ISAINTEK: Jurnal Informasi, Sains dan Teknologi
Vol. 8 No. 2 Desember 2025
ISSN: 2828-7207, ISSN: 2829-2758, Hal 570-582
DOI: https://doi.org/10.55606/isaintek.v8i2.384

Intelligent Flood Monitoring System Using IoT and Real-Time Notifications

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Abstract. *Flood is a frequent natural disaster in Indonesia, often exacerbated by delays in information delivery from conventional manual monitoring systems. This study aims to design and build an automatic flood early warning system based on the Internet of Things (IoT) integrated with a web dashboard and WhatsApp notifications. The system utilizes the ESP32 microcontroller and MaxBotix MB7389 ultrasonic sensor for real-time water level data acquisition. The Research and Development (R&D) method was employed, focusing on device accuracy validation and system integration. The measured data is transmitted to a .NET-based server and stored in a PostgreSQL database. Results indicate that the system functions according to design. Sensor accuracy testing demonstrated a high degree of precision (99.12% - 100%) compared to manual measurements. Furthermore, the system successfully sends timely warning notifications via WhatsApp when water levels exceed predefined thresholds, providing a more effective solution than manual monitoring to enhance community preparedness.*

Keywords: *Flood Early Warning, Internet of Things, WhatsApp API, ESP32, Ultrasonic Sensor*

BACKGROUND

Flooding is one of the most frequent natural hazards in Indonesia, particularly during the peak rainy season. Hydrologically, flooding occurs when water volumes exceed the storage or conveyance capacity of river channels or drainage systems(Azizah, M.A. et.al 2021). Such events result in substantial infrastructure damage, economic disruption, and threats to human life(Ni'matussyahara, D.; Muryani, C.; Wijayanti 2022). Data from the National Disaster Management Agency (BNPB) indicate 8,333 flood incidents between 2014 and 2023, with 1,255 reported in 2023 alone, highlighting the urgent need for more effective early warning systems (EWS) (H. S. Harahap; 2024).

Flood hazards in Indonesia arise from the interaction of intense rainfall with reduced environmental carrying capacity. Urban areas such as Bandung are especially vulnerable due to land-use conversion, riverbed sedimentation, and drainage obstruction

Received Desember 08, 2025; Revised Juni 23, 2025; Accepted Desember 30, 2023
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by solid waste. (Suharto, S.; Setiawan 2022) The Cibeunying Ciateul Weir in Regol District represents one of the city's critical points, having experienced repetitive flooding for more than a decade. Major inundation in 2012 and recurring events—including severe flooding in 2024 with water levels reaching 1.5 meters—underscore the sustained hydrological risk in this area (Djoharam, V. et.al 2022).

Despite the high flood frequency, existing monitoring in Cibeunying Ciateul remains largely manual. Field observations show that water-level assessment is conducted through visual inspection, which is limited by the inability to provide continuous and real-time monitoring (Husein, M.; Akbar, M.; Sobri 2023). Consequently, information is often disseminated only after overflow reaches residential zones, leaving minimal time for evacuation or protective action. To support timely decision-making, residents require an information system that delivers accurate, real-time alerts (Pratama, N.; Darusalam, U.; Nathasia 2020). Recent advancements in Internet of Things (IoT) technologies offer a practical foundation for improving flood monitoring. IoT enables sensors to transmit measurements autonomously to centralized servers without human intervention (Ratmini, Y.; Atina, V.; Purwanto 2025). In disaster management, this capability supports the development of responsive and reliable EWSs that operate continuously under diverse hydrometeorological conditions.

This study employs the MaxBotix MB7389 ultrasonic sensor, chosen for its waterproof design and superior outdoor reliability compared to commonly used modules such as the HC-SR04. The sensor determines water-surface distance via ultrasonic ranging and transmits data to an ESP32 microcontroller, which integrates Wi-Fi connectivity and sufficient computational capacity for real-time (Ilmuddin, I.; Putra 2022). This hardware combination supports stable and autonomous data acquisition.

