Circuit: Jurnal Ilmiah Pendidikan Teknik Elektro
Volume 9 No. 2 March 2025 - August 2025
ISSN: 2549-3698; E-ISSN: 2549-3701
DOI: 10.22373/crc.v9i2. 29461

Design of a Flood Detection System Using VL53L1X Sensor Based on SMS Gateway

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Submitted: 16-03-2025 Accepted: 26-07-2025 Published: 30-08-2025

Abstract

Floods often occur suddenly, disrupting community activities, damaging infrastructure, and threatening human lives. Traditional flood monitoring methods, such as using rulers at dams or floodgates, are less effective because they cannot provide real-time alerts. Therefore, a more efficient and responsive system is needed. This research focuses on the design and development of a flood early detection system using the VL53L1X sensor integrated with an SMS Gateway. The system is capable of monitoring both water levels and rainfall in real-time and automatically sending notifications when potential flooding is detected. The study applies the ADDIE method—Analysis, Design, Development, Implementation, and Evaluation—to ensure systematic development and testing. Based on experimental results, the system successfully measured water levels and rainfall while sending SMS notifications. In the first test, the water level was 29.8 cm with 19.25 mm of rainfall, categorized as safe. In the second test, the water level rose to 59.9 cm with 45 mm of rainfall, generating a warning alert. The third test showed a water level of 81.5 cm and rainfall of 47.75 mm, categorized as danger. The system demonstrated reliable performance, with an average notification delay of just three seconds, proving effective for early flood detection.

Keywords*: Flood,* SMS *Gateway, VL53L1X Sensor*

Abstrak

Banjir sering terjadi secara tiba-tiba, mengganggu aktivitas masyarakat, merusak infrastruktur, dan mengancam nyawa manusia. Metode pemantauan banjir tradisional, seperti penggunaan penggaris pada bendungan atau pintu air, kurang efektif karena tidak dapat memberikan peringatan secara langsung. Oleh karena itu, diperlukan sistem yang lebih efisien dan responsif. Penelitian ini berfokus pada perancangan dan pengembangan sistem deteksi dini banjir menggunakan sensor VL53L1X yang terintegrasi dengan SMS Gateway. Sistem ini mampu memantau tinggi muka air dan curah hujan secara langsung (real-time) serta mengirimkan notifikasi secara otomatis ketika potensi banjir terdeteksi. Penelitian ini menerapkan metode ADDIE—Analisis, Desain, Pengembangan, Implementasi, dan Evaluasi—untuk memastikan pengembangan dan pengujian yang sistematis. Berdasarkan hasil percobaan, sistem berhasil mengukur tinggi muka air dan curah hujan sekaligus mengirimkan notifikasi SMS. Pada pengujian pertama, tinggi muka air adalah 29,8 cm dengan curah hujan 19,25 mm, yang dikategorikan aman. Pada pengujian kedua, tinggi muka air naik menjadi 59,9 cm dengan curah hujan 45 mm, sehingga menghasilkan peringatan. Pengujian ketiga menunjukkan ketinggian air 81,5 cm dan curah hujan 47,75 mm, yang dikategorikan berbahaya. Sistem ini menunjukkan kinerja yang andal, dengan rata-rata penundaan notifikasi hanya tiga detik, terbukti efektif untuk deteksi dini banjir.

Kata kunci: Banjir, SMS *Gateway*, Sensor VL53L1X

Introduction

Floods are natural disasters that have the potential to damage and endanger human life. Its sudden and unpredictable occurrence makes it difficult for people to avoid its impact [1]. Flood is a large amount of water overflow that occurs when the flow of water from high areas cannot be accommodated, thus forming puddles or streams that overflow naturally [2]. Floods consist of five types based on their causes, namely flash floods, water floods, mud floods, tidal floods, Cileunang floods [3]. Floods often occur due to high rainfall and urbanization that causes land use change. The reduction of absorption land makes the flow of water on the surface increase, exceeding the capacity of rivers and drainage channels [4].

Jambi City is located along the Batanghari River, a major river in the area, and often experiences flooding [5]. The Batanghari River itself is the longest river on the island of Sumatra, having a main river length of about 870 km. Its river width ranges from 300-500 meters, and its depth is between 6-7 meters [6]. In 2024, flooding in Jambi City affected 2,238 residents in 8 out of 11 sub-districts. A total of 589 households were affected in 24 urban villages, with 466 housing units submerged in water levels of 6-201 cm [7]. Sudden flooding hampers community activities and is characterized by a significant increase in water discharge. Water level changes are usually monitored at dams or sluice gates with conventional measuring instruments such as measuring rulers [8]. Thus, a system is needed that can help the community to get warnings related to the potential for more effective flooding. Previous studies have attempted to detect flooding using various types of sensors and different methods. The study by [9] used ultrasonic sensors, but encountered problems related to the accuracy of water level measurements, which were affected by waves on the water surface.

