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Prototype Development of a Water Level Detection System with an Emergency Light Pole and Real-Time Flood Alerts Powered by a Solar Panel Using an ESP32 Microcontroller

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ABSTRACT

Flooding is one of the most damaging natural disasters, especially in the Philippines because to its placement in the Pacific Typhoon Belt, rapid urbanization and insufficient drainage infrastructure. This serious problem is addressed in this work by proposing and evaluating a low-cost solar-powered water-level sensor system with real-time alarm system and an emergency light pole. The device is powered by an ESP32 microcontroller, the "brain" of the system with Wi-Fi built-in. The water level sensor is constantly looking for rising water. If the water level crosses the set limits, the system activates the localized warnings immediately. Localized warnings are active buzzer and LCD display. Additionally, a special emergency light pole typically produces a steady white light, but turns to red to indicate a quick evacuation during crucial situations. At the same time the ESP32 sends live wireless alerts to the neighborhood. It is powered by a sustainable, off-grid power configuration using a solar panel, 12V lithium ion battery and a step-down converter to ensure system does not fail during extreme weather and power outages. The prototype has proven to be quite reliable in experimental tests. The device is able to deliver wireless notifications within one second and 100 % accuracy in critical water level detection. Moreover, the emergency light pole worked very well since it was in good view at all flood stages from 20 m away. The prototype is a practical, durable and highly effective supplementary early warning tool to boost disaster resilience in vulnerable populations at about PHP 2,120.00.

Keywords: Flood Monitoring, Water Level Detection System, ESP32, Solar Power, Early Warning System.

INTRODUCTION

Flooding is one of the most common and devastating natural disasters, especially in many Asian cities such as the Philippines. This is especially true for coastal and low-lying areas, where property, infrastructure and livelihoods are severely damaged and even lives are lost. According to Asian Disaster Reduction Centre (ADRC, 2010), Asia has the highest number and the greatest proportion of people affected by natural disasters in the world. Floods, among these hazards, are among the most frequent and devastating events, causing extensive damage to communities, infrastructure, and economic activities. The Philippines is one of the most disaster-affected countries in the world. Its location in the Pacific Typhoon Belt exposes it to severe weather disturbances and flooding. Poor drainage systems, rapid urbanization, and large-scale rainfall incidences in many parts of the country are aggravating flood threats. Such conditions demand a reliable flood monitoring and early warning system to provide timely information to the public and authorities. They can be used to help enhance disaster preparedness and reduce the impact of flooding on communities whilst minimizing damage.

As climate change intensifies and increases the frequency of floods worldwide, flood monitoring technology and early warning systems are increasingly critical for disaster preparedness and response. A novel approach to this issue is to combine water-level sensors with microcontroller systems, such as the ESP32. Similarly, the Arduino-based Flood monitoring systems were discussed by Wan Hassan et al. (2019), where the ESP32 is a low-cost, efficient, and flexible platform for real-time data monitoring and wireless communication.

The objective of this study is to design and develop a water-level detection system with a real-time alert function using an ESP32 microcontroller and solar-powered water-level sensors. Furthermore, installing solar panels provides a sustainable and reliable source of power, especially during emergencies and power outages caused by extreme weather events. The system also includes a light pole with emergency lighting to provide illumination during flooding incidents, especially at night or during power outages. The emergency light is a visual warning device that can be very helpful in assisting residents to identify flooded areas, evacuation routes, and dangerous locations in the event of an emergency. The system is intended to continuously monitor water levels and alert users immediately when the level reaches a critical threshold. With this innovation, the researchers hope to help improve community-based flood preparedness, promote disaster resilience, and provide a cost-effective means for flood monitoring in disaster-prone areas.

