Flood Detection and Mitigition System Using SMS Notifications

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1. Introduction

The main causes of flood are hydrological condition, metrological condition, geographical condition, planning problem and environmental status due to human activity etc. [1]. Hydrological condition arises due to the discharge of heavy rain fall and the enormous water. The hydrological condition is directly and indirectly associated with the metrological condition such as heavy rainfall, cyclone and storm. The geographical condition is also a major factor for flooding condition, for example, altitude of the place. Lower is the altitude of a place; the water flows from the neighbouring higher altitude. The planning problem such as poor drainage, high siltation in river, breaching of the embankments, spilling of floodwaters over them, contribute to flooding situation. The environmental status due to human activity is a significant cause for flooding situation, for example, deforestation, different type of pollution and more buildings construction etc. [1]. Floods can have devastating consequences and can have effects on the economy, environment, and people. During floods (especially flash floods), roads, bridges, farms, houses and automobiles are destroyed. The environment also suffers when floods occurred [2].

Today many flood detection systems in rural area in Malaysia used the conventional way to predict the disaster; where the resident itself keeps watching water raises event near the river side. This action is too risky because the area near the river become dangerous for their safety, which can caused current water level data cannot be collected causing a delay in notifying all resident [3]. The existing flood detecting system just monitor water level for the main rivers but not providing an efficient alert system especially to the resident near the river.

2. Related Work

Jaymala Patil and Anuja Kulkarni [4] came with an idea to enhance safety of track over bridges against any unforeseen flash floods and breaches. The project used LPC 2148 Microcontroller as the controller, when it rise in water level will be sensed by the electromechanical float sensor and sends the signal provided to the Central Processing Unit (CPU). The project also included with GSM modem which turn to send Short Message Service (SMS) notification.

Danny Hughes and Phil Greenwood from Computing Department, Infolab21, Lancaster University [5] developed an intelligent and adaptable grid-based flood monitoring and warning system. In their project, they used Gridstix platform in order to describes a wireless sensor network (WSN) for flood warning which is not only capable of integrating with remote fixed-network grids for computationally-intensive flood modelling purposes, but it also capable of performing on-site flood modelling by organising itself as a 'local grid'.

Nivethithaa.P and Karthiga S.R [6] from Krishnamy College of Engineering & Technology, Cuddalore, India comes out with the role of satellite Zigbee technology in flood monitoring and communication system. Zigbee is the latest wireless weather monitoring technique. The vital role of the designed satellite Zigbee technology in flood monitoring and communication sytem is based on mobile apps. The mobile apps is used to communicate with the people during flood times and is to continuously monitor, detect and report the environmental status to a control unit using water level sensor, satellite Zigbee and the readings are displayed in it.

Anthone et al. [7] has described about an alternative network as a substitute to the usual communication links which are unavailable during major disaster. They proposed an alternative network for maintaining communications capabilities during major natural disasters and other emergency situations by a system that utilizes Short Message Service (SMS) of length up to 7bits over Wireless Mesh Sensor Networks (WMSNs). This technique is relatively simple and inexpensive. Other related works on flood detection and mitigation system are described in Table 1.