Meanwhile, research by [5] used float switch water level sensors, but had limitations in terms of the effectiveness and efficiency of sensor use. This type of sensor requires multiple units to monitor various water levels, making the installation and maintenance process more complicated, especially in terms of cables and connections between sensors. Additionally, the float switch sensor only provides a binary signal (ON/OFF) without the ability to measure changes in water level in detail, making it unsuitable for flood detection systems that require continuous and accurate water level monitoring.

This research uses the VL53L1X sensor to detect water levels. This sensor belongs to LIDAR (Light Detection and Ranging) technology and applies the Time of Flight (ToF) method to measure distance [10]. The VL53L1X is the fastest miniature ToF sensor on the market, with an accuracy of up to 4 meters and a measurement frequency of up to 50 Hz [11]. This sensor works by emitting a short light pulse and calculating the travel time of the signal from sending to receiving back [12]. This research uses the SMS Gateway platform to send notifications of potential flood warnings.

SMS Gateway is a platform that serves as an intermediary in sending and receiving SMS messages from mobile devices through short codes [13]. This system works as software that distributes messages through mobile networks connected to information systems [14]. According to [15], a more effective flood early warning system is needed because the range of existing systems is still limited. One alternative that can be used is SMS, which allows the delivery of information regarding rising water levels and currents that have the potential to cause flooding [16]. In addition, GSM network-based SMS is an ideal solution for areas with limited internet access [17].

Method

The method used in this study is ADDIE. This model consists of five main stages, namely Analysis, Design, Development, Implementation, and Evaluation. With this approach, the ADDIE model allows for continuous adjustments to increase its effectiveness [18]. The ADDIE model shows a high level of flexibility and is effective in responding to problems [19]. Analysis: At this stage, system requirements were identified through literature studies and reviews of previous research. It was found that the use of ultrasonic sensors has weaknesses in terms of water surface reading accuracy, mainly due to interference from water waves. Meanwhile, float switch water level sensors were also considered ineffective because they only provide binary signals (ON/OFF) without being able to show water levels in detail. Additionally, to read multiple water levels, multiple sensor units are required, making installation and maintenance more complex. Based on these findings, the researchers decided to develop a system using more accurate and reliable sensor types.

Design: At this stage, a comprehensive system design is carried out, covering both hardware and software design. Before going into the details of the design, a system block diagram is first created to provide an overview of the workflow of the system being developed.

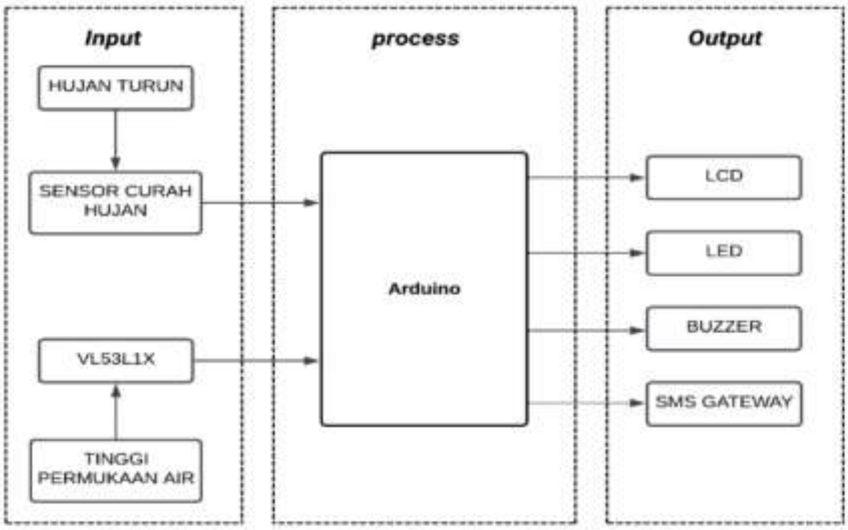

Figure 1. System Block Diagram

Figure 1 shows a block diagram of the flood detection system. This system consists of three main parts: input, process, and output. The input section includes two sensors: a rain gauge sensor to measure rainfall intensity and a VL53L1X sensor to measure water levels. The processing section uses an Arduino to process data from both sensors. Meanwhile, the output section displays flood level indicators via an LCD screen, LED lights, a buzzer, and an SMS Gateway to send alerts.

a. Hardware Design

Hardware design consists of two main aspects, namely mechanical design and electronic design. In the mechanical design section, the design is carried out using

SketchUp 2022 software to visualize the physical form of the system. Once the design is complete, the components are assembled to form a complete system.

