setting up the circuit hardware on a breadboard with no errors in connections, the wires are soldered to the stripboard as shown in Figure 8 to create strong electrical connections and ensure the connections do not easily come unplugged.

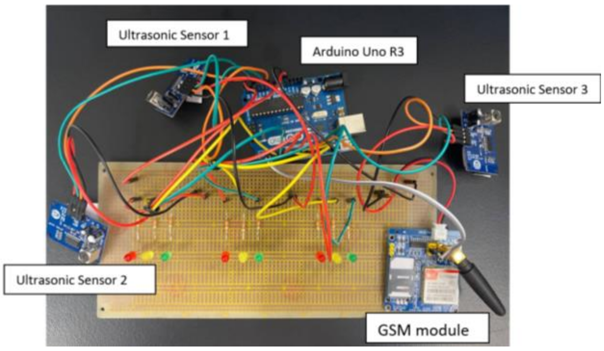

Figure 8 : Hardware setup soldered on a stripboard

Figure 9 below shows the overall prototype for this project which indicates the three location stated and used in this project.

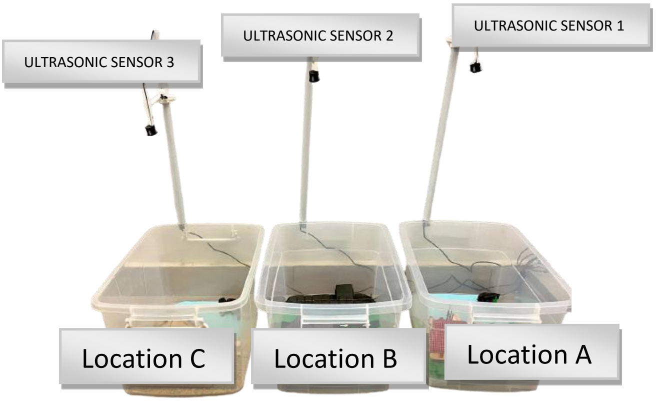

Figure 9 : The Overall Prototype of The Project

3.2 Sensor Result On Serial Monitor

Based on Figure 10 below, the serial monitor created by using Arduino IDE software shows the reading of the ultrasonic sensors at three different heights. These readings on the serial monitor help to ensure whether the height level detects by waterproof ultrasonic sensor is precise with the actual reading.

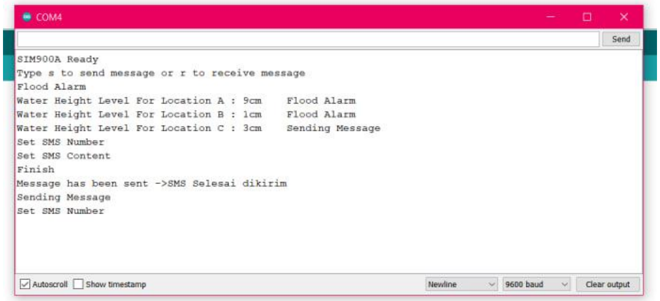

Figure 10 : Result of three ultrasonic systems on Serial Monitor

3.3 System Performance Validation

The System Performance Validation in this project is the data collected these three cases indicate the Ultrasonic Sensor 1, Ultrasonic Sensor 2, and Ultrasonic Sensor 3. This data is collected to test and measure if the readings of these Waterproof Ultrasonic Sensor are accurate.

3.3.1 Data For Waterproof Ultrasonic Sensors

The water level sensor is tested for accuracy from 0cm to 7cm. Data is gathered to measure the sensor's effectiveness and accuracy. The average difference between real measurement and sensor measurement is 0.287cm for SONAR 1, 0.300cm for SONAR 2, and 0.188cm for SONAR 3. Table 3 shows data for ultrasonic sensor readings using different LED lights to indicate safety levels in three locations: Location A, B, and C. If the water level is below a certain height in cm, the green LEDs will turn on, if it exceeds a certain level in cm, the red LEDs will turn on, and if it is between a certain cm range, the yellow LEDs will turn on indicating a cautionary level. This LED indication gives real-time information to people about the safety level of their location.

Table 3 : Data for Ultrasonic Sensors readings

Actual Value (cm)	SONAR 1		SONAR 2		SONAR 3	
	Sensor Measurement (cm)	Difference (cm)	Sensor Measurement (cm)	Difference (cm)	Sensor Measurement (cm)	Difference (cm)
0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.3	0.3	1.2	0.2	1.2	0.2
2	2.2	0.2	2.3	0.3	2.2	0.2
3	3.5	0.5	3.5	0.5	3.1	0.1
4	4.3	0.3	4.3	0.3	4.5	0.5
5	5.6	0.6	5.2	0.2	5.3	0.3
6	6.3	0.3	6.5	0.5	6.0	0.0
7	7.1	0.1	7.4	0.4	7.2	0.2

From Figure 11 below, the graph visualizing the data in this way can be useful to compare the accuracy of the sensor in a different locations and might help to identify any issues or inconsistencies in the sensor readings across the locations.

Figure 11 : Data graph for Ultrasonic Sensors readings

3.4 Development of Alert System Using GSM

The GSM module used in this system required any type of network provider in Malaysia region to transmit data through SMS. In order to test the time taken for GSM to send the message, several test has been done to get an average reading for GSM.