Table 1 - Existing flood detection and monitoring system

Project	Description	Pros and Cons
Early Flood Detection System [8]	Power supply AC to DC (transformer) Electrode 8051 series microcontroller GSM module	Need AC power supply to turn on
Citizen Flood Detection Network [9]	Small battery (lithium 3.6v) Ultrasonic rangefinder Ciseco SRF shield deploys under bridge or overhang above water	Small batteries Includes temperature sensor
Automatic Flood Detection and Warning Device, a Prototype [10]	6 x 1.5 V battery Overhang above water	Does not emit smoke, burning smell or spark while being used Does not overheat The components of the device do not blow up or short circuit.
The ALERT121A [11]	Integrated battery bracket that can accommodate up to 24 hour of rechargeable battery Style stand pipe installations	Configurable as an alert transmitter and repeater Sealed, circular sensor connectors on lid of canister Modular mounting of components for easier field servicing and expansion.
Telemetry System [12]	AC power supply Telemetry system Integrated data logging system tipping bucket rain gauge Radar water level sensor Live data Bridge or overhead structure for securely mounting the radar sensor	Data updated 24 hour per day Real time data accessed Radar sensors maintenance free To ensure the sensor provide accurate data by visually checking the sensor and measurement beam using a portable distance sensor or nearby staff gauge.
Fujitsu Flood Detection [13]	Thermoelectric converter that transforms energy from fluctuations of the manhole cover's heat into electricity Thermoelectric converter Drainage pipes	Transmit water level info to the cloud every 5mins Extends the time between battery replacement to five years from 10 months
Smart Flood Warning System [14]	Bank of siren Scale pole Near the river	There were markings on the scale, but no indication as to which water level was the signal for precaution to be taken

Flood Protection Systems [15]	Long life battery Moisture Sensors are placed or installed in potential leak, overflow, or flood-risk locations throughout the home–this may be directly on the floor, in a cabinet beneath a sink or water heater, in the basement, or beside a bathtub. Once water is detected, the sensor sets off the alarm—likely a loud, audible sound and/or blinking light	Early detection of moisture, water leaks and flooding, which often go undetected for long periods. Protection against mold, which can be a serious health risk. Protection for elderly and children from falls caused by water leaks and overflows.
Flood Sensing Network by Arduino and WSN [16]	Powered by solar panel Arduino Uno R3 Xbee Near The River	Battery always rechargeable Only siren as alert warning Inexpensive Solar panel thus benefits villagers, because of a limited access to electricity.

3. System Design

This system consists of ultrasonic sensor (HC-SR04) as the water level detection. The Arduino UNO is selected as the system microcontroller and connected to the GSM modem. Both of the Arduino UNO and GSM modem supplied by a battery. The system intended are to provide information of the current water level status in the selected area and give an alert notification to the user if the water level rises that would cause a flood. This system is user friendly and be attained anywhere as long as mobile communication coverage is available. Figure 1 shows the block diagram of the system.

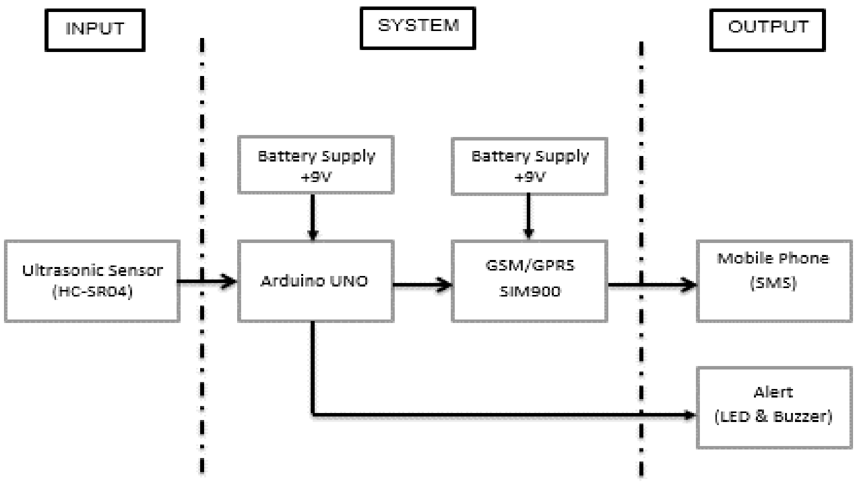

Fig. 1 - Block diagram of the system with GSM/GPRS module

Figure 2 shows deployment of the system to detect current water level of a river, drain, or etc. Table 2 indicate the parameters that being used.

