Continuous Water Level Monitoring in Wells Using Automatic Weight Gauge Mechanism: A Key Component for Groundwater Level Analysis

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ABSTRACT

Groundwater, defined as water infiltrating Earth's surface and accumulating in subterranean aquifers, is vital for ecosystems and human endeavors. Monitoring groundwater levels in wells provides direct indications of local groundwater levels, which is crucial for understanding aquifer dynamics. Seasonal fluctuations, driven by factors like precipitation and temperature, underscore the need for continuous monitoring to observe patterns and trends. Conventional monitoring systems use capacitive, ultrasonic, pressure, and conductive sensors but face drawbacks such as extensive electrical wiring and limited adaptability to varying water well depths. To address these challenges, this paper introduces an innovative groundwater level monitoring system that employs an automatic wire weight gauge mechanism integrated with IoT technology. This mechanism eliminates the need for extensive wiring and significantly reduces power consumption. Additionally, its enhanced adaptability to varying water well depths allow for more accurate and efficient monitoring across different geological contexts and enables real-time transmission of water level data to the cloud. Detailed prototype implementation and operational principles demonstrate the system's feasibility and potential to revolutionize sustainable groundwater monitoring practices. By facilitating accurate and efficient data collection, this IoT-enabled system holds promise for improving water resource management and contributing to environmental conservation efforts.

Keyword: - *Water level monitoring, IoT network, Wireless communications, Groundwater sustainability, Sensor technology, Resource management*

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1. INTRODUCTION

Groundwater, a vital resource for communities globally, serves as a primary source of drinking water, supporting both domestic needs and agricultural activities [1]. The reliance on wells and boreholes tapping into underground aquifers underscores the critical role groundwater plays in providing clean and safe drinking water. Agriculture, a major consumer of groundwater, utilizes wells for irrigation, especially in regions where surface water availability is limited.

This groundwater irrigation not only ensures a stable water supply for agriculture but also contributes significantly to global food security. Moreover, groundwater sustains diverse ecosystems by influencing river flow, maintaining wetlands, and supporting aquatic habitats. Its unique properties, such as relatively stable temperatures throughout the year, play a crucial role in providing thermal stability for aquatic ecosystems. Groundwater also acts as a natural storage system, allowing for access to water during dry periods or emergencies when surface water sources may be contaminated or unavailable. However, the increasing challenges faced by water resources, driven by factors such as population growth, climate change, and land use changes, necessitate a proactive approach to groundwater monitoring. Recognizing groundwater as a finite resource, monitoring its levels becomes crucial for assessing aquifer health and sustainability. In the context of climate change, where regions experience more frequent and severe droughts, groundwater monitoring provides early indicators of water stress, aiding in effective resource management during periods of reduced precipitation.

This research project addresses the significance of monitoring groundwater levels by proposing an innovative system for remote and wireless monitoring. The system utilizes automatic wire weight gauges, employing two gauges—one submerges to the ground surface, while the other, hollow and floating, reaches the water surface. By measuring the difference between them, the proposed system allows for automated calculation of groundwater levels.

The proposed system integrates Internet of Things (IoT) technology, enabling real-time transmission of groundwater level data to cloud platforms for analysis and monitoring [2].

2. LITERATURE SURVEY

Various sensors are used in water level monitoring systems, each with its advantages and limitations.

1 In the study by Maqbool and Chandra [3], the authors utilized Zigbee technology for real-time wireless monitoring and control of water systems, employing conductive sensors for water level measurement. Conductive sensors detect water levels by measuring electrical conductivity.

Conductive sensor: Despite their utility, conductive sensors are prone to corrosion and fouling over time, especially in corrosive environments. The longer electrical wires required for deeper wells can increase resistance and power consumption, posing challenges for reliable measurement.

2 On the other hand, Bento et al. [4] focused on designing and developing a real-time capacitive sensor for automatically measuring liquid level. Capacitive sensors emit electromagnetic fields to measure changes in capacitance, offering advantages such as high accuracy and reliability.

Capacitive sensor: Capacitive sensors, commonly used for well water level measurement, face limitations due to environmental factors such as temperature, humidity, and electrical interference. Debris and sediment in water can disrupt measurements, requiring regular calibration for accuracy, particularly in harsh well environments.