The system is structured around seamless integration of three major components: (1) high-precision data acquisition using MaxBotix sensors and ESP32 microcontrollers, (2) web-based data processing and visualization through a server-hosted dashboard, and (3) automated dissemination of early warning messages via the WhatsApp API. Through this multi-tiered architecture, the system is expected to significantly improve community response times by delivering timely, accurate, and accessible alerts directly to personal devices. In addition to providing operational benefits to the target community, this research contributes to the broader field of disaster-mitigation technology by demonstrating a scalable, low-cost, and reliable approach to early warning system design. The integration of IoT sensing, cloud-based analytics, and real-time mobile messaging addresses key shortcomings in both conventional monitoring systems and several existing IoT-based prototypes. As such, the framework developed in this study has the potential to be adapted and implemented in other flood-prone regions facing similar hydrometeorological challenges (Syahri and Ulansari 2024).

THEORETICAL REVIEW

This section provides an in-depth review of prior studies relevant to the development of early warning systems, the application of Internet of Things (IoT) technologies, and the integration of modern communication media. The analysis of the literature aims to map technological developments while identifying research gaps that justify the urgency of the present study.

Developments in IoT-Based Monitoring Systems

Research on IoT-based water monitoring systems has proliferated, largely motivated by the limitations of manual measurement methods that are prone to delays in information delivery. One notable study emphasizes the need for real-time data acquisition for monitoring reservoirs prone to overflow events (Wicaksono, A.M.; Hasan, Y.; Rahman 2021). The implemented method utilized sensors to measure water levels and microcontrollers to transmit the recorded data to a server. (Wikantama, P.T.; Puspitasari 2023) The findings demonstrate that a real-time monitoring system can be effectively established, achieving sensor accuracy exceeding 90% and successfully visualizing data through a web-based dashboard. Nevertheless, a fundamental limitation of the study lies in its exclusive focus on visual monitoring; it does not incorporate automated notification features delivered directly to users' personal devices. Consequently, critical information is only accessed when operators or residents actively check the monitoring website.

Another relevant study addresses IoT-based natural hazard monitoring, particularly through the development of an early warning system for landslide mitigation using displacement sensors. (G. Sugiyono; 2025) The researchers employed a Research and Development (R&D) methodology to design a prototype detection device. The results indicate that an early warning mechanism can be successfully implemented for identifying potential landslides. However, the relevance of this study to flood contexts remains limited due to differences in hazard characteristics (landslides versus flooding). Moreover, the system does not utilize instant messaging platforms such as WhatsApp for disseminating warnings, rendering its communication reach confined to more conventional methods.

Effectiveness of Information Dissemination Platforms and Notification Systems

The effectiveness of information dissemination to affected communities is a critical component of early warning systems. One study highlights the recurrent problem in which warnings fail to reach citizens promptly. Through case studies and questionnaire analyses, the researchers evaluated the effectiveness of various communication media(Tenda, E.P.; Lengkong, A.V.; Pinontoan 2021). Empirical findings indicate that WhatsApp is highly effective and widely preferred for disseminating emergency information due to its extensive user penetration across Indonesian communities. However, a major limitation of the system examined in the study is its dependence on manual data input. Because the system is not integrated with automated sensor-based detection, the speed and accuracy of message dissemination depend heavily on the responsiveness of personnel receiving field reports and manually composing messages—an approach vulnerable to human error and latency (S. Hanung; S. Imam; 2025).

Efforts to combine IoT technologies with early warning mechanisms have also been documented in systems designed to address flood hazards. Although these systems are capable of detecting flood events, their notification mechanisms still rely on legacy technologies, such as sirens or SMS. In contemporary communication environments, SMS is considered less effective, incurs higher operational costs, and is often disregarded compared to notifications from internet-based instant messaging platforms. Moreover, sirens are only effective within limited auditory ranges and fail to reach stakeholders located farther from the hazard zone. A related study discusses the integration of WhatsApp API for automated notifications triggered by predefined conditions. The study successfully demonstrates the feasibility of implementing API-based messaging automation, offering a significant reference point for system development. However, the application context pertains to managerial or administrative use cases rather than to disaster mitigation, where real-time responsiveness and life-safety urgency are paramount. Thus, there remains a need to adapt this automated notification technology to environmental hazard detection systems.

