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Research Paper

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Water Depth Monitoring based on Affordable Modem to Prevent Flooding and Wildfires, Study Case in Teluk Seruo Lake, Indonesia

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Abstract
A cutting-edge telemetry system for water depth monitoring is essential for achieving effective and reliable measurements through bidirectional communication. This system is designed to operate at any time requested by the user, enhancing the relevance of the collected data while promoting significant energy and memory savings. We propose implementing this innovative design at a Teluk Seruo Lake, featuring advanced flood and drought warning functions to proactively address the challenges of seasonal natural disasters. Using an Arduino board paired with an ultrasonic sensor and equipped with a Wi-Fi modem, users can seamlessly communicate with their smartphones to initiate measurements and access real-time water depth data via a dedicated website. Our laboratory tests confirm that timely alerts were successfully sent to users' phones whenever water levels exceeded critical thresholds. Furthermore, during field tests, continuous monitoring of the lake's water depth was efficiently conducted through the website, powered by 8400 mAh batteries that supported up to 75 data transmissions over a 12.5-hours period. This remarkable performance establishes a solid baseline for modem power consumption, underscoring the system's effectiveness and reliability.

Keywords
Bidirectional Communication, Node MCU, Telemetry, Ultrasonic Sensor, Water Monitoring, Website

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1. INTRODUCTION

Monitoring water levels is a crucial activity for various purposes, including ensuring product quality in industrial systems (Santosh et al., 2020), achieving optimal rice production in paddy fields (Xiao et al., 2013; Maneekul and Suwannapong, 2017; Saptomo et al., 2023; Morchid et al., 2024), mitigating flood risks in cities along riverbanks (Mousa et al., 2016; Yunita et al., 2020; Machefer et al., 2022; Susanti et al., 2024), and managing water distribution networks in communities (Loizou and Koutroulis, 2016; Shi et al., 2021; Singh et al., 2021; Bathre and Pradipta, 2022). Traditional monitoring methods are often ineffective and expensive due to the reliance on manual data collection, which requires measurements to be taken at precise locations and times. To address these limitations, water level monitoring should utilize telemetry systems, which can minimize the challenges associated with manual measurements (Idris et al., 2016; Jones, 2024; Panyadee and Champrasert, 2024). A telemetry design for water depth monitoring should incorporate bidirectional communication links, enabling real-time data access for users from any location and at critical times.

The devices employed for gauging water levels were classified into several categories: hydrostatic pressure sensors, radar level meters, optical fiber sensors, laser-based measurement tools, capacitive sensors, and ultrasonic sensors (US) (Mohindru, 2023). Among these, the US is the most commonly employed due to its high accuracy. Typically, these sensors are controlled by microprocessors that gather data before storing it in digital memory. In 2018, Natividad and Mendez (2018) developed an early warning system for flood risks using US technology and an Arduino connected to a GSM module, which communicated alerts to citizens in the Philippines via SMS. In 2019, Diriyana group combined US with the NodeMCU-Esp8266 to create an early flood warning system that utilized the Telegram application (Diriyana et al., 2019). The research group from Brazil, Pereira et al. (2022) installed five ultrasonic sensors in a chamber with flowing channels to validate the sensor's accuracy in turbulent water conditions, although this research did not include any form of data transmission.

This paper presents an affordable telemetry system aimed at monitoring water depth in Teluk Seruo Lake in South Sumatera, Indonesia. This lake is located 4.5 km from the University of Sriwijaya campus. Implementing this system is essential to mitigate flooding during the rainy season and prevent wildfires in the summer. South Sumatra is particularly susceptible to these disasters every year, largely due to its 1,262,000 hectares of peatland (Lestari et al., 2021; Irfan et al., 2024; Indonesian Ministry of Environment and Forestry, 2024). Effectively monitoring water levels in these areas, including peatlands, lakes, and other bodies of inland water, allows officials to be alerted when water levels exceed maximum thresholds to prevent flooding or fall below minimum levels to avert wildfires. It is well recognized that low moisture conditions can lead to fire risks, making minimum water depth a crucial indicator for predicting potential dangers (Taufik and Setiawan, 2011).