3 In the research conducted by Han and Guo [5], ultrasonic sensors were employed in a water resources remote monitor and control system based on GPRS technology. Ultrasonic sensors emit sound waves to measure water levels by detecting the time it takes for waves to bounce back from the surface.

Ultrasonic sensor: While effective in many scenarios, ultrasonic sensors may struggle with accuracy in narrow tanks, where wave spread is uneven and can lead to inaccuracies, particularly near the tank edges. Additionally, improper wave propagation angles may cause waves to reflect off tank walls, resulting in false readings.

4 Pressure sensors, another common choice for water level monitoring, were discussed in the literature by Liu et al. [6]. Pressure sensors measure the water level by detecting the pressure from the water column above them.

Pressure sensor: While generally reliable, pressure sensors can lose accuracy at extreme depths or under high pressure. Precise calibration is essential to account for factors like atmospheric pressure changes and liquid density variations, ensuring accurate readings.

3. METHODOLOGY

3.1 Automatic Wire Weight Gauge Mechanism

When it comes to the health of ecosystems and the various activities that humans engage in, groundwater is an essential resource. One of the most important aspects of effectively managing water supply is maintaining a close watch on the levels of groundwater. In this section of the approach, we go into the proposed groundwater level monitoring system in detail, with a particular emphasis on the automatic wire weight gauge mechanism that is connected to the internet of things (IoT).

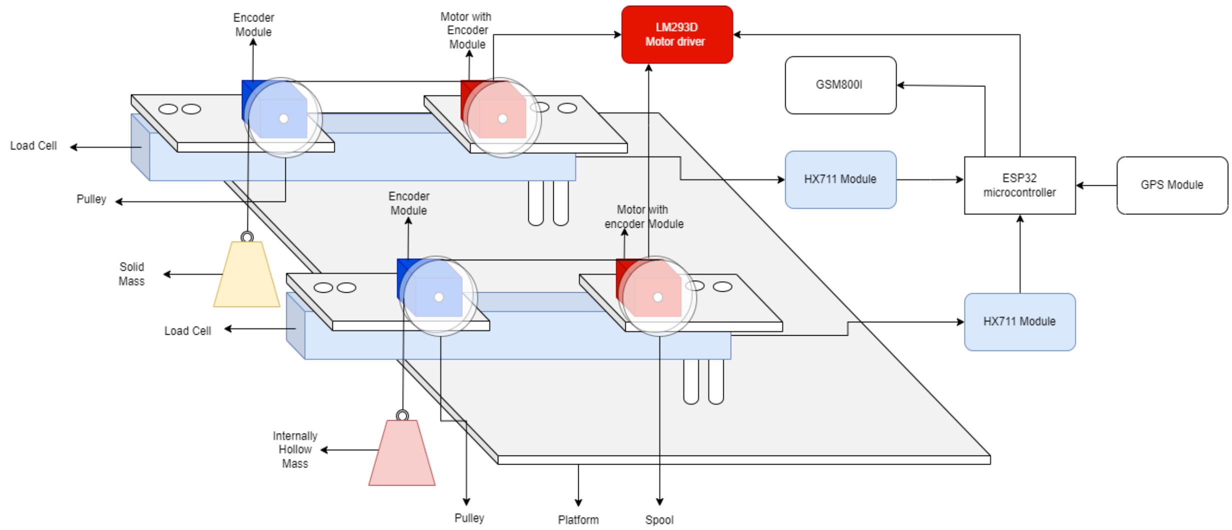

Fig. 1: Automatic wire-weight gauge mechanism drawing

The proposed system utilizes an automatic wire weight gauge mechanism comprising two weights: one hollow and one solid, connected to threads. These threads are systematically arranged with sensors and modules on a platform. Fig. 1 illustrates the layout, where two load cells, linked to HX711 load cell amplifier modules, are mounted on the platform. Each load cell is equipped with a pulley and an encoder module. Magnets are positioned on one side of each pulley, with Hall sensor modules placed in front of them. This arrangement forms the Encoder module, as the Hall sensor detects the presence of magnets and outputs logic signals accordingly.

The threads connected to the weights pass through the pulleys, winding around them once before reaching a spool connected to a motor. Two motors, each with an encoder module, rotate the spools to wind and unwind the thread, allowing the weights to descend and ascend into the well. The encoder module, coupled with the pulley, measures the thread's length as the weights descend into the well by counting the number of rotations made by the pulley. Each rotation is detected when four magnets pass by the Hall sensor, indicating a complete revolution.