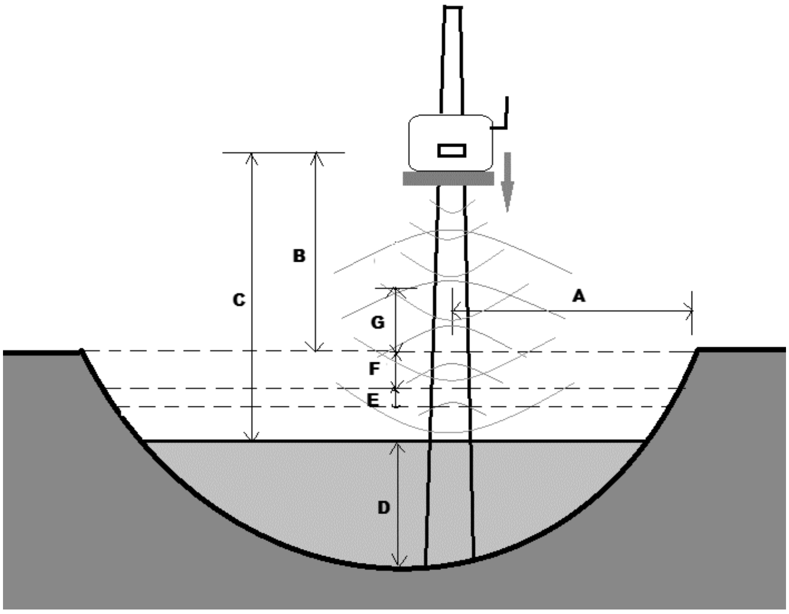

Fig. 2 - Visualization of device implementation

Table 2 - Parameters for water level calculation

Parameter	Description	Notes
A, *B*	Distance from cliff (1 meter)	-
C_{deploy}	Distance of sensor to water surface during deployment	-
$C_{current}$	Current distance of sensor to water surface	
D_{deploy}	Level of water during deployment	-
E	STANDBY level (Green Indicator/	40 cm below the bank
F	EVACUATE level (Yellow Indicator)	20 cm below the bank
G	Danger Level (Red Indicator)	Above 20 cm from from the bank

In order to deploy the system, a procedure should be followed as the following:

1. Measure the current water depth (D_{deploy}) using a benchmark stick.
2. The device must be placed 1 meter upper and 1 meter apart from the water bank (refer A and B).
3. When placing the device, make sure that the ultrasonic sensor of the device is facing the surface of the water.
4. Set the depth of water (D_{deploy}) and current reading of ultrasonic sensor (C_{deploy}) during deployment manually in the source code and program the device.
5. The ultrasonic sensor will detect the rising of water level. The current water level ($D_{current}$) is calculated using the equation (1).

$$D_{current} = D_{deploy} + (C_{deploy} - C_{current}) \quad (1)$$

6. The current water level reading ($D_{current}$) is send to the user using SMS.
7. Alert notifications are sent to the user when the water level reaches STANDBY, EVACUATE and DANGER level.

4. Experimental Works

4.1 Indoor Experiment

Figure 3 shows the indoor measurement setup that consist of a measuring stick, a big container, a laptop and a table. The important parameters about the indoor experiment setup is shown in Table 3. The purpose of these experiments are to study about the accuracy of the system, the effect of wave and floating materials on the water level reading of the system.