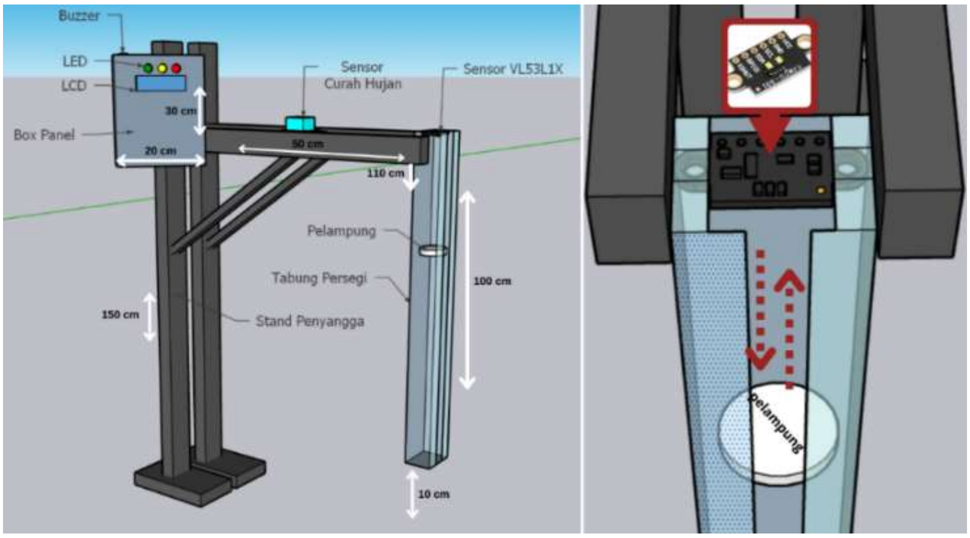

Figure 2. Mechanical design

Figure 2 shows the mechanical design of the system device. The VL53L1X sensor is mounted on the top of the square tube, with the sensor transmitter and receiver facing inward. This 100 cm long tube contains a float that moves with changes in the water surface. The sensor reads the water level based on the position of the float. The device structure is supported by a 150 cm tall pole and equipped with a 50 cm long support arm to hold the sensor and tube. Additionally, a rain sensor is installed to measure rainfall intensity, while the Arduino and other supporting components are housed inside a panel box to protect them from damage.

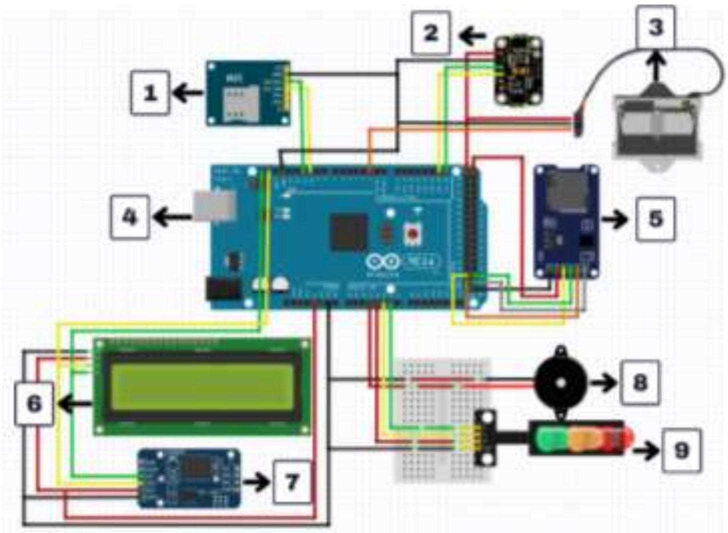

Figure 3. Electronics Circuit Design

Figure 3 shows the wiring diagram and components used in the system, listed in order from 1 to 9. These components include the GSM SIM800L V2 module, VL53L1X sensor, rain sensor, Arduino Mega 2560, SD Card module, LCD I2C 16×2, DS3231 RTC module, buzzer, and LED RYG.

b. Software Design

Software design includes stages in system development to ensure optimal performance and in accordance with the expected output. The following figure shows the flow chart of the designed flood detection system.