Through this process, the system estimates the distance the weights descend into the water well by calculating the thread length and the number of pulley rotations. Additionally, encoder module installed on the motors monitor the direction in which the motor winds the thread.

As both weights descend into the water well, the hollow weight floats on the water surface while the solid weight reaches the ground surface. This mechanism enables the calculation of the thread's length used, thereby determining the depth of both the water surface and the ground surface.

3.2 Data Collection and Processing

Illustrated in **Fig. 2**, the ESP32 microcontroller, renowned for its versatility in the Internet of Things (IoT), takes on the pivotal role of collecting and processing sensor data. Functioning as the primary controller, the ESP32 is equipped with a 12-bit ADC, Wi-Fi module, and Bluetooth module, providing comprehensive functionality within a compact package. Its responsibilities extend beyond mere data acquisition from the wire weight gauge mechanism; it orchestrates the entire system.

Initially, the ESP32 meticulously calibrates the load cells to accurately measure the weights of both the hollow and solid weights. Once calibrated, the ESP32 initiates motor activation, directing them to lower the weights into the water well. It closely monitors the encoder modules of the motors, ensuring the correct direction of rotation for descending or ascending the weights. Throughout this process, the ESP32 tracks the number of rotations of the pulley to calculate the length of the thread and thus, the depth to which the weights have descended.

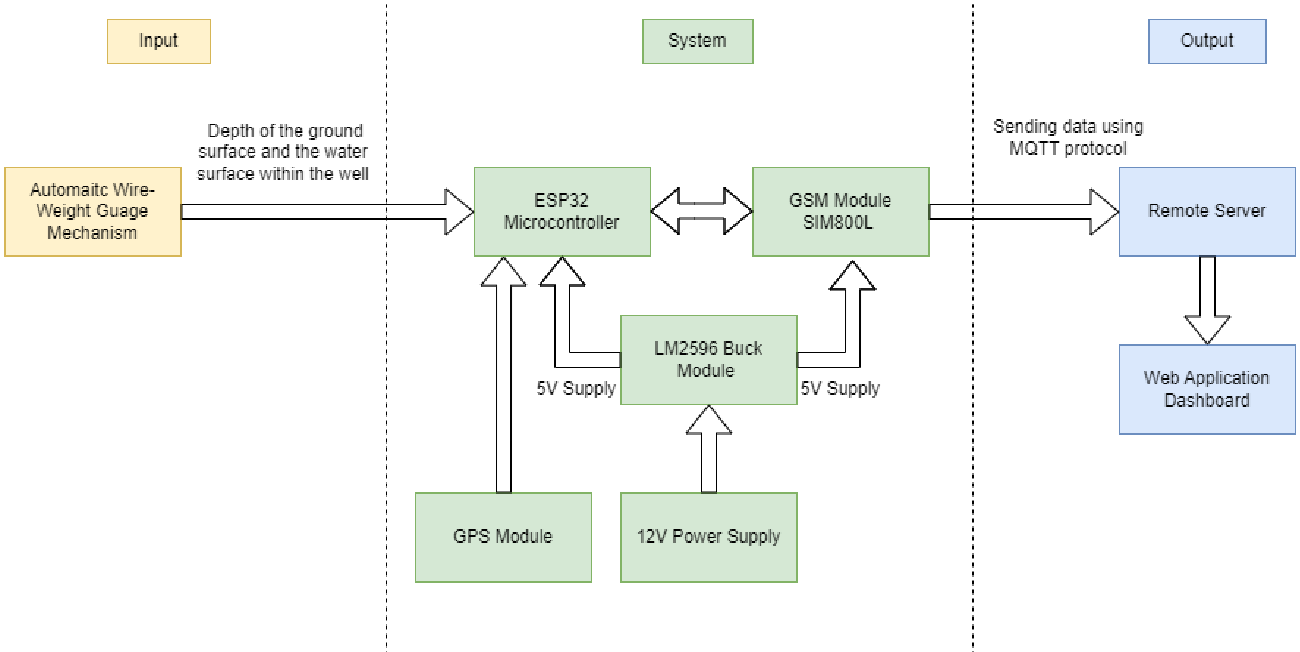

Fig. 2 Water Level Monitoring System drawing

Upon contact of the weights with the water and ground surfaces, the ESP32 detects the slackening of the thread, indicating the respective depths. Utilizing the known diameter of the pulley, it precisely calculates the length of thread lowered. Subsequently, the ESP32 utilizes the Sim800L GSM and GPRS module to transmit this data, along with GPS coordinates and timestamp, to a remote server in real-time. In case of internet connectivity issues, the ESP32 stores the data in its 4MB internal memory.