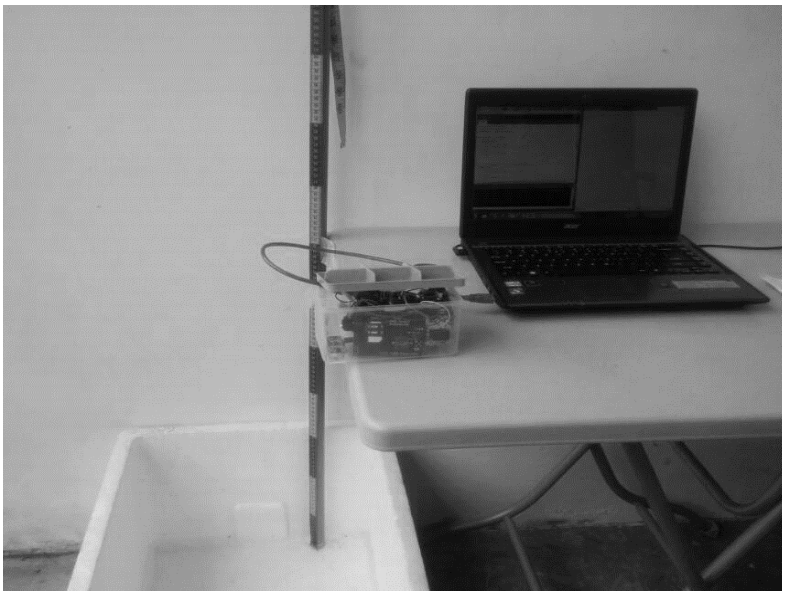

Fig. 3 - Tools that have been set up before doing the experiment

Table 3 - Parameters for indoor experiment setup

Parameter	Values
Distance between sensor and water surface (C)	68 cm
Current Depth (D)	2 cm
Box Container Depth	29 cm

4.2 Actual Implementation

The purpose of these experiment is to study the actual performance of the system. Two experiments have been conducted in selected areas within UTHM. Figure 4 and Figure 5, shows the actual experiments were conducted at two different locations in UTHM campus: drain between block E14 & E15 and drain in front of Diploma Study center (PPD). In this experiment, the system collects level of the water for three times each day. Each time, ultrasonic sensor collects data for three times every 10 minutes Average water level is calculated based on these readings. The water level status is send along with the sensor reading via SMS notification, as shown in Figure 6.

Fig. 4 - Actual experiment setup at the drain between block E14 & E15

Fig. 5 - Actual experiment setup at the drain in front of Diploma Study center (PPD)

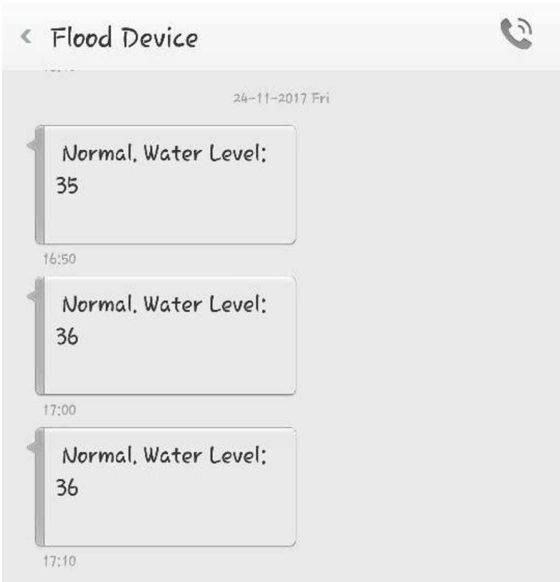

Fig. 6 - Water level readings sent via SMS

5. Data Analysis for Indoor Experimental

5.1 Accuracy of the Water Level Reading

The purpose of this experiment is to determine the accuracy of the water level reading collected by the system. As comparison, the actual water level is measured using measuring stick. Initially, the water container is filled with water until it reach to the level equal to 2cm. The system collects about 14 readings of water level. Then, each sensor reading is sent to a laptop using serial communication. Then, t water level is increased for each 2 cm. The same step is repeated for each increase of the water level. Figure 7 shows the water level reading from the system compared to the actual measurement. Based on the result, the water level reading from the same is almost consistent with the actual measurement and the highest standard error deviation is ±0.33.