State of the Art

Based on the reviewed literature, several significant research gaps can be identified. Study exhibits strengths in sensor accuracy but lacks active notification capabilities (Wicaksono, A.M. et al 2021). Study, in contrast, recognizes the strengths of WhatsApp as a communication medium but does not incorporate automation, relying instead on manual input. Study employs IoT technologies yet continues to depend on conventional notification methods (SMS or sirens). Meanwhile, the sophisticated WhatsApp API technology demonstrated in study has not been applied in the context of flood early warning systems. To date, no integrated system combines high-precision sensing, real-time web-based monitoring, and automated WhatsApp notifications within a unified architecture for flood mitigation.

Building upon these identified gaps, this study proposes a state-of-the-art, fully integrated flood early warning system. The novelty of this research lies in the integration of three critical components:

a. Accurate detection using high-precision MaxBotix ultrasonic sensors and the ESP32 microcontroller
b. Real-time data visualization through a web-based dashboard for operator monitoring
c. Automated notification delivery using the WhatsApp API to transmit “Alert” or “Danger” warnings directly to residents’ personal devices without manual intervention

This integration ensures that water-level information is not only accurate but also disseminated rapidly (in real time) and through a highly accessible and personal communication medium. The proposed approach is expected to enhance community preparedness and reduce the impacts of flood hazards more effectively than previous methods.

RESEARCH METHODS

Method

The research employed the Research and Development (R&D) methodology, with the primary objective of developing a technological product in the form of a Web-Based Flood Early Warning System integrated with IoT and WhatsApp notifications . The R&D method was selected because it encompasses all stages of systematic product development, beginning with needs analysis and system design, followed by prototype construction, functional testing, and accuracy validation under real environmental conditions(G. Sugiyono; 2025).

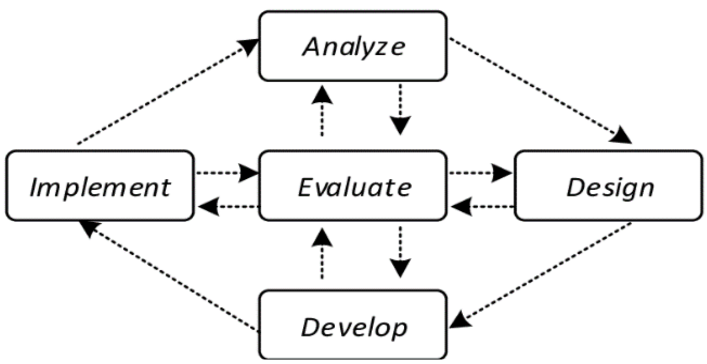

Figure 1. R&D Method

R&D constitutes a process involving the creation of new products or the refinement of existing ones. It is utilized to generate a specific product through a structured series of investigations and evaluations. Accordingly, this method is highly relevant for ensuring that the system developed is not only technically functional but also effective and reliable when deployed in actual field environments. The research followed the steps below:

a. Research and Information Collection: Field observations and interviews for problem identification and literature review related to IoT, WhatsApp-based notifications, and supporting technologies.
b. Planning: Formulation of system objectives (real-time monitoring, web dashboard, automated notification). Specification of hardware and software components. Determination of research scope.
c. Developing the Preliminary Product: Design of system architecture, workflow diagrams, and electronic schematics. Development of ESP32 firmware, Web API, database, and dashboard. Integration of WhatsApp API.
d. Preliminary Field Testing: Initial testing of sensors, Wi-Fi connectivity, data transmission, and database operations.
e. Main Product Revision: Debugging, sensor calibration, and dashboard refinement.
f. Main Field Testing: Accuracy testing of sensors and evaluation of notification speed; collection of user feedback.
g. Operational Product Revision: Analysis of test results and improvements to system logic and threshold parameters. Preparation of final documentation.
h. Operational Field Testing: Operational-level testing at the study site for full real-world validation.
i. Final Product Revision: Final revisions, including firmware optimization, dashboard refinement, and sensor recalibration.
j. Dissemination and Implementation: System deployment, user training, integration with local disaster response agencies (BPBD), and dissemination of research results.

System Overview

This study was conducted at the Cibeunying Ciateul Weir, located at Jl. Moch. Ramdhan No. 78, Ciateul Village, Regol District, Bandung City, West Java. The site is highly susceptible to flooding, especially during the rainy season when water levels frequently rise and inundate surrounding residential areas.