Integrated through UART protocol, the GPS module aids in location tracking, specifying the area from which water level data is monitored. Meanwhile, the SIM800L module serves as the wireless communication gateway, facilitating data transmission and real-time internet access. The MQTT protocol ensures efficient data transmission to the server, optimizing the monitoring process.

The entire system, comprising the encoder modules, ESP32 controller, load cells with HX711 load cell amplifiers, N20 motors with encoder modules, SIM800L module, and GPS module, operates on a 5-volt power supply, ensuring seamless functionality and reliability.

3.3 Implementation and Testing:

The proposed groundwater monitoring system undergoes extensive testing and evaluation to ensure its reliability and effectiveness in real-world scenarios. Field tests are conducted in a variety of geological environments to assess how well the system performs and determine its suitability for different regions. The installation process is depicted in **Fig. 3**.

During these trials, the groundwater tracking system is installed in actual wells, and groundwater levels are monitored over an extended period of time. The data collected during these field trials is carefully compared with Manual ground-level readings to validate the accuracy of the system.

System performance evaluation involves assessing how effectively the system operates under various environmental conditions. This includes examining the impact of fluctuating water levels, temperature variations on sensor performance, and the system's ability to maintain wireless connectivity in different conditions. Additionally, field trials assess the system's reliability, durability, and energy efficiency.

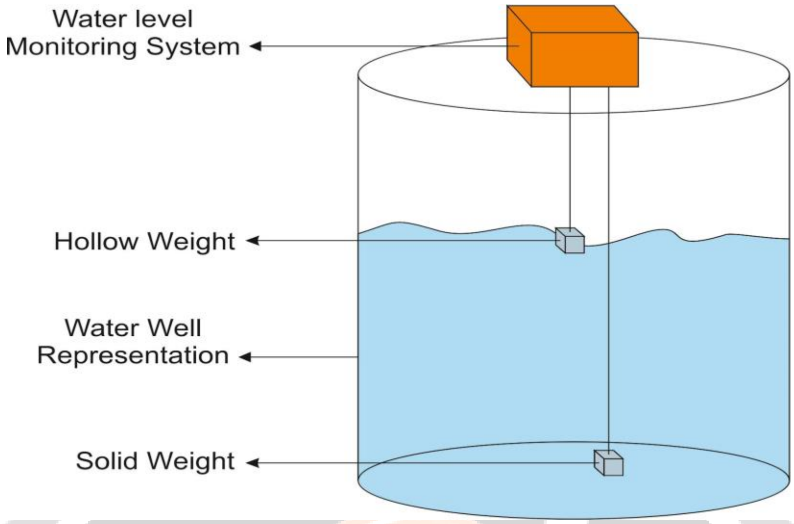

Fig. 3: Virtual implementation of water level monitoring system

Continuous improvement of the groundwater tracking system is driven by insights gained from field test results and performance evaluations. This ongoing optimization process may include recalibrating sensors to improve accuracy, enhancing data processing capabilities, or implementing changes to enhance overall system reliability. Real images of the hardware used in the system are provided in **Fig. 4**.