The ESP32 is also the main controller, or "brain," of the system, processing data and controlling the device's operation. The ESP32 is a powerful microcontroller with built-in Wi-Fi and Bluetooth, making it a perfect choice for real-time monitoring and wireless communication. To accurately measure changes in water level, the researchers developed a smart flood monitoring device equipped with an ESP32 and a water level sensor. When the water level reaches a certain level, the system sends real-time alerts to warn residents and authorities of possible flooding. The researchers also integrated a solar panel as the system's main power source, so the system can continue to operate even if power is cut off due to severe weather. Solar power makes the device more sustainable, energy-efficient, and reliable for long-term outdoor use. The water level sensor continuously monitors rising water levels in flood-prone areas. Now the ESP32 gets the data and triggers the alert function as required. The installed light pole with emergency lighting automatically activates in critical situations to enhance visibility and safety for affected communities.

This project aims to help communities be more prepared and responsive during heavy rainfall, typhoons, and flooding incidents in the Philippines. The researchers intend to create a low-cost, scalable, and efficient flood monitoring and early warning system by combining ESP32 technology, water level sensors, solar-powered energy systems, and emergency light poles. This innovation seeks to contribute to disaster risk reduction efforts, improve public safety, and lessen the impact of flooding in vulnerable communities.

Scope And Delimitation

This study is about the development of a solar-powered flood monitoring and early warning system. It consists of an ESP32 microcontroller, water level sensors, and an emergency light pole. The siren is employed to warn residents of low-lying and coastal areas of rising water levels. The device constantly monitors these levels and issues real-time alerts, so communities are prepared to evacuate quickly in floods.

The scope of work includes design, construction, programming, and testing of the prototype. It has a standalone solar panel for uninterrupted operation during severe weather conditions and power cuts. The integrated emergency light pole also serves as a visual warning device, enhancing visibility of nighttime flood events.

Regarding limitations, the system performs extensive checks on water levels and sends alarms when thresholds are reached. It does not predict weather conditions, forecast the occurrence of floods or estimate the severity of floods. This prototype is limited in scope and range compared to highly advanced infrastructure, such as the established Marikina City water level monitoring system. This localized prototype cannot replace the existing Marikina system, which remains much more effective for modern city-wide disaster management. This device only functions as an auxiliary device. It can supplement existing official emergency systems by providing a low-cost, localized warning system for smaller, vulnerable sectors. Finally, prototype testing is restricted to controlled environments that may not accurately reflect real flooding events.

METHODOLOGY

This section explains the research design and system architecture of the automated, off-grid flood monitoring prototype. It is a hardware-software co-designed solar-powered water-level detector. The system also includes real-time Wi-Fi alerts and a color-changing emergency light pole for high visibility.

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The system is controlled with an ESP32 Development Board. It continuously reads distance measurements from a water level sensor. The ESP32 triggers local alarms when the water reaches certain levels. These include a 16x2 LCD, an active buzzer, and LED indicators, utilizing warning mechanisms similar to those evaluated by Magnaye et al. **(**2024**)**. Meanwhile, the built-in Wi-Fi module sends notifications to the internet instantly. This feature relies on a localized Wi-Fi network, and the credentials must remain active to prevent interruptions to alerts. In addition, the ESP32 dynamically controls the elevated emergency light pole. It emits a constant white light in normal weather and blinks bright red when critical levels are reached, indicating an immediate evacuation.