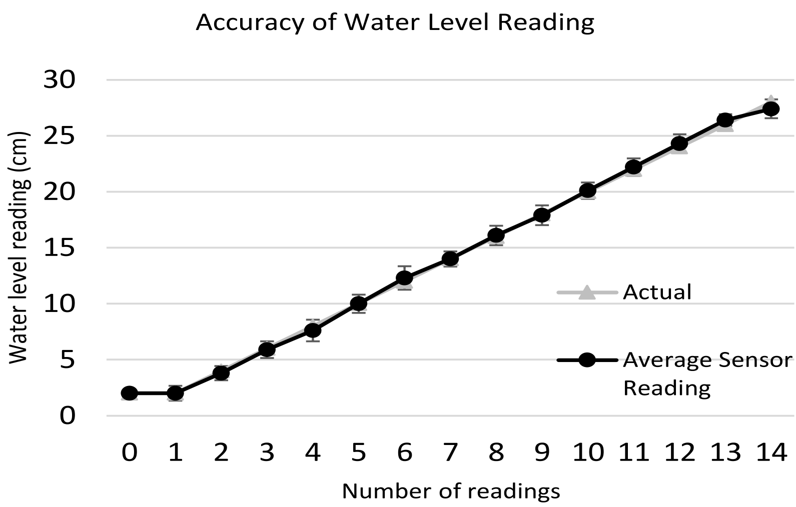

Fig. 7 - Graph of water level reading through measuring stick against serial monitor

5.2 Effect of Wave on the Water Level Reading

This experiment is conducted to understand the effect of wave of the water level reading. Three different levels of water are tested: 9cm, 17cm and 25 cm. In this experiment, wave is generated in this experiment by shaking the water using an empty bottle. Small part of the bottle is sunk into the water. The bottle is rotated for about 20 times per minute to create wave. The water level reading is taken for a duration of 150 seconds. The time interval for each reading is 5 seconds. The experiment is repeated for 5 times. Figure 8 shows the plotted graph of water level reading over time for each water level.

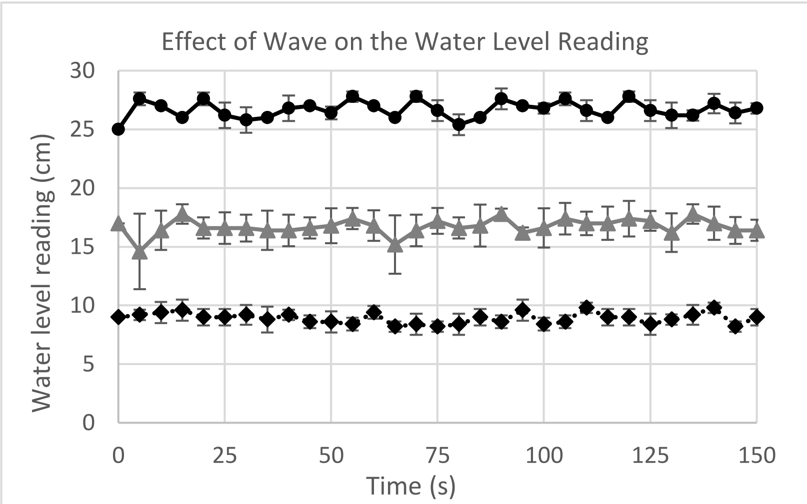

Fig. 8 - Graph effect of slow wave on standby water level reading

Based on Figure 8, the result shows that wave has a significant effect on the water level reading. The water level data is fluctuated. It is because wave on the surface of the water may increase or reduce the water level reading. The result also shows that, the higher the water level, effect of wave of the water level become more significant.

5.3 Effect of Floating Materials on the Water Level Reading

This purpose of the experiment is to determine effect of floating materials on the water level reading of the system. Four floating materials are used: bottle, polystyrene, biscuit container and tree bark as shown in Table 4. The level of water is fixed at value of 23 cm.