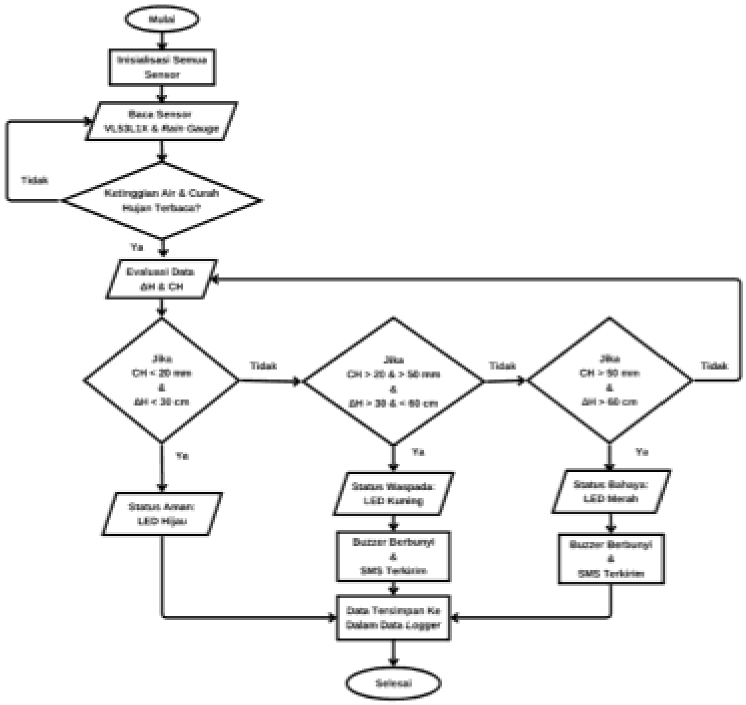

Figure 4. Flowchart System

Figure 4 shows the flowchart of the flood detection system designed to monitor water levels and rainfall as early indicators of potential flooding. The system begins with sensor initialization, then the Arduino reads data from the VL53L1X sensor and rainfall sensor. After that, the system evaluates the sensor data readings and determines the status of water level (ΔH) and rainfall (CH) based on predefined logic. If the rainfall is < 20 mm and the water level is < 30 cm, the condition status is safe. If rainfall is between 20-50 mm and water level is 30 cm to < 60 cm, alert condition status. If rainfall > 50 mm and water level > 60 cm, the condition status is danger.

Based on the processing results of the water level and rainfall status, the system will turn on the green LED for safe conditions, yellow for alert conditions, and red for danger conditions. In alert and danger conditions, the buzzer will sound, and the system will send a warning via SMS Gateway. All data obtained will be stored in the data logger using the Micro SD Card module.

Development: At this stage, researchers developed a system using VL53L1X sensors to detect water levels. This sensor was chosen to address accuracy issues with ultrasonic sensors and the limitations of float switches, which require multiple units to monitor several water levels. These conditions pose challenges in installation and maintenance, particularly regarding cables and connections between sensors. With this update, the system is expected to have improved performance and reliability.

Implementation: At this stage, the previously designed system begins to be realized through the process of installing and assembling all components, both hardware and software. Implementation includes the installation of sensors, microcontrollers, and other supporting modules.

Evaluation: The evaluation stage was conducted to measure the overall performance of the system and identify potential errors. The evaluation included testing the accuracy of the sensors, message delivery speed, and data storage capacity of the SD card module. Sensor testing is carried out by comparing the measurement results from the sensor with conventional measuring instruments to evaluate the level of accuracy. Next, the percentage of error is calculated to determine the error value in the sensor test results [20].

$$\%Error = \frac{Actual\ value - Measured\ value}{Actual\ value} \times 100 \quad \text{........................ (1)}$$

In this study, the device was tested using a water tank simulator to simulate river conditions. The use of a simulator allows for controlled and measurable testing. This helps ensure the accuracy of sensor readings, proper program logic, and the system's response to conditions as expected.

Result and Discussion

a. System Implementation

System implementation is carried out in accordance with the flowchart and design that has been designed. This stage realizes the concept that has been made before. A series of trials were also conducted to ensure the system functions properly and meets the research objectives. The overall appearance of the tool is shown in Figure 5.

Figure 5. Prototype of the Flood Early Detection System

b. VL53L1X Sensor Testing

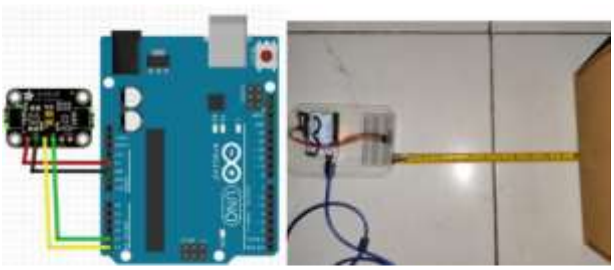

Figure 6. VL53L1X Sensor Testing

Sensor testing was carried out within a distance range of 20 cm to 400 cm by pointing the sensor at the measured object. The sensor reading is then compared to the actual distance, and the difference is recorded as an error value.