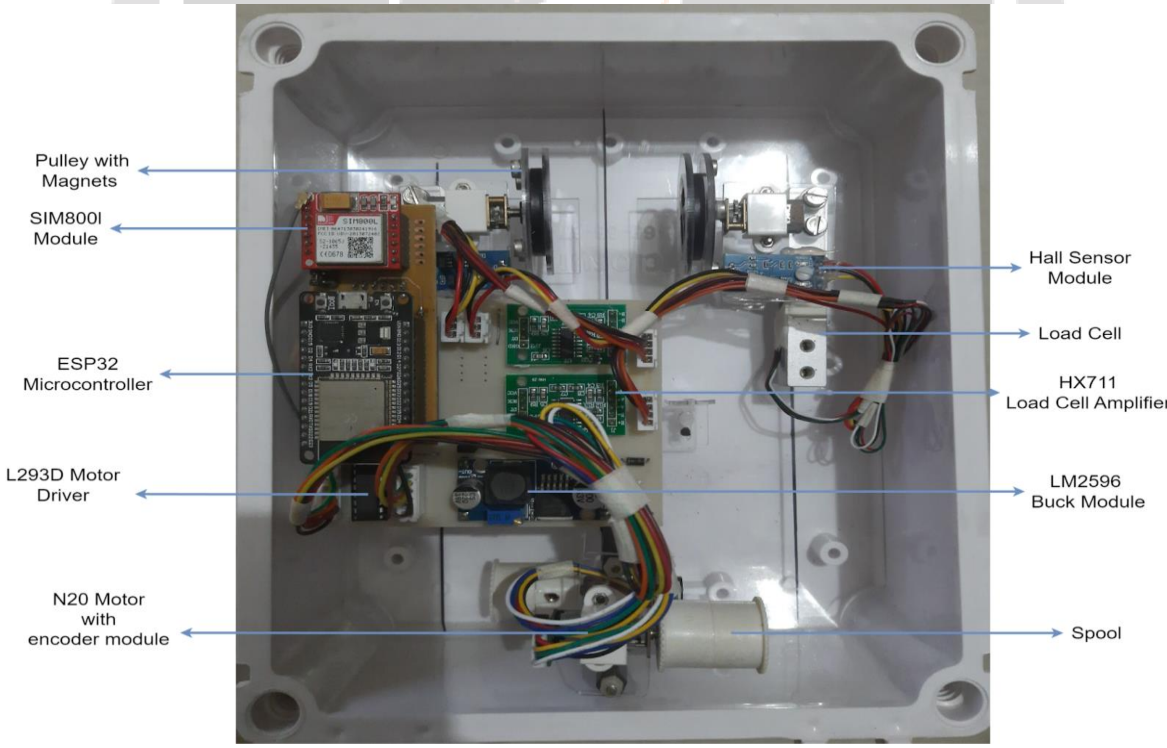

Fig. 4: Actual Image of water level monitoring system

4. RESULT

4.1 Readings of Each Day Per Hour

The groundwater monitoring system operates continuously, capturing readings every hour throughout the day. The variations in groundwater levels are observed over a 24-hour period. The recorded readings for each hour of the day offer a detailed view of groundwater levels over the course of 24 hours.

Index	GPS Location	Date	Time	Water Level (feet)	Ground Surface Depth (feet)
0	21.128384, 79.120552	2024-03-03	0:00:00	15	40
1	21.128384, 79.120552	2024-03-03	1:00:00	14	40
2	21.128384, 79.120552	2024-03-03	2:00:00	14	40
3	21.128384, 79.120552	2024-03-03	3:00:00	16	40
4	21.128384, 79.120552	2024-03-03	4:00:00	15	40
5	21.128384, 79.120552	2024-03-03	5:00:00	16	40
6	21.128384, 79.120552	2024-03-03	6:00:00	15	40
7	21.128384, 79.120552	2024-03-03	7:00:00	16	40
8	21.128384, 79.120552	2024-03-03	8:00:00	16	40
9	21.128384, 79.120552	2024-03-03	9:00:00	14	40
10	21.128384, 79.120552	2024-03-03	10:00:00	14	40
11	21.128384, 79.120552	2024-03-03	11:00:00	16	40
12	21.128384, 79.120552	2024-03-03	12:00:00	14	40
13	21.128384, 79.120552	2024-03-03	13:00:00	15	40
14	21.128384, 79.120552	2024-03-03	14:00:00	15	40
15	21.128384, 79.120552	2024-03-03	15:00:00	16	40
16	21.128384, 79.120552	2024-03-03	16:00:00	16	40
17	21.128384, 79.120552	2024-03-03	17:00:00	15	40
18	21.128384, 79.120552	2024-03-03	18:00:00	15	40
19	21.128384, 79.120552	2024-03-03	19:00:00	16	40
20	21.128384, 79.120553	2024-03-03	20:00:00	14	40
21	21.128384, 79.120554	2024-03-03	21:00:00	15	40
22	21.128384, 79.120555	2024-03-03	22:00:00	14	40
23	21.128384, 79.120556	2024-03-03	23:00:00	15	40