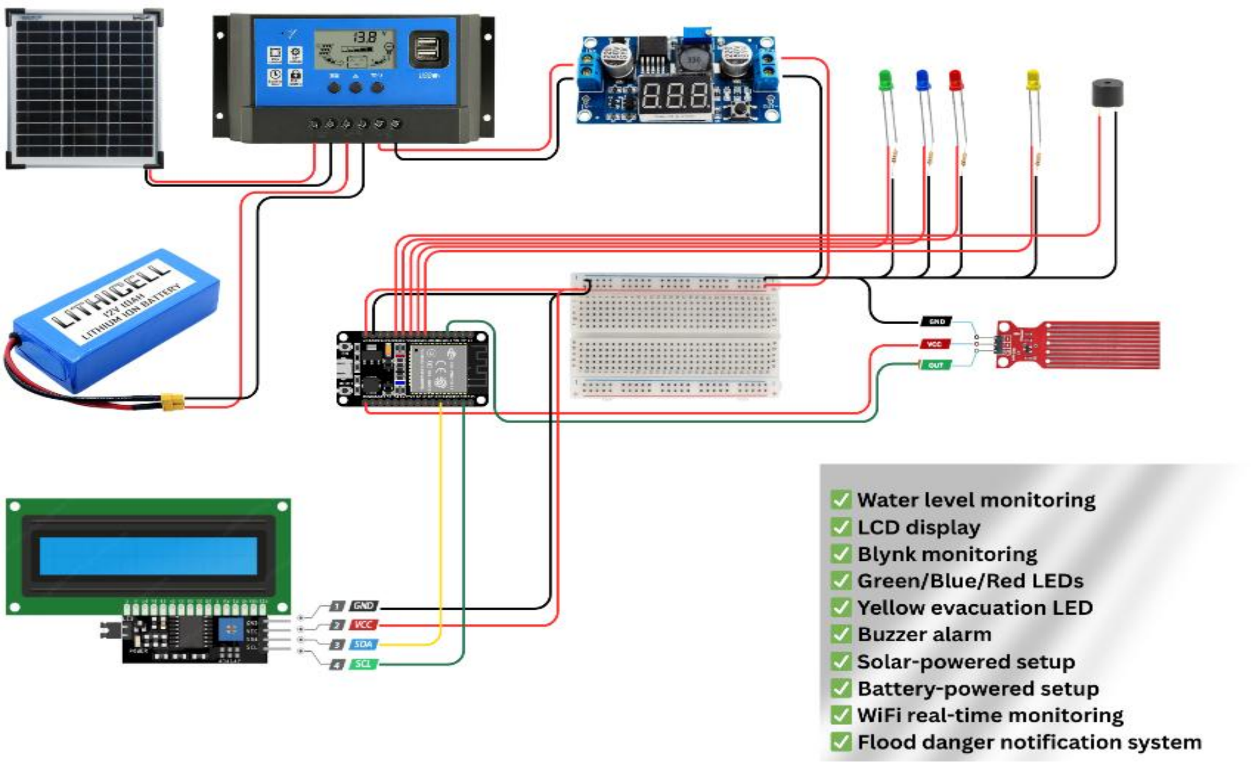
And an independent solar power setup means you'll be able to use it even when the power is out. A solar charge controller is used to charge a 12V battery from a solar panel. The battery output is regulated to a stable 5V by an LM2596 Buck Converter. This supplies safe power to the sensitive electronic components.

Research Process: Stage Preparation and Component Acquisition

The development of the system required several major hardware components. Adapting the foundational hardware requirements for automated water level alarms presented by Magnaye et al. **(**2024**)**, this project includes a 30-pin ESP32 Development Board, a water level sensor, and a 16x2 I2C LCD. It requires green, blue, and red LEDs, an active buzzer, 220Ω resistors, and basic wiring. The power and casing consist of a 12V battery, a solar panel, a charge controller, an LM2596 buck converter, and a modified plastic storage box.

The choice of materials was based on the experience gained in the circuitry and programming laboratory in the BSCPE programmer. The main electronic modules were purchased from specialized online shops to keep costs down. The plastic storage box and mounting hardware were locally sourced to create a weather-resistant enclosure. A detailed budget was kept to evaluate the project's economic viability. Total expenses for all materials and components were PHP 2,120.00.

Figure 1. Schematic Circuit Diagram of Wiring Layout Diagram.



Stage 2: Building and Development of the Project

The prototype was constructed physically, and the software was written in two to three weeks. The ESP32 development board was selected for its efficient environmental monitoring. It is Wi-Fi enabled and hence very suitable for IoT-based disaster response systems.