To construct an affordable water depth monitoring system, we developed a setup using an Arduino board and US, featuring a bidirectional communication system that employs radio frequency to connect users with data. Users can initiate measurements through commands on a website (downlink) while data is displayed on the website via uplink communication, allowing for data collection at any time from any location. A research group Moreno et al. (2019) previously reported a river water level monitoring device based on a microcontroller and the US, which sent data to a website every five minutes using one-way mobile communication. We believe that conducting measurements during significant events, such as intense downpours or sweltering afternoons, is more effective and energy-efficient than relying on a pre-set automated schedule. This focused data collection strategy conserves digital memory for data storage. Therefore, implementing bidirectional communication is vital for achieving an effective, efficient, and environmentally friendly monitoring system.

2. EXPERIMENTAL SECTION

2.1 Materials

Figure 1 is the hardware design of a low-cost modem we proposed in this work. There are two batteries with 4200 mAh capacities used to supply power for the electronic components inside the modem: HC-SR04 as the water depth sensor; Node MCU ESP8266 as the microcontroller which collect the sensor data and send them to the website; while TP4056 and T6845 boards were used as power manager to maintain the voltage source of the circuits keep stable at 5 V. On the other side of software design, we developed the code for Node MCU using Arduino IDE version 2.3.3. It managed data input and control, before efficiently handled communication between the modem and the user. The system delivers real-time alarm signals directly to the user's smartphone through the WhatsApp application, ensuring immediate awareness of water level changes. Therefore, data acquisition strictly adheres to the architecture illustrated in Figure 2. The website seamlessly retrieves sensor data using the HTTP protocol embedded in the Node MCU for uplink communication, while the downlink facilitates users-who activate the start button on the website-sending instructions to the Arduino where the sensor is installed. This innovative approach not only enhances monitoring capabilities but also empowers users with timely alerts to manage water levels effectively.

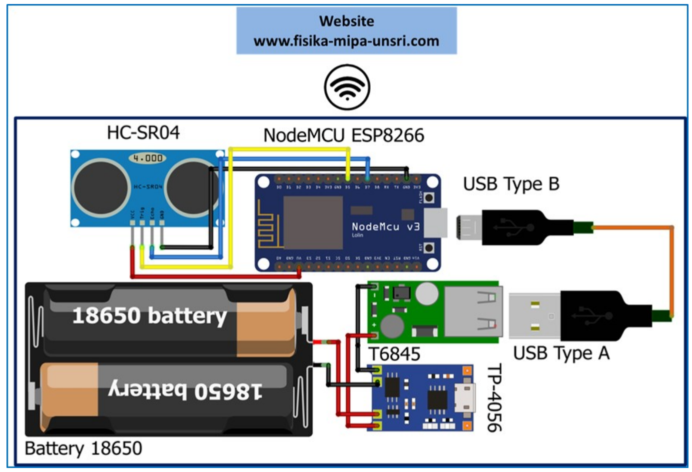

Figure 1. Components of the Low-Cost Proposed System

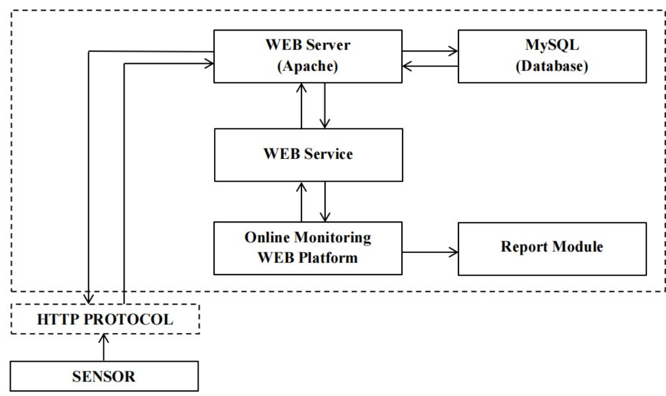

Figure 2. Data Acquisition of the Modem Bidirectional Communication

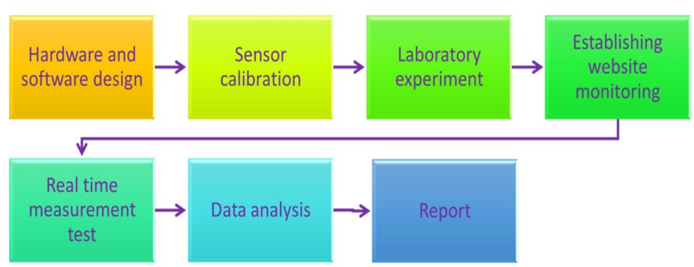

Figure 3. Schematic Diagram of Research Flow

2.2 Methods

After finishing the hardware and software designs, experiment was started in the laboratory. First of all, the calibration of ultrasonic sensor must be done to make sure the measurement