Table 1. VL53L1X Sensor Testing Results

Test Distance (cm)	Sensor Reading (cm)	Error (%)
20	20	0
40	40	0
60	59	1,6
80	80	0
100	96	4
120	118	1,6
140	139	0,7
160	159	0,6
180	179	0,5
200	197	1,5
220	219	0,4
240	240	0
260	257	1,1
280	276	1,4
300	296	1,3
320	320	0
340	338	0,5
360	357	0,8
380	376	1,05
400	393	1,7
Average Error (%)		0,93

Table 1 shows the data of the VL53L1X proximity sensor test results conducted 20 times with various distances. Based on the test results, the average reading error value is 0.93%.

c. Rain Sensor Testing

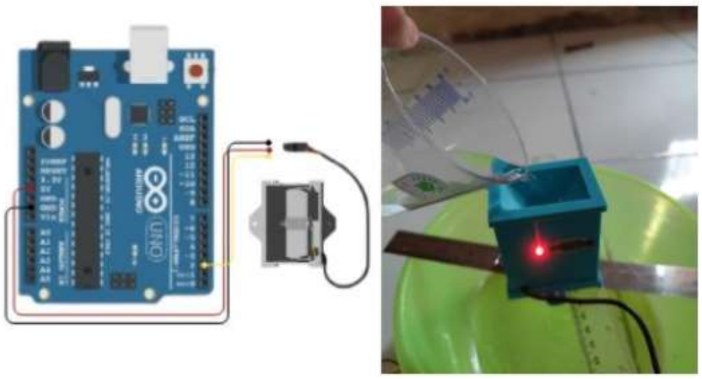

Figure 7. Rain Sensor Testing

Testing is done by pouring water using a measuring cup in the volume range of 10 mL to 50 mL The purpose of this test is to evaluate the accuracy of the sensor and ensure that the sensor readings match the actual conditions. The results of the rainfall sensor test are presented in Table 2.

Table 2. Rainfall Sensor Testing Results

No	Volume of water poured (mL)	Sensor Readings (mL)	Error
1	5	5	0,0
2	10	10	0,0
3	15	15	0,0
4	20	20	0,0
5	25	25	0,0
6	30	30	0,0
7	35	35	0,0
8	40	40	0,0
9	45	45	0,0
10	50	50	0,0
Average Error (%)			0,0

Based on Table 2, the test results show that there is no difference between the sensor reading and the volume of water poured. The test was conducted using a measuring cup to ensure the accuracy of the sensor reading. In addition, calibration of the rainfall sensor is carried out by adjusting the measurement parameters to the sensor readings to avoid a large error rate. Calibration is done by recording the amount of tipping that occurs and the volume of water wasted in each tipping. This data is then used to adjust the rainfall calculation so that the measurement results are more accurate.

d. SIM800L V2 Module Testing

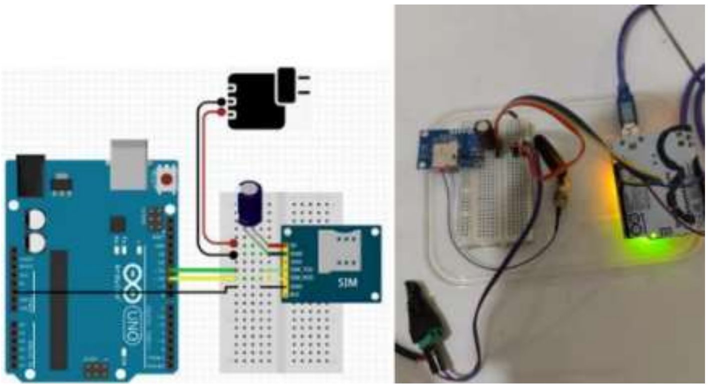

Figure 8. SIM800L V2 Module Testing

Testing was done by connecting the SIM800L V2 module to a 5V 3A adapter as a power source and connecting the RX and TX pins to the Arduino Uno. To stabilize the voltage, a 2200uF/16V capacitor is added, because the module requires a stable voltage of around 4.7V-5V to search for networks and send SMS. The test results of sending SMS through the SIM800L V2 module can be seen in Table 3.

Table 3. Message Delivery Test Results

Test	Testing on Modules	Status	Delivery Delay (seconds)
1	Send SMS	sent	3
2	Send SMS	sent	3
3	Send SMS	sent	3
4	Send SMS	sent	3
5	Send SMS	sent	3
6	Send SMS	sent	3
7	Send SMS	sent	3
8	Send SMS	sent	4
9	Send SMS	sent	5
10	Send SMS	sent	5

SMS sending tests were carried out 10 times, the results showed that the module can send SMS well as expected. The time it takes to send a message until it is received by the user has an average delay of about 3 seconds. On the 8th to 10th trial, the module experienced a delay of 4 to 5 seconds.

e. Micro SD Card Module Testing

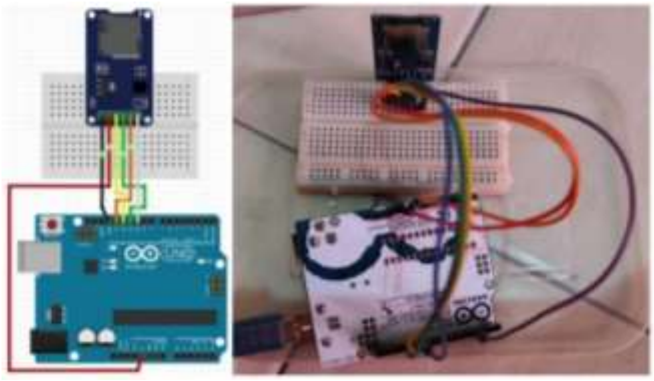

Figure 9. Micro SD Card Module Testing.