Figure 2. Research Location

The proposed early warning system is designed as an integrated framework that combines both hardware and software components to support continuous monitoring and real-time warning dissemination. The system architecture follows a client–server model. The client comprises IoT devices deployed in the field, consisting of an ESP32 microcontroller and a MaxBotix ultrasonic sensor responsible for automatically transmitting water-level data(Fadilah, F.D.; Putra, E.L.; Marzenda, I.; Albaab 2025).

The transmitted data are received by the server, which functions as the processing center. The backend infrastructure was developed using the .NET Framework, while PostgreSQL serves as the database for storing all recorded information (Dwiyanto, M.I.; Wardoyo, A.E.; Pater 2025). Processed data are presented through two main interfaces which, a web-based dashboard for monitoring by administrators or authorized personnel, and early warning notifications distributed to the community via the WhatsApp API.

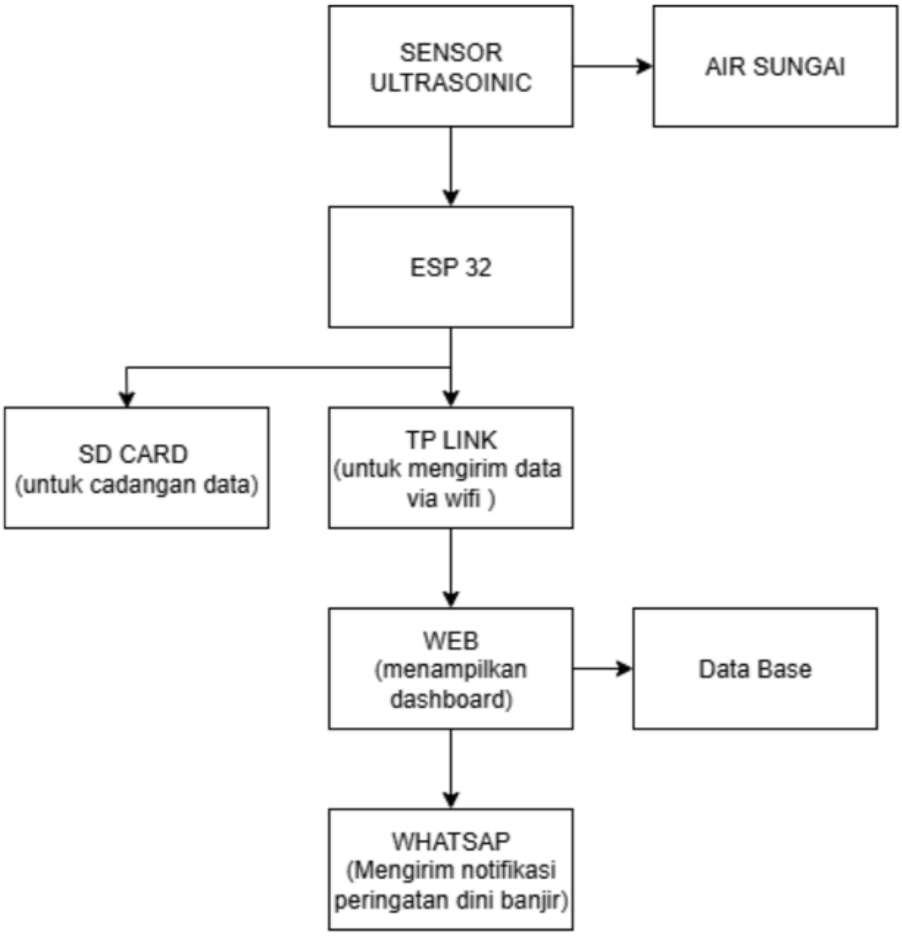

Figure 3. System Block Diagram

a. Local Measurement and Logging (Field Unit)
   1) The MaxBotix ultrasonic sensor continuously measures water surface height.
   2) Measurement data are sent to the ESP32 microcontroller for initial processing.
   3) The ESP32 performs two primary functions:
      a) Local Data Logging via SD Card Module: Serves as a data logger to ensure data preservation in the event of internet disruption.
      b) Real-Time Data Transmission: Utilizes the built-in Wi-Fi module to send data to a TP-Link modem for network access.

b. Connectivity and Data Transmission
   The TP-Link modem serves as the gateway connecting the IoT device to the internet, enabling continuous data transmission to the server.