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The building started with hardware integration. The water level sensor used was an ESP32 to accurately read the changing water levels. The microcontroller was connected to the LCD, active buzzer, and LED indicators for local monitoring. And they installed an automated emergency light pole that changed color for maximum visual warning. Meanwhile, the autonomous power subsystem has been constructed. The solar panel powers a charge controller that recharges the 12V backup battery. After that, we calibrated the LM2596 buck converter to have a steady 5V output.

Once the hardware was assembled, the ESP32 was programmed with the Arduino IDE. The code runs in a loop, reading the sensor data and setting the baselines for normal conditions. It also provides for warning and critical flooding levels. If water levels exceed these limits, automated actions are triggered by conditional statements. These include updating the LCD, buzzing the buzzer, and changing the color of the emergency light post. Also, it allows sending real-time wireless notifications to identified recipients through the Wi-Fi module.

Finally, all internal electronics were safely housed in the modified plastic storage box to protect the wiring from water and rain. The emergency light pole was mounted outside to improve visibility. Then the finished assembly was tested under control first. This confirmed sensor accuracy, changes in light color, and Wi-Fi alert sending.

Figure 2: System Flowchart of the ESP32 Water Level Detection System

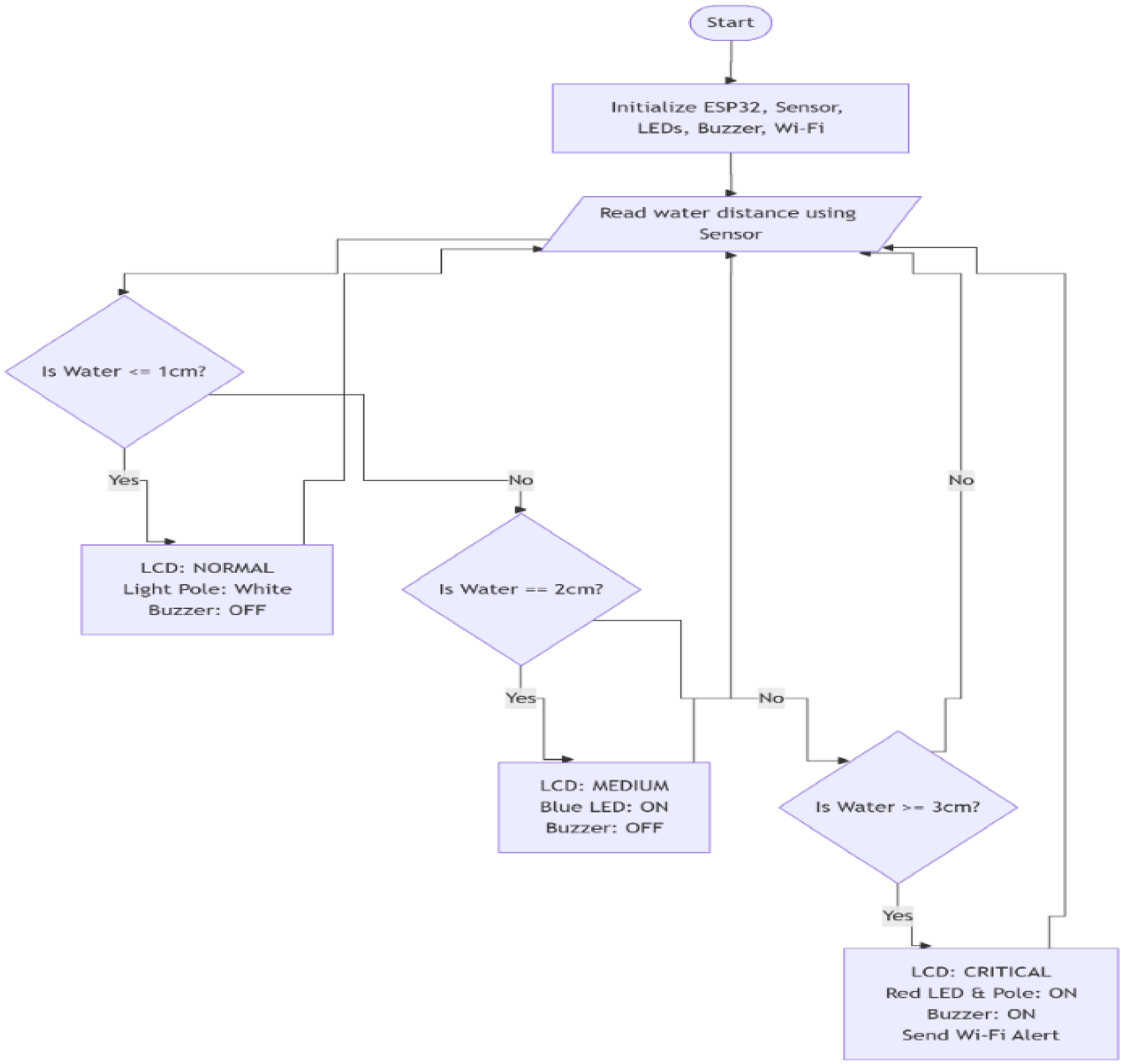

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Figure 3. Actual Product of the Solar-Powered Water Level Detection System with Real-Time Flood Alerts and Emergency Light Pole

Stage 3: Experimental Stage, Observation, and Data Recording

The experimental phase was used to test the prototype's operational performance and responsiveness. **T**he system was installed on a controlled water reservoir. This enabled the researchers to safely test real-time water-level fluctuations before deployment.