3.4.1 Alarm Alert System Accuracy

The time taken was collected by using the stopwatch shown in Figure 12 below. This data collection was made on mobile devices to see if a message had been sent as feedback for an earlier command. As a result, it was discovered that the relay operated normally in accordance with the instructions from the provided input string and was able to send alert messages in response to the command that had just been sent. The frequency of notifications is adjusted based on the circumstances and location. If there is a sudden increase in the flow rate, the system will send notifications more frequently so that the user stays informed.

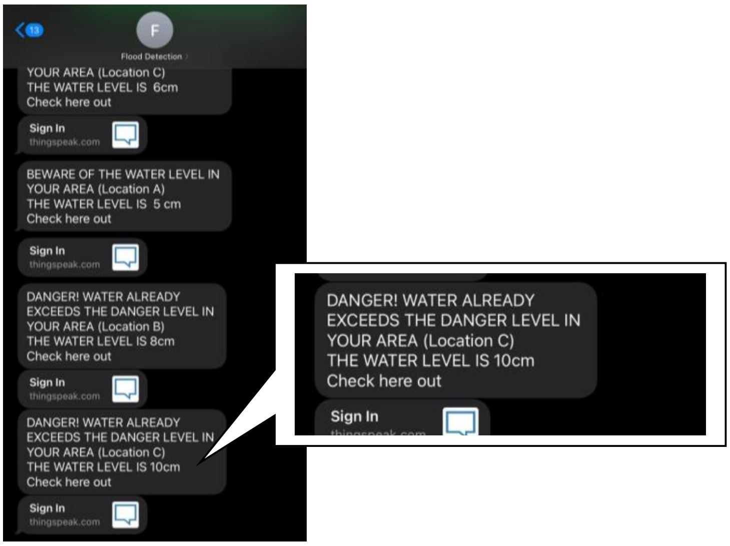

Figure 12 : The message received from the GSM

For the results shown in table 4, some messages were sent on time while others experienced delays, possibly due to issues with the GSM module or poor network coverage. Factors such as network congestion, the control of data delivery by the telecommunications provider, and network congestion affect transmission time. As the system takes around 60 seconds, it is crucial to use GSM900A in this project.

Table 4 : Data for time taken to receive message

No	GSM module Measurement (s)	Time Taken to Received SMS from GSM (s)
1	60.00	63.25
2	60.00	61.32
3	60.00	57.43
4	60.00	62.57
5	60.00	60.89
6	60.00	59.65
7	60.00	61.22
8	60.00	62.73

3.4.2 Effectiveness of the Warning System

Table 5 shows the messages sent to users through SMS using a GSM module, which notifies them based on their location. The GSM system has the advantage of fast transmission and wide coverage, particularly in rural or isolated areas.

Table 5 : Message sent by the GSM

Type of messages	Content of messages
Safe	-
Caution	BEWARE OF THE WATER LEVEL IN YOUR AREA (Location _) Water Height Level : _cm Check here out https://thingspeak.com/channels/1994967/private_show
Danger	DANGER! WATER ALREADY EXCEEDS THE DANGER LEVEL IN YOUR AREA (Location _) Water Height Level :_cm Check here out https://thingspeak.com/channels/1994967/private_show

3.4.3 Development of ThingSpeak Platform

Figure 13 below shows the ThingSpeak Flood Detection Visualisation. The ThingSpeak is a platform that allows people to build applications around the data collected by sensors. It gives its consumers simple data visualization, near real-time data processing, and data collection. Data is organized into channels, and these channels offer the user a variety of services.

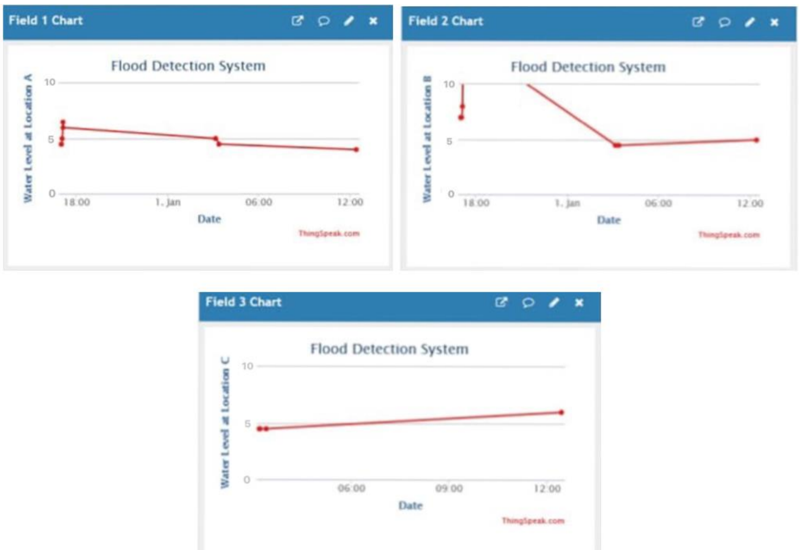

Figure 13 : ThingSpeak Flood Detection Visualisation

4. Conclusion

The prototype flood detection and warning system show promising results in detecting and warning of flood events. The system uses a combination of sensors and hardware to monitor water levels location with three different locations namely river, drain, and coastal side. Data collected by sensors is used to generate warnings that are disseminated to local users through SMS and web-based interface. However, there are still areas for improvement in the prototype system. In summary, the prototype flood detection and warning system shows promise as a tool for reducing the risks and impacts of flooding. Further development and testing are needed to refine and optimize the system, but the results to date are encouraging and suggest that the system has the potential to make a significant contribution to flood risk management efforts.

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