Table 1: Readings of Each Day Per Hour

The readings taken over a day by every hour are depicted in **Table 1.**

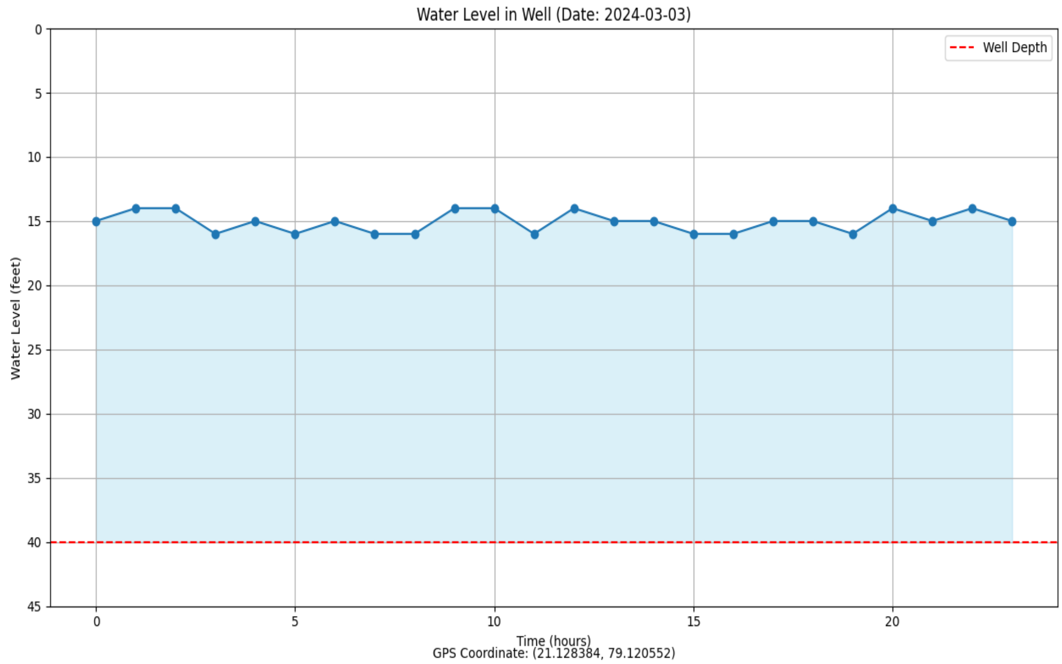

Fig. 5: A graph that illustrates a single day reading

The corresponding graph of the readings is presented in **Fig. 5**, allowing for further analysis of the daily fluctuations in water levels.

4.2 Readings for a Month

In addition to daily variations, the groundwater monitoring system also records data over longer time frames to capture trends and patterns in groundwater levels. In Table 1, the readings collected over the span of one month are displayed. Averaging is performed for each day, aggregating the hourly readings to provide a representative value for daily groundwater levels.

Date	Water Level	Date	Water Level	Date	Water Level
3/18/2024	15.17640523	3/28/2024	16.04888712	4/7/2024	16.81366654
3/19/2024	15.143464	3/29/2024	16.28335839	4/8/2024	17.23777565
3/20/2024	15.30477035	3/30/2024	16.31748308	4/9/2024	17.36230569
3/21/2024	15.53443415	3/31/2024	16.35699509	4/10/2024	17.30509384
3/22/2024	15.6005489	4/1/2024	16.49266219	4/11/2024	17.70973408
3/23/2024	15.41951359	4/2/2024	16.58509157	4/12/2024	17.44077033
3/24/2024	15.7156985	4/3/2024	16.80458032	4/13/2024	17.69423102

3/25/2024	15.70900221	4/4/2024	16.73810486	4/14/2024	17.77438506
3/26/2024	15.81726432	4/5/2024	16.89337574	4/15/2024	18.04982965
3/27/2024	15.97209433	4/6/2024	16.88010767	4/16/2024	18.14693588

Table. 2: Readings for a Month

Table. 2 showcases the readings collected over the span of one month, with averaging done for each day, providing a comprehensive overview of groundwater levels over an extended period.