c. Server-Side Processing (Cloud)
1) Field data are received by the web server application.
2) The application automatically stores all incoming data into the database.
3) The server then executes core system logic, including analysis of water levels to determine whether predefined thresholds have been exceeded.

d. Presentation and Notification (User Interface)
1) The website retrieves data from the database and presents it in graphical or dashboard formats accessible to administrators.
2) When hazardous conditions are detected, the system automatically sends early warning notifications to registered residents via the WhatsApp API.
3)

Device Design

The design of the electronic circuitry aims to visualize the physical connections among all hardware components. The resulting schematic serves as a technical blueprint for assembling the IoT prototype, illustrating detailed pin-to-pin configurations between the microcontroller, sensors, and peripheral modules(Asri, M.; Abdussamad 2023). This schematic ensures that all components operate as intended and minimizes potential implementation errors.

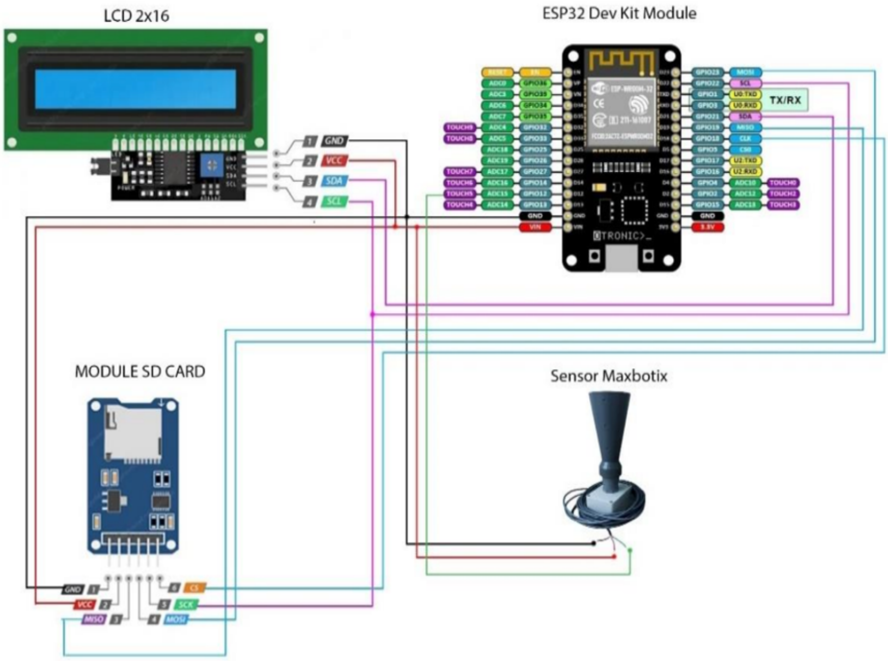

Figure 4. Device Schematic

The system employs the MaxBotix MB7389 ultrasonic sensor as the primary water-level measurement device due to its extended range of up to 10 meters and its high accuracy. Sensor outputs are processed by the ESP32 microcontroller, selected for its capability to handle Wi-Fi connectivity and simultaneous data processing (Al'Aziz, R.M.; Rifai 2024). For data transmission, the system uses the HTTP communication protocol to send measurements to the server. The hardware configuration is powered by a 5V/2A power supply equipped with a backup battery, ensuring uninterrupted operation even during power outages.

Testing Parameters

To maintain system focus and effectiveness, this research utilizes a single key physical parameter for flood detection: water surface height, obtained in real time from the field-deployed ultrasonic sensor as seen in Fig. 5.

Figure 5. Sensor Measuring Water Level

This parameter functions as the primary indicator because it measures the vertical distance between the sensor and the water surface. The resulting distance values are used to calculate the actual water level continuously (Iqbal, M.; Rosadi, A.; Andana 2023). Time-of-flight: The duration required for emitted ultrasonic waves to return to the sensor after reflecting from the water surface. Also 0.000343 m/µs: The speed of sound in air, converted to meters per microsecond. A systematic accuracy testing procedure was designed to ensure valid results. Data collection was conducted by placing the ultrasonic sensor and a manual measuring tool side by side at the same location, allowing simultaneous measurements of water height.