Based on the test, the module successfully functions according to the expected output. In Figure 10, the reading results on the serial monitor show that the Micro SD Card module can work properly, the SD Card is read, and the data can be saved. The file stored in the module is in .txt format with the name Coba.txt. In addition, the file can be accessed and read properly, as shown in Figure 10.

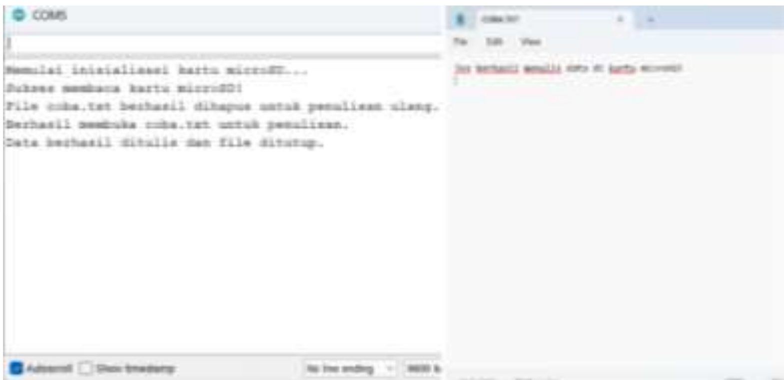

Figure 10. Micro SD Card Module Testing Results

f. Overall System Testing

Figure 11. Overall System Testing

System testing was conducted by simulating flood conditions using a 1.5×1.5 m water basin with a water capacity of up to 90 cm. The test was conducted three times within a span of 5 hours. Water was gradually filled into the tub while monitoring the water level sensor readings, as well as pouring water onto the rainfall sensor to simulate rainy conditions. This test aims to ensure each component of the system is functioning properly, observe changes in water level and rainfall detected by the sensors, and evaluate the accuracy of sending SMS when a potential flood is detected.

In the first test, the system is tested with an initial water level in the simulator tub of 9.4 cm and slowly dripping water onto the rainfall sensor, then the response of the system made to changes in water level and rainfall recorded will be seen.

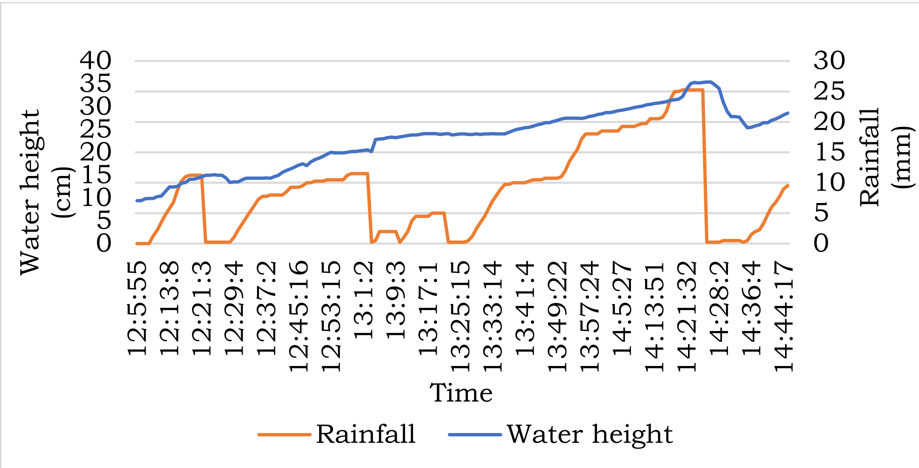

Figure 12. First Test Result Graph

Figure 12 shows the results of testing the entire system that has been made, by recording water level and rainfall data on February 4, 2025, from 12:05 to 14:08 WIB. The resulting graph illustrates changes in water level and rainfall, where the initial water level was recorded at 9.4 cm with 0.0 mm of rainfall, then increased to reach 29.8 cm with 19.25 mm of rainfall at 14:08. In this condition, the system outputs a warning level with a safe status. The display on the LCD screen shows the safe condition parameters, the green LED is on. The output results of the first test can be seen in Figure 13.