Table 1. Calibration Data of Ultrasonic Sensor

Length Meter	Sensor Output of Water Depth (cm)										Average (cm)	Errors (%)
	1	2	3	4	5	6	7	8	9	10		
5	5	5	5	5	5	5	5	5	5	5	5	0
10	10	11	10	10	9	10	10	9	10	10	9.9	0.01
20	20	22	19	20	20	20	20	20	20	19	20	0
30	30	30	30	30	30	30	30	33	30	30	30.3	0.01
40	38	39	39	39	40	40	41	40	40	40	39.6	0.0105
50	50	50	50	50	50	50	50	50	50	50	50	0
60	57	57	59	60	60	63	61	60	60	60	59.7	0.0052
70	69	70	67	70	70	70	70	70	70	70	69.6	0.0058
80	76	78	78	77	80	80	78	80	80	80	78.7	0.0171
90	89	90	91	91	91	90	90	91	91	90	90.4	0.0045

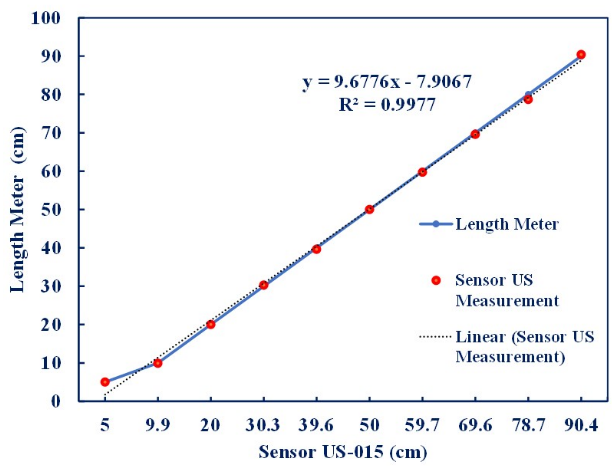

Figure 4. The Calibration Results of Ultrasonic Sensor HC-SR04

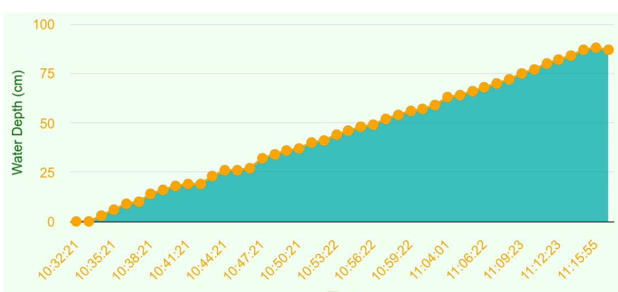

Figure 5. Water Depth Measurement in the Laboratory as Displayed on the Website

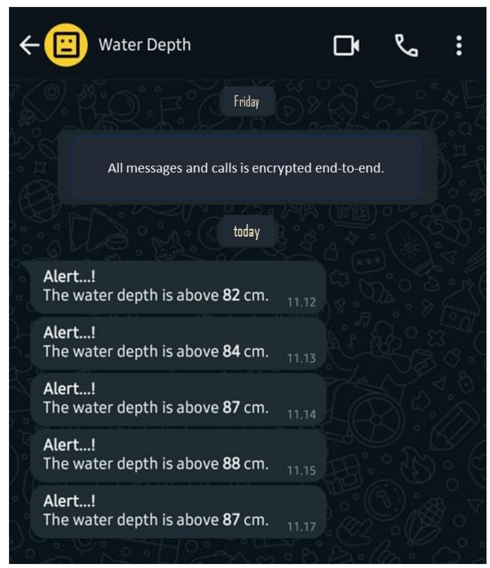

Figure 6. Example of Warning Output using Whatsapp Application

data is valid. We compared sensor reading of certain water depth with the conventional length meter to make the sensor standardized. As Figure 3 shown, stage 3 was carried out in the laboratory to validate the efficiency of our alert system. We designated 80 cm as the critical threshold for simulating a flooding situation. Thus, whenever the sensor detected a water depth exceeding 80 cm, a buzzer would sound, and the user would instantly receive an alert notification via WhatsApp. During the actual monitoring process in the field, we recognized that this threshold would need to be fine-tuned to match real-field warning scenarios. As the sensor data displayed on the website, the successful results from this stage convinced us that the system could effectively process commands and deliver accurate water depth information to users. This confidence led to the real-time measurement test at the Seruo Lake (stage 5).