Figure 6. Accuracy Testing Procedure

Measurements from both methods were recorded in a test table containing timestamps, manual measurement values, and sensor readings (Pratama, N.; Darusalam, U.; Nathasia 2020). The procedure was repeated across multiple water-level conditions as shows in

Fig.6 to evaluate consistency and reliability. Quantitative analysis was performed using a acuration formula to compute sensor accuracy, reflecting the degree of similarity between sensor outputs and manual measurements.

RESULTS AND DISCUSSION

System Deployment

The prototype was deployed at the Cibeunying Ciateul Weir, Bandung. The hardware integrates an ESP32 microcontroller with a weather-resistant MaxBotix MB7389 ultrasonic sensor, housed in a waterproof panel containing a 4G LTE modem and SD card for local data logging .

Figure 7. System Implementation

Fig. 7 shows the unit was mounted on a midstream support pole to ensure perpendicular measurement to the water surface and minimize edge interference.

Information System Integration

A web-based dashboard serves as a command center for monitoring personnel. Key features include:

a. Geospatial visualization using Google Maps API, enabling rapid assessment of multiple sensor locations via interactive markers

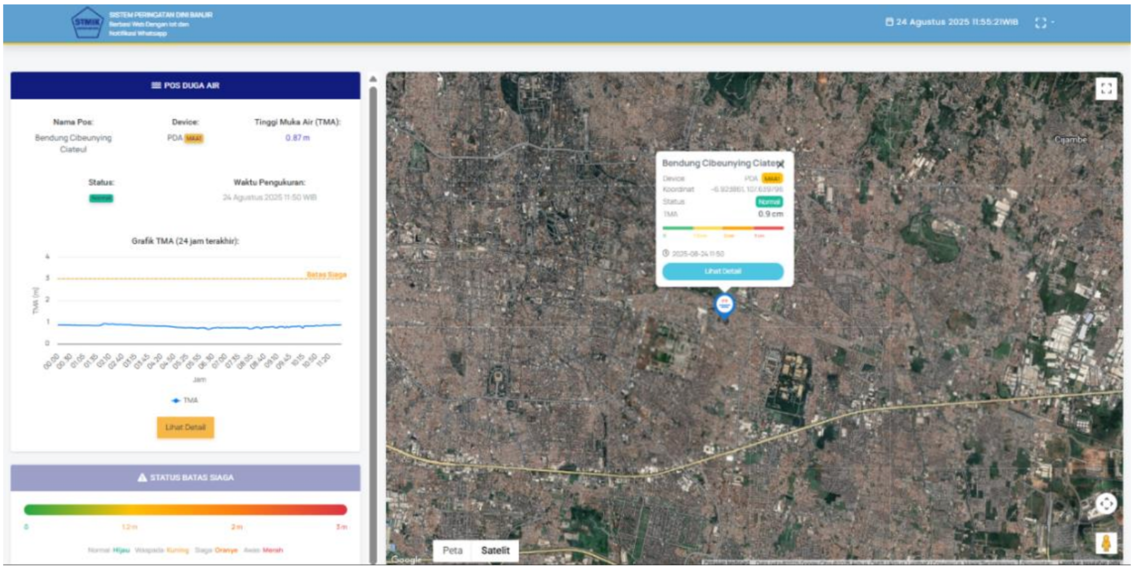

Figure 8. WEB Dashboard

Fig. 8 shows 24-hour line charts displaying water-level trends, highlighting rapid rises to facilitate proactive decisions

b. Tabular telemetry with timestamps and water-level values for auditing and reporting. Threshold lines provide visual cues shown in Fig.9 for water-level status (Normal, Alert, Danger), supporting immediate situational awareness.