Figure 13. System Output

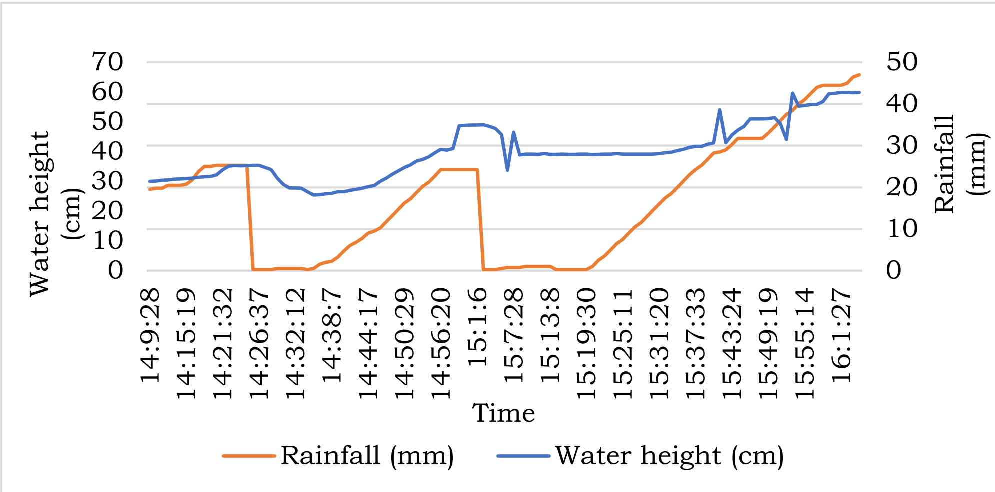

Figure 14. Second Test Result Graph

Figure 14 shows the results of the system test conducted from 2:09 pm to 4:02 pm. The graph records changes in water level and rainfall, where at 14:09, the water level reached 30 cm with 19.5 mm of rainfall, so the system gave an alert warning. However, at 2:33 pm, the water level decreased to 27.7 cm with 0.5 mm of rainfall. In this condition, the system again changed the warning to a safe status, as seen in Figure 15.

Figure 15. System Generated Output

At 14:48, the water level rose again to 32.4 cm with rainfall recorded at 13.32 mm. The increase continued until 16:02, when the water level reached 59.9 cm and 45 mm of rainfall. Under these conditions, the system remained on alert status. During the alert status, the system automatically sends a notification via SMS Gateway as an early warning. Figure 16 shows the final output of the system in the second test, including the display of the notification that was successfully sent via SMS Gateway.

Figure 16. Final System Output in the Second Test

The system automatically detects and determines conditions every 30 seconds based on predefined parameters. If an alert or danger status is detected, the system will immediately send a notification via SMS Gateway. Table 4 shows the test results of sending SMS by the system when detecting a warning level in an alert state.

Table 4. Test Results of Message Delivery in Alert Condition

Water Height (cm)	Rainfall (mm)	Category Level	Delivery Status	Delay (Second)
30	19,5	Alert	Sent	3
30,1	19,75	Alert	Sent	3
30,1	19,75	Alert	Sent	3
30,2	19,75	Alert	Sent	3
30,3	19,75	Alert	Sent	3

Based on table 4, SMS is successfully sent when the system detects an alert condition with a delivery time delay of 3 seconds.

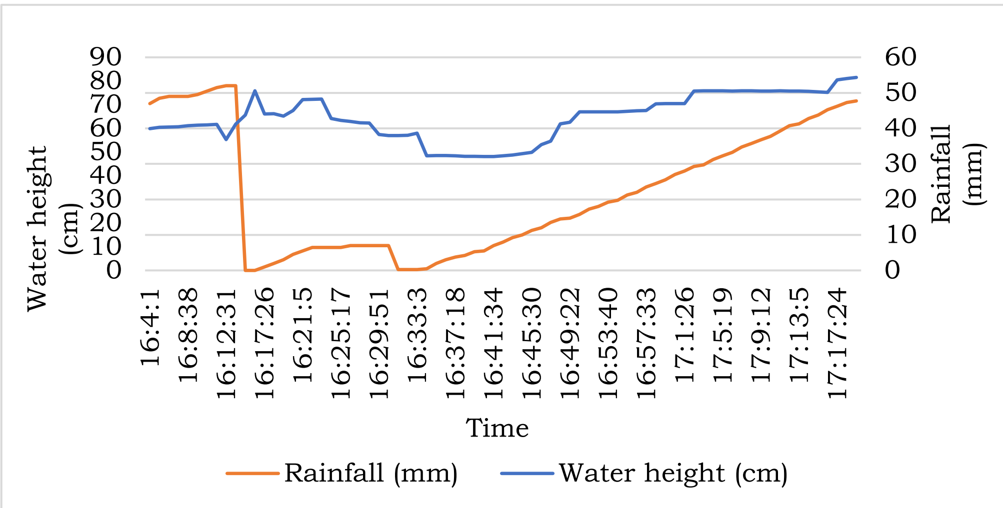

Figure 17. Third Test Result Graph

Figure 17 shows the readings of the water level and rainfall recorded by the system during the test, which took place from 16:04 to 17:19 WIB. The graph shows the changing rate of water level and rainfall, starting from 59.9 cm and 47 mm of rainfall at 16:04 with a warning level of alert. At 16:08, the water level increased to 61.1 cm with 49 mm of rainfall, so the system responded to this change by raising the warning level to danger status.