3. RESULTS AND DISCUSSION

3.1 Calibration

We calibrated the ultrasonic sensor US-015 by measuring water heights at 5, 10, 20, and up to 90 cm, as detailed in Table 1. For each height, we conducted ten measurements with the sensor before calculating the average values and error margins.

Table 2. Real Time Measurement Testing in the Laboratory

Convensional Length Meter		Website Display		Delay
Time	Data (cm)	Time	Data (cm)	(s)
18:59:49	90	18:59:52	90	3
19:09:49	90	19:09:51	90	2
19:14:49	90	19:14:51	90	2
19:19: 49	90	19:19:51	90	2
19:24: 49	90	19:24:51	90	2
19:29: 49	90	19:29:51	90	2
19:34: 49	90	19:34:51	90	2
19:39: 49	90	19:39:51	90	2
19:44: 49	90	19:44:51	90	2
19:49: 49	90	19:49:50	90	1

The average measurements closely matched the actual water depths, resulting in error values below 1%, which is acceptable for practical applications. Figure 4 illustrates the calibration results, with the sensor readings represented by the red curve and the length meter's measurements depicted by the blue line, showing a strong linear correlation (R^2=0.9977) between the sensor output and the reference measurements, confirming the sensor's accuracy.

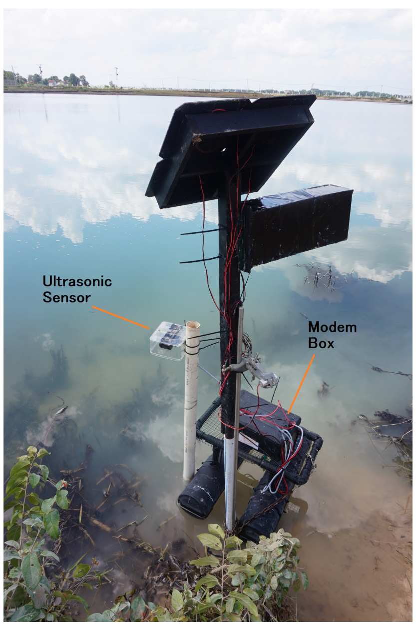

Figure 7. Water Depth Measurement in Teluk Seruo Lake by Placing the Modem on the Lakeside

3.2 Laboratory Test

The laboratory experiment was conducted to verify that the ultrasonic sensor could accurately gauge water depth and that the modem successfully displayed the data online. A 100 cm high water tank was filled with water between 10:32 and 11:15 a.m., reaching a maximum height of 90 cm to maintain a 10 cm gap between the water surface and the sensor. As the water level rose, the sensor's measurement of water depth increased accordingly, as seen in the graph on the website (Figure 5). These values matched those recorded by the length meter. To model a flooding scenario, we set a threshold of 80 cm for maximum water depth. Consequently, if the sensor readings exceeded 80 cm, a notification was sent to the user via the WhatsApp application, as presented in Figure 6.

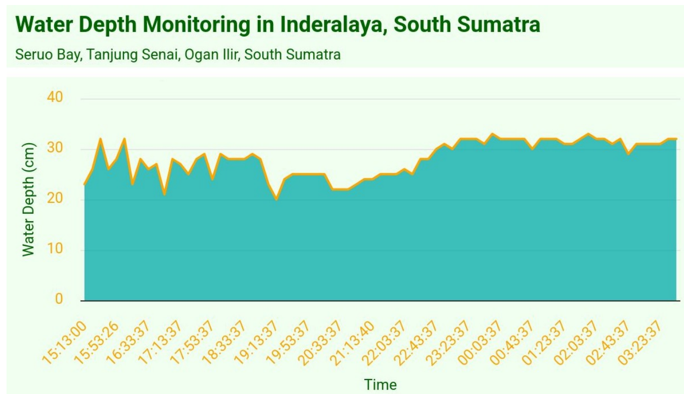

Figure 8. Water Depth Measurement Data Displayed on the Monitoring Website

3.3 Real-Time Measurement Test

A laboratory test was conducted to examine the delay in real-time communication between the website and modems. Table 2 presents a comparison of the measurements from a standard length- meter against the readings shown on the website. The maximum delay observed was 3 seconds, which was attributed to the time it took for data from the modem to reach the website's database. This delay resulted from the data acquisition links connecting the modems to the user, as illustrated in (Figure 2). The sensor in the modem communicates with the user via radio frequency using HTTP protocol that connects the data to the web server and database besides displaying the result on the user's monitor.