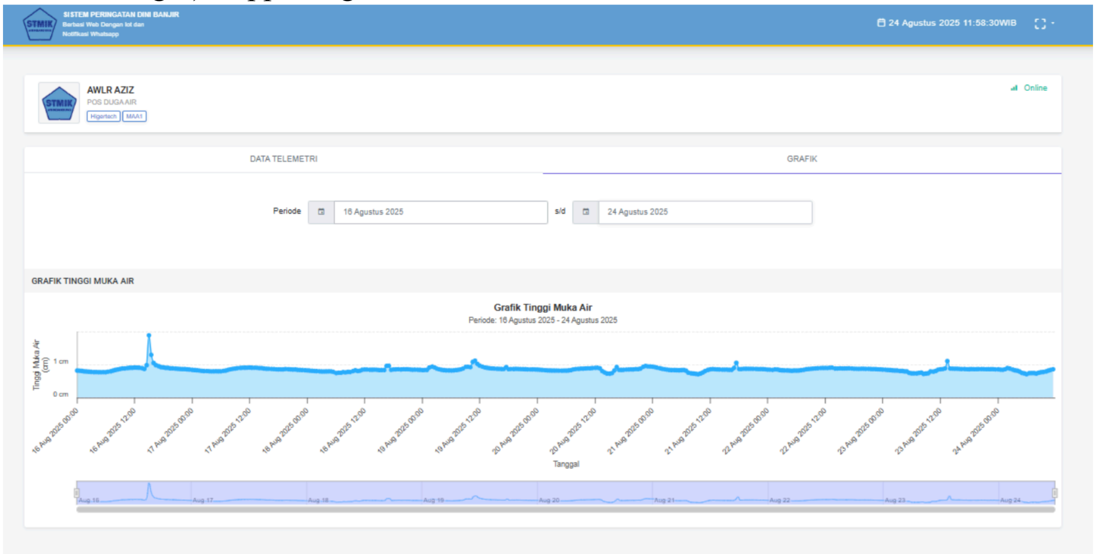

Figure 9. Tabular Telemetry

WhatsApp API Notification Effectiveness

Integration of the WhatsApp API achieved real-time alert delivery. The server processes incoming sensor data against pre-set thresholds (Normal <1.0 m; Alert 1.0–1.5 m; Danger >1.5 m). Upon exceeding thresholds, messages are dispatched with minimal latency (seconds), providing critical lead time for residents. An anti-spam algorithm prevents repeated notifications during marginal fluctuations. Field validation demonstrated effective messaging dynamics: routine "Normal" updates were sent periodically, while sudden rises triggered immediate "Alert" notifications, with automatic updates when conditions returned to normal.

Sensor Accuracy and Reliability

Testing across multiple sessions in August 2025 showed high precision of the MaxBotix MB7389 sensor, with average accuracy exceeding 99%. Minor deviations (1–5 cm) were attributed to surface ripples, temperature and humidity variations, and digital rounding, all within acceptable tolerance for flood early warning. Importantly, these deviations do not compromise threshold-based alerting, validating the system's reliability under field conditions.

User Evaluation

End-user feedback from 11 local residents and community leaders indicated strong acceptance and usability. Approximately 91% rated the WhatsApp notifications as clear and easy to understand. Over 80% reported increased preparedness and confidence, highlighting the system's psychological and practical benefits. Minor lower ratings (9.1%) suggest areas for further socialization and training during initial deployment.

CONCLUSIONS AND SUGGESTIONS

The results of this study show that the proposed system effectively addresses key limitations found in prior research. Unlike Wicaksono et al. (2021), which relied solely on web-based visual monitoring, this system integrates automated WhatsApp notifications, providing a more actionable early warning mechanism for residents. Compared with approaches using SMS or sirens, WhatsApp API delivers richer, time-stamped information at lower operational cost and with broader accessibility. The system also resolves the dependency on manual reporting observed in Harahap (2024) by implementing a fully automated sensing-to-notification pipeline, thereby eliminating delays and human error. Field testing confirmed that alerts were transmitted promptly during critical water-level increases. The MaxBotix ultrasonic sensor demonstrated high accuracy under outdoor conditions, while the PostgreSQL–.NET architecture maintained stable performance with no data loss, indicating strong feasibility for real-world deployment. Overall, the IoT- and WhatsApp-based early warning system fulfills its intended objectives: accurate flood detection, real-time data delivery, and rapid dissemination of alerts to the surrounding community. The system represents a practical and scalable technological solution for reducing flood risk at the Cibeunying Ciateul Weir.

Further research should explore (1) integration of multi-parameter sensing—such as rainfall intensity, river discharge, or turbidity—to improve hazard prediction; (2) the use of machine learning for forecasting flood onset; (3) redundancy mechanisms such as LoRaWAN or cellular fallback to ensure continuity during network outages; and (4) multi-channel alerting that includes mobile apps, loudspeakers, and government platforms to expand communication coverage. Such enhancements would strengthen system robustness and broaden its applicability across diverse flood-prone regions.

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