Initial tests have been conducted to calibrate the water level sensor for proper threshold detection. System accuracy was verified visually using a 16x2 LCD. The researchers monitored whether the LED indicators accurately turned on at the specified low, medium, and high water levels. Also tested was the ESP32's communication capability. The researchers measured the exact response time in seconds. This measured the lag between crossing a critical threshold and the delivery of the Wi-Fi alert.

Output components were confirmed to be synchronized through visual and auditory observations. Researchers recorded system behavior under different water levels. Normally, they kept the emergency light pole steadily lit white. They said that in critical moments, the buzzer was activated immediately, and the pole was changed to a red signal evacuation. The power circuit was carefully monitored during these tests. Researchers also tested the LM2596 Buck Converter and confirmed that it consistently gives a stable 5V output. This stability prevented the microcontroller from resetting when high-draw components were powered on simultaneously.

To preserve data integrity, each trial was recorded on structured observation sheets. And a lot of multimedia evidence was assembled. These included photographs and video recordings of the system outputs and the assembly process, which acted as the actual proof of the prototype's real-world functionality

RESULT AND DISCUSSION

Table 1: Status of the Automated Flood Water Level Sensor and Alarm System using ESP32 in terms of Accuracy

Accuracy of the Water Level Sensor and Alarm System

Trial	LED Status (White, Blue, Red)	LCD Status Display	Buzzer Status (ON / OFF)	Actual Water Level (cm)	Measured Water Level (cm)	Difference (cm)	Accuracy
1	WHITE	NORMAL	OFF	4cm	1cm	3	25%
2	GREEN	MEDUIM	OFF	4cm	2cm	2	50%

3	BLUE	WARNING	ON	4cm	3cm	1	75%
4	RED	DANGER	ON	4cm	4cm	0	100%
Average						1cm	75%

Table 1 shows the actual water level in comparison with the measured water level. Note that in this project, each centimeter (cm) in the prototype corresponds to one foot (ft) in actual flood conditions. Thus, an actual water level of 4 cm represents an equivalent of 4 feet of water height. As shown in Table 1, as the water level increases, the proposed flood water level sensor and alarm system appropriately responded by changing LED colors, displaying new messages on the LCD monitor, and sounding a buzzer when required.