3.4 Real-Time Monitoring

On February 13rd, 2025, real-time monitoring of the water depth at the lake was conducted (Figure 7). The modem was powered by a set of two batteries (3.7 V, 4200 mAh). Our goal was to assess the energy usage and lifespan of this sensor system under the given power conditions. Measurements were taken every ten minutes, revealing that the batteries lasted for only 75 data transmissions, approximately 12.5 hours of operation. The Node MCU and ultrasonic sensor required 17.4 mA and 5 V for their operational power. We believe that if measurements were taken daily, the battery would be able to support at least 60 data sampling sessions, which would last for approximately two months. In line with earlier studies conducted by Pearce et al. (2024), which demonstrated that a set of four AA batteries

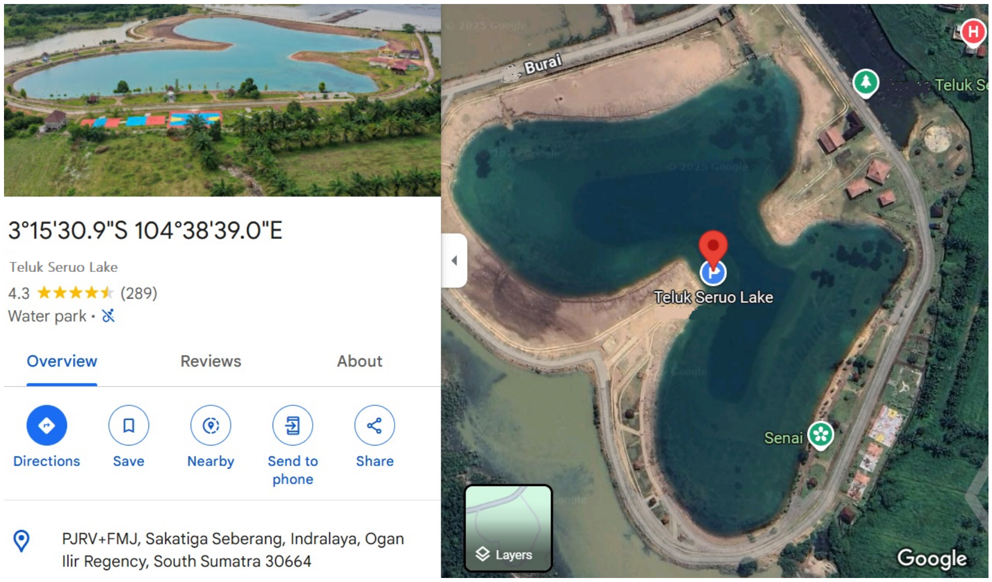

Figure 9. Teluk Seruo Lake Position in Google Maps

(1.5 V, 500 mAh) could operate an Arduino-based logger for a duration of three months, our project demanded a greater amount of energy because it incorporates bidirectional communication features. Furthermore, while their logger had a cost of USD 168.26, the monitoring systems created in this project were priced at only USD 130.60.

Examples of real-time lake monitoring data can be viewed on the website, as illustrated in Figure 8. The water depth registered was approximately 33 cm over the 12.5-hours period. We anticipate that these values will remain relatively stable in a lake spanning about 5.6 hectares over short time frames Figure 9. Consequently, measurements should be taken upon user request during critical times, ideally once daily, necessitating effective bidirectional communication. Several obstacles may come in context when the signal is lost so that the sensor data cannot be retrieved or sometimes general server problems might happen so the data cannot be displayed on the website.

4. CONCLUSIONS

A cost-effective bidirectional telemetry system for water depth monitoring has been successfully implemented at Teluk Seruo Lake. The ultrasonic sensor was calibrated and tested in the laboratory to ensure accurate depth measurements. Data was transmitted over the internet using the HTTP protocol on a Node MCU board and displayed on a webpage. During field testing, water depth readings in the lake ranged from 20 to 33 cm, with data collected 75 times over a period of 12.5 hours. These consistent readings highlight the effectiveness and efficiency of the proposed bidirectional link for telemonitoring, providing real-time data that is critical for users rather than depending on a fixed time for automatic measurements. The system operates on just 87 mWatt per measurement, which aids in energy conservation and minimizes data storage requirements. This modem should be deployed to monitor peatlands, lakes, and other inland water bodies in South Sumatra to help prevent seasonal disasters like flooding or wildfires.

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