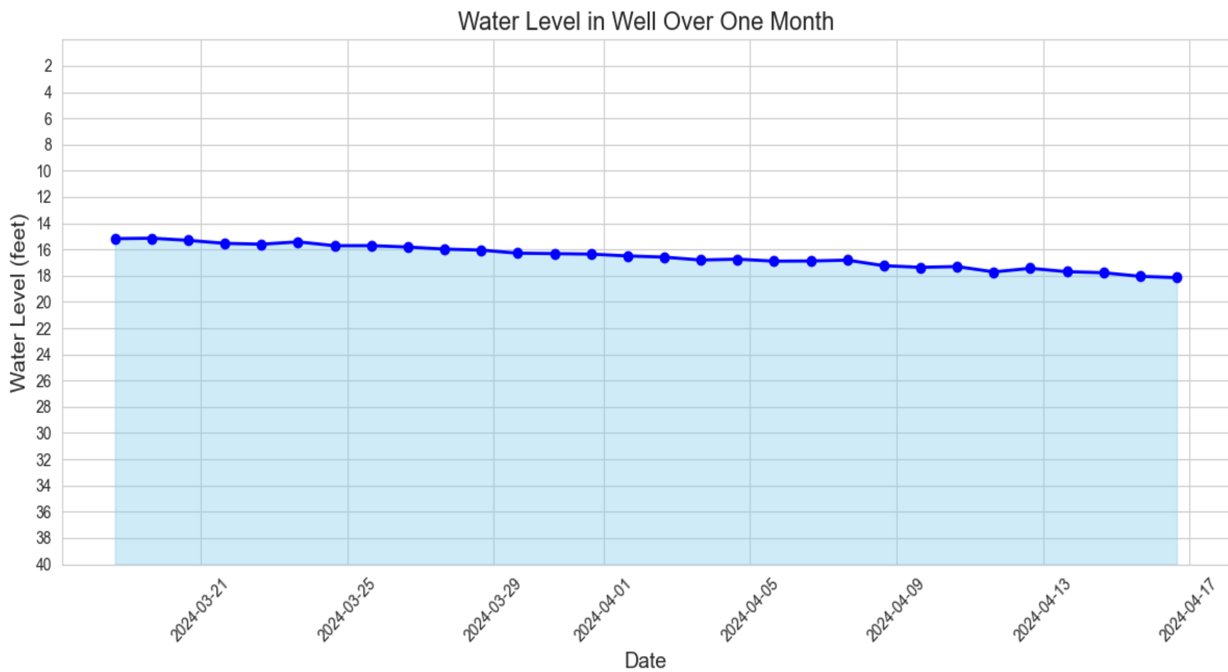

Fig. 6: A graph that illustrates a single day reading

The corresponding graph of the one-month readings is depicted in Figure 6, offering insights into the long-term behavior of groundwater resources.

5. CONCLUSION

In conclusion, creating and using the groundwater tracking system has been a big step toward managing water resources in a way that is effective and lasts. The system has shown that it can correctly measure and keep an eye on groundwater levels in real time by combining an innovative automatic wire weight gauge mechanism with IoT technology.

The data from the four weeks of monitoring have given us important information about how the groundwater levels in the well being watched changed over time. Changes in groundwater levels were accurately recorded and studied, which led to smart choices in managing water resources.

The one-foot fall in groundwater levels over four weeks shows how important it is to keep an eye on things to see how groundwater supplies are changing. The groundwater tracking system helps people take action against problems like water shortages, contamination, and over-extraction by giving them up-to-date and correct information.

The pictures of the hardware parts and the whole system show how well the system is designed and put together. The system's small size and ability to adapt to different environments make it useful for a wide range of tracking situations.

To make the groundwater tracking system work better and be more reliable in the future, it will need to be optimized and improved even more. To solve problems like accurate calibration, power efficiency, and reliable data transfer, more research and development need to be done.

Groundwater monitoring systems address the limitations of traditional sensor technologies. By utilizing an automatic wire weight gauge mechanism, we ensure accurate readings in narrow tanks and challenging environments, overcoming issues like uneven wave spread and signal degradation.

The system's wireless transmission minimizes the susceptibility to corrosion and fouling, common in conductive sensors, while IoT integration enables real-time data transmission and automated calibration adjustments, addressing concerns of pressure sensor accuracy.

Moreover, robust calibration algorithms compensate for environmental factors in capacitive sensors, ensuring consistent measurements in harsh conditions. Overall, our system represents a significant advancement in groundwater monitoring, offering accurate and efficient water resource management solutions.

Finally, the groundwater monitoring system has a huge amount of ability to help with long-term water management and protect valuable groundwater resources for future generations. We can work toward a more resilient and water-secure future by keeping up with technological progress and working together across different areas.

6. REFERENCES

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