Table 4 - Floating materials

Materials	Plastic bottle	Polystyrene	Biscuits Container	Tree Bark
Thickness	9 cm	6 cm	14 cm	5 cm
Picture				

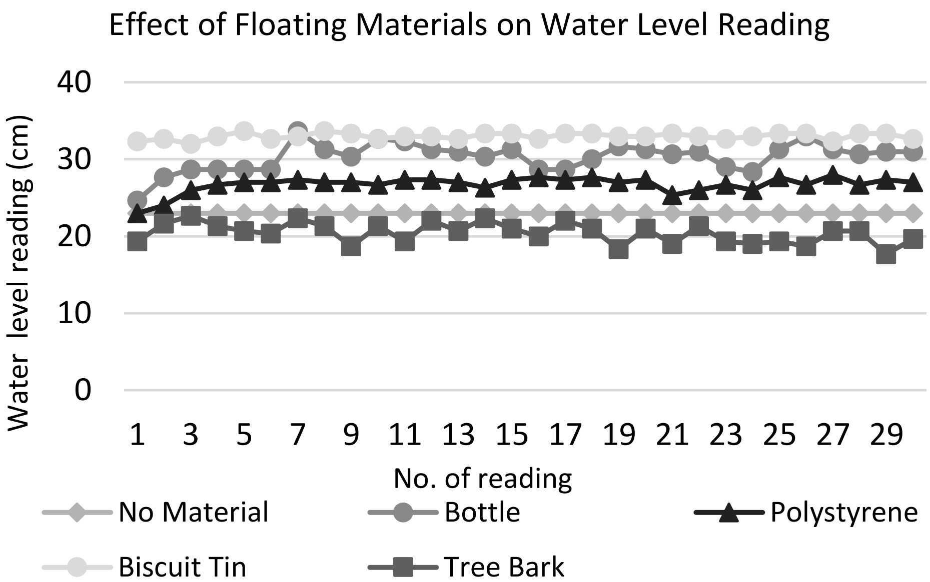

Fig. 9 - Graph of the effect of floating materials on water level reading

Figure 9 shows water level readings over time for all the floating materials. Overall, the results shows that the water level reading of the system affected by the floating materials. It is found that the floating materials make the water level readings becomes inaccurate. This is because, the floating materials exist between the ultrasound sensor and the surface of water. This will caused the emitted signal of the ultrasound sensor is reflected by the floating materials and not the surface of the water that gives an accurate reading. The error in water level reading depends on the thickness of the floating materials. The higher the thickness of the floating material, the larger the error of the water level readings. In addition of that, if the floating materials have uneven or bumpy surface, can caused an error in the reading because of the signal is not reflected back to the ultrasound sensor. As an example, water level reading for tree bark is in error because the reading is below the actual water level.

6. Data Analysis of Actual Implementation in UTHM

6.1 Experiment Result for Drain between Block E4 & E15, UTHM

Figure 10 shows water level reading for drain between block E4 & E15, UTHM. The experiment was conducted for 8 days from 23/2/2017 until 30/11/207. Based on the Figure 10, the highest water level was recorded on 29/11/2017 in the afternoon, which is equal to 41.67cm due to heavy rain. The lowest water level was on 25/11/2017, which the water level reading equal to 23.63cm height.