Figure 18. System Generated Output

In this test, it was simulated that the water level had decreased to 57.4 cm with 7 mm of rainfall at 16:29. In this condition, the system responded with a warning level of alert. However, at 16:48, the water level rose again to 61.9 cm with 14.5 mm of rainfall, causing the warning level to change to danger, as shown in Figure 18. The water level continued to rise until it reached 81.5 cm with 47.75 mm of rainfall at 17:19, indicating a higher potential danger.

Figure 19. Final System Output in the Third Test

Figure 19 shows the final output of the system in the third test, including notifications sent via SMS Gateway when the system detects a hazardous condition. The test results of sending SMS when the system detects a warning level in danger can be seen in Table 5.

Table 5. Test Results of Message Delivery in Danger Conditions

Water Height (cm)	Rainfall (mm)	Category Level	Delivery Status	Delay (Second)
59,8	46,5	Alert	Sent	3
59,9	47	Alert	Sent	3
59,9	47	Alert	Sent	3
60,5	47,5	Danger	Sent	3
59,9	48	Alert	Sent	3
60,5	48,5	Danger	Sent	3
60,5	49	Danger	Sent	3
60,5	49	Danger	Sent	3
60,5	49	Danger	Sent	3
60,5	49	Danger	Sent	3
60,5	49	Danger	Sent	3
60,5	49	Danger	Sent	3
60,5	49	Danger	Sent	3

Based on Table 5, SMS is also successfully sent when the system detects a hazardous condition with a delivery time delay of 3 seconds. Figure 20 shows the water level and rainfall readings recorded by the system during the test. This data is classified based on Safe, Alert, and Danger conditions according to predetermined parameters. All data obtained is stored in the data logger using the SD Card module in .txt format, so that it can be accessed and analysed further.

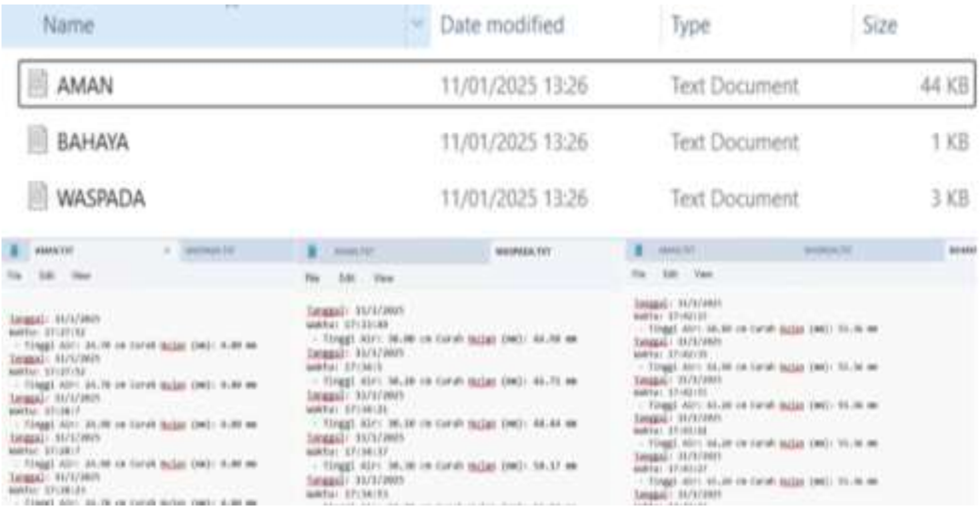

Figure 20. System Data Logger Display

Conclusion

The results of three tests show that the designed system works well in detecting changes in water level and rainfall and provides an appropriate response. In the first test, the water level reached 29.8 cm and the rainfall was 19.25 mm resulting in a safe category warning. In the second test, the water level reached 59.9 cm and 45 mm of rainfall resulted in an alert category warning. In the third test, the water level reached 81.5 cm and rainfall of 47.75 mm resulting in a danger category alert. The system can determine the final conditions of Safe, Alert, and Danger, based on predefined parameters. The system successfully provides warnings through LED indicators and buzzers according to the detected conditions. The system also successfully sends notifications via SMS Gateway during Alert and Danger conditions with a delay of 3 seconds. All data from water level and rainfall readings are successfully stored in the SD Card, which can be opened and read clearly and stored in real-time.

Based on the results of this study, further research should focus on developing a system that applies machine learning algorithms to predict flood potential more accurately. This approach allows for the use of a wider range of parameters, not limited to water levels and rainfall, enabling the system to provide smarter and more adaptive early warnings based on environmental conditions.

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