Trial 1 measured water level was 1 cm (4 ft equivalent), 3 cm (3 ft) variation, and 25% accuracy from the real reference water level of 4 cm (4 ft). The system showed NORMAL status and triggered white LED with buzzer OFF indicating a normal water level. In the Trial 2, the measured water level was 2 cm, therefore we found the difference was reduced to 2 cm and the accuracy was improved to 50%. The system performed the correct actions of displaying MEDIUM status , turning on the green LED and maintaining buzzer OFF thus showing that it was able to identify varied water levels . The measured water level in the Trial 3 was 3cm with a difference of only 1cm. The system performed an increase in accuracy to 75%, accurately displayed the CRITICAL state on the LCD, actuated the blue LED and sounded the buzzer. For the last trial, Trial 4, the measured water level was 4 cm, resulting in a difference of 0 cm and an accuracy of 100%. So the LCD showed DANGER, the red LED was on, and the buzzer was ringing, signaling the current scenario was in great danger.

Table 2: Response Time of the Alert System

Trial	Water Level Reached Threshold	Alert Sent (Yes/No)	Response Time (seconds)
1	1cm	Yes	1
2	2cm	Yes	1
3	3cm	Yes	1
Average			1

In the experiment, the response time across all trials was consistently 1 second. Thus the system is quite reliable when it comes to sending a prompt warning when the target water level has been reached. This quick response of 1 second may be majorly ascribed to the efficient processing capability of the ESP32 microcontroller and its in-built Wi-Fi module which significantly reduces latency during wireless data transmission. This suggests that the designed water-level detection system can warn of imminent floods nearly instantly. This feature makes it incredibly efficient since in such circumstances early warning is vital to make sure preventive measures are performed before any damage is done. In conclusion, the results show that the alert system is efficient and dependable.

Table 3: Performance of the Solar System

Trial	Solar Panel Voltage (V)	Battery Voltage (V)	System Status
Morning	10V	11.5V	NORMAL
Noon	10V	12V	NORMAL
Afternoon	10V	12V	NORMAL
Evening	10V	11V	NORMAL

As seen in Table 3 above, the Solar panel gave a steady measurement of 10V output over the observation time. This steady 10V reading is likely a regulated voltage level being communicated to the charge controller to protect the electronics. On the other hand, the voltage of the battery was between 11V and 12V which means that the battery has enough electrical energy stored for continued operation. The maximum voltage of the battery 12 V was obtained around noon and in the afternoon due to the best exposure to the sunshine. The lowest battery voltage was 11.5V in the morning and 11V in the evening due to the limited amount of solar energy received. However, the system was normal since there was a DC step-down converter, which changes the high voltage to a low, safe voltage. Overall, the results proved the solar energy source can efficiently maintain the system operation and provide the continuous operation and power availability during the day.

Table 4: Effectiveness of the Emergency light Pole

Trial	LED Status	Water level Status	Emergency Light Activated (Yes/No)	Visibility Distance (meters)
1	White	Normal	Yes	20m
2	Green	Medium	Yes	20m
3	Blue	Warning	Yes	20m
4	Red	Danger	Yes	2om
Average				

Table 4 shows the efficiencies of the Emergency Light Pole for the different water level. As can be seen in Table 4, the Emergency Light Pole was successfully activated in all four trials. This implies that the system performed well regardless of the water level measured. So when the water level changed, the color of the LED changed accordingly.

On the first try the system was showing the typical water level with the white LED. In this trial, the emergency light was successfully lightened and the visibility distance was 20 meters, which means that the system could provide illumination and direction even under normal conditions.