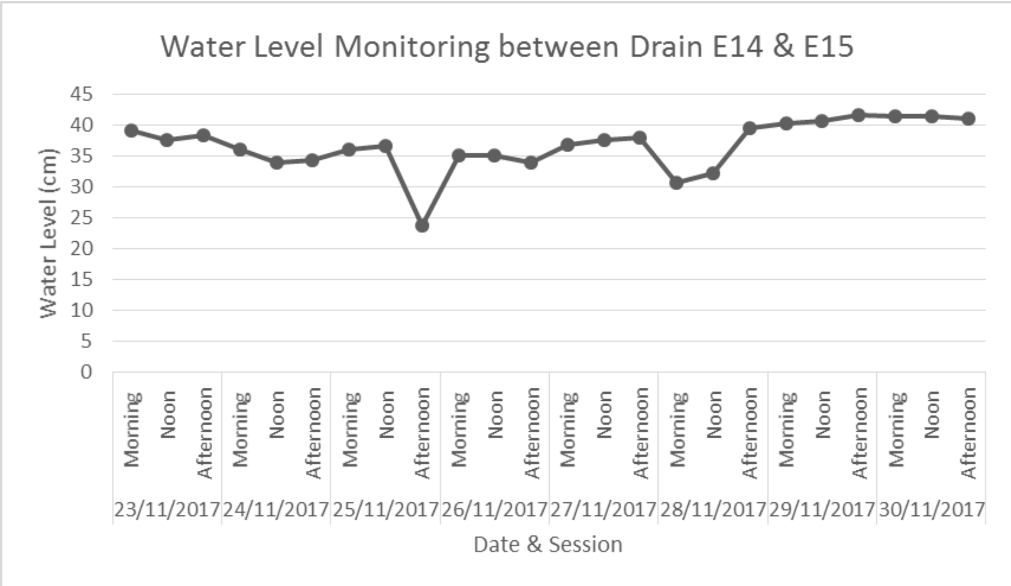

Fig. 10 - Graph of water level reading at the drain E14 & E15

6.2 Experiment Result for the Drain in front of PPD, UTHM

Figure 11 shows the water level reading for the drain in front of PPD. The experiment was conducted for seven days from 29/11/2019 until 5/12/2017. It is found that the water level decreased throughout the week due to no rain. The highest water level was recorded in the afternoon on 29/11/2017, which is equal to 43.67cm. The lowest water level reading was recorded in the afternoon on 5/12/17 with the reading value equal to 34cm.

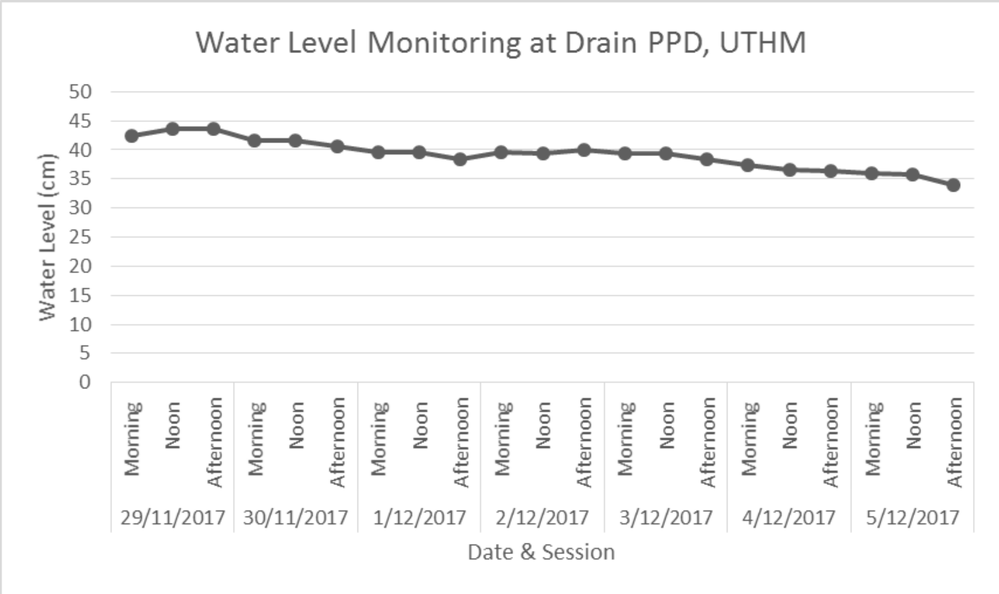

Fig. 11 - The graph of water level reading at the drain in front of PPD

7. Conclusion

As a conclusion, the flood detection and mitigation system has been developed to monitor water level of river, drain, stretch or canal, and provide an early warning of flood. The system is built using Arduino Uno microcontroller. Ultrasound sensor (HC-SR04) is connected to Arduino to detect current water level. GSM/GPRS SIM900 modem is included in the design in order to allow water level reading and notification message to be delivered via SMS. In order to determine the performance of the system, few experimental works had been conducted. These experimental work includes to determine the accuracy of water level reading, the effect wave and floating materials on the water level reading. The actual experimental are conducted in UTHM area. As a recommendation, the system should be improved to provide more accurate water level readings in the condition of wave and floating material.

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