In Trial 2 the water level was medium and the system was showing a green LED . The emergency light was effective and visibility was 20 meters. Trial 3: Blue LED indicates water level condition approaching the alert level. The emergency light was turned on (visibility distance of 20 meters) for this trial. In Trial 4 the danger threshold was reached and the system showed the red LED as a result. Even under such difficult conditions the emergency light was still fully functional at a sight distance of 20 meters. Therefore, the results indicated that the Emergency Light Pole was 100% functional. The constant visibility distance of 20 m and the repeated activation of the emergency light indicate that the visual warning system was very efficient at all flood levels.

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CONCLUSION AND RECOMMENDATION

This study designed and developed a Solar-Powered Water Level Detection System and Emergency Light Pole with Real-Time Flood Alerts using an ESP32 microcontroller. The developed prototype was capable of monitoring the water level changes, providing real-time flood alerts, and activating visual warnings through the emergency light pole whenever critical water levels were detected. The incorporation of solar power may still enable the system to be functional during power interruptions, thus making it more reliable during emergency situations. The tests and evaluations carried out showed that the system was able to detect changes in water level and respond to the set warning thresholds. The ESP32 efficiently managed sensor data, enabling timely alert transmission. In general, the study objectives were successfully met and provide evidence on the developed prototype that can provide an economical, practical, and reliable flood monitoring and early warning system for flood-prone communities.

Future researchers can also consider adding a water-flow velocity sensor to the developed system to measure the velocity of rising or flowing water during flooding events. Also, other features may be integrated to estimate the rate of water-level rise and the time interval between water-level changes, which can provide more useful information for flood monitoring and response planning. Also, more sensors can be added at various locations and integrated with the monitoring platform to improve the system's accuracy, reliability, and coverage. These improvements may provide more detailed information about floods, thereby enhancing the overall effectiveness of the system in supporting flood preparedness and early warning efforts.

REFERENCES:

1. Asian Disaster Reduction Centre. (2010). Information on disaster risk reduction of the member countries. Asian Disaster Reduction Centre.
2. Crucillo, E. E., & Lucero, H. R. (2026). FEWS: IoT-based flood early warning system for Barangay Doña Imelda, Quezon City. Research and Scientific Innovation Society.
3. Diakakis, M., Boufidis, N., Salanova Grau, J. M., Andreadakis, E., & Stamos, I. (2020). A systematic assessment of the effects of extreme flash floods on transportation infrastructure and circulation: The example of the 2017 Mandra flood. International Journal of Disaster Risk Reduction, 47, 101542. https://doi.org/10.1016/j.ijdrr.2020.101542
4. Faturochman, W., Dauni, P., & Abdurrohim, I. (2025). Design of flood early warning monitoring system using a ESP32 microcontroller ultrasonic sensor based on website and telegram chat bot. Jurnal Elektronik Sistem Informasi.
5. Jose, J. P., & Joseph, J. (2025). Real-time IoT-based flood detection using ESP32 a scalable and low-power solution for risk mitigation. International Journal of Science and Research (IJSR), 14(4).
6. Koyun, A., et al. (2025). A real-time water level and discharge monitoring station: A case study of the Sakarya River. MDPI Applied Sciences, 15(4), 1910. https://www.mdpi.com/2076-3417/15/4/1910
7. Magnaye, A. A. B., Cruz, S. M. S., Reguyal, V. X. M., Ascaño, A. J. L., Quilit, M. A. A., & Limos-Galay, J. A. (2024). Automated flood water level sensor and alarm system using Arduino Uno. International Journal of Research Studies in Educational Technology, 8(3), 61–69.
8. McClean, D. (2010). World disasters report 2010: Focus on urban risk. International Federation of Red Cross and Red Crescent Societies.
9. Umari, C., Setiawan, A., & Widodo, P. (2024). Design of flood warning prototype using ESP32 module-based ultrasonic sensors. Scribd Repository.
10. YPMMA Research Group. (2026). Designing a solar-powered IoT-based flood early warning system prototype with audio-visual alarm for Aceh region. Journal YPMMA.