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Development of a Telemetric Watershed Monitoring Station

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Abstract*– In the context of the growing concern for environmental monitoring and water resources management, this research emphasizes the study of river level monitoring systems through the implementation of equipment such as ultrasonic sensor and cellular router for remote transmission and processing of information. Due to recent technological advances and the ability to use considerably small and practical telecommunications equipment for operations in free space, where previously required antenna installations on a medium scale, allow the implementation of a connection to the internet network, together with some protocols that this involves, the application of the internet of things is achieved, starting from the study of radio frequencies to protocols and network configurations to transmit and receive data in a safe, reliable and effective way from a remote point to its destination. The integration of this system through terrestrial wireless waves, such as cellular communication, capable of reaching places where wiring is a high cost factor and the least viable, being this the technique addressed in this topic as a way to access information from the physical area of study.

***Keywords*-- flood monitoring, wireless transmission, river water level, cellular network, IOT network implementation.**

I. Introduction

Watershed monitoring is an important practice for understanding and effectively managing one of the Earth's most important natural resources, water. It is essential for assessing water quantity, predicting and managing extreme events such as floods and droughts. It also helps maintain a sustainable balance between human development and the protection of aquatic ecosystems, and contributes to the conservation of biodiversity and the protection of water sources.

The Ulúa River plays a vital role in the region's economy, its water is used for crop irrigation, and along its course are located important urban and industrial centers such as San Pedro Sula, in which, historically, river transport has been an important part of the transportation of goods in the region, which is why the present work is focused on this basin of the country.

This monitoring process includes the collection and analysis of data on rainfall, river flow, water level and other relevant parameters, using modern technologies, such as a weather station, sensors and geographic information systems, where information is collected in real time.

Widely used in various industries and scenarios, this technology can track and store information effectively and accurately, highlighting that IoT sensors are the basis of wireless monitoring. Delving into the characteristics of these devices, we find that they can measure various parameters such as movement and liquid level, essential information to understand the environment. One of the advantages of IoT devices usually use wireless technologies such as Wi-Fi, Bluetooth or cellular network, as used in this case, to transmit data to a central network or platform, providing instant data transfer and long distance communication, these data collected by the sensors are sent to the IoT platform where they are stored, allowing users to access these and generate reports, set up alerts and perform advanced analysis. Real-time data enables informed decisions and allows us to respond quickly and efficiently to changing situations, which is especially important in critical applications such as healthcare and emergency management.

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This process allows us not only to better understand water systems, but also to take steps to protect and use them responsibly, ensuring a safer and more sustainable future for generations to come.

In the development of a telemetric watershed monitoring station, mobile networks play a key role as they provide reliable mobile connectivity because they provide global coverage and high availability, allowing IoT devices to be on the move or in remote locations, and maintain a constant connection to the Internet. They are designed to handle a large number of connected devices at once, making them ideal for large-scale IoT deployments, managing and updating IoT devices remotely, facilitating their maintenance and repair without physical intervention, and have a variety of applications, including industrial automation, precision agriculture, environmental monitoring, smart consumer devices, telemedicine, fleet management and smart cities.

II. CONTEXT

As Flash Flood Guideline, it refers to the average precipitation required in an area during a specific time period to cause flooding in small-scale tributaries within that area, this concept also includes the average amount of precipitation required in a region during a specific period to cause flooding at a specific location, i.e., at points of origin and other points downstream where a vertical reference is established, immediately downstream of the region mentioned above[1].

The specific guidelines for flash flood forecasting (FFG) are one of the most widely used flood forecasting techniques and three main components are taken into account in the FFG: a model that allows the constant calculation of soil moisture, calculations related to the FFG and minimum criteria that indicate favorable flood conditions. [2]. The architecture of the FFG computer system uses file system organization structures and a series of tables in a relational database (PostgreSQL) with a primary focus on ease of use so that data manipulation takes place in real time between these two data management domains as data products are collected, prepared, and processed through the modeling elements of the system, resulting in the creation of text and image products for end-user use [3]. Due to its relevance, the use of these technologies and methods is the tool that improves the traditional early warning protocols, due to its effectiveness in remote readings and data availability while maintaining a stable connection to the network, positioning this application as the solution to the possible risks due to flooding in areas with greater risk of these natural phenomena in the country.

Figure labels should be legible, at 8-point type.

A. THE INTERNET OF THINGS (IOT).

The Internet of Things (IoT), an advancing technology endows devices with intelligence and ease of use when linked through communication protocols and cloud platforms. [4]" at the beginning of a sentence: "Reference [4] Its operation in the cellular network is constituted from the local service provider's mobility data center and is securely connected to the local infrastructure and the receiving equipment is connected through an encrypted point-to-point connection, so this structure has two inherent advantages: 1) the use of standardized components so that the solution is applicable to all IoT devices available in the market and 2) the guarantee of end-to-end security without requiring a high level of data encryption from the device to the receiving equipment, which would result in excessive cost. [5]. Radio frequency identification (RFID) technology, sensor technology, nanotechnology, and embedded intelligence technology are some of the key technologies of the Internet of Things. Among these, RFID is fundamental to the IoT. To carry out infrastructure information gathering, this component will use RFID as a passive data collection mechanism. [6]. Recently, going back to the hints of Industry 4.0 in the current period of new technology development, many converge on the ability to remotely operate and monitor electronic devices, not to mention a few; sensors, actuators, cameras, industrial machinery, among others. To date, what is currently known as IoT, highlight its characteristics of data transmission by radio frequencies being the soul of this methodology that applying in the field and is presented as the improvement tool [7]. They have enabled research in the hydrographic field and make possible along with ZigBee technologies, the interconnection of devices to the internet, in a viable way to a solution as described in the development of "RiverCore" addresses the description of electronic devices used to measure the flow of water, which measure factors such as composition, speed and depth, among others. In this context, nine key indicators are presented to measure a particular type of high velocity flow, also known as debris flow. Of these indicators, it has been chosen to focus on the following:

-Maximum absorption level.
-Subsurface sounds.
-Half of the flow velocity.
-Acceleration of the water surface.
-Evolution of flow depth over time.
-Surface vibrations
-Base forces
-Fluid pressure on the pores.
-Influence intensity.

The creation of RiverCore is based on this methodology and suggests a strategic fusion of these devices to measure the variables necessary to anticipate floods and high velocity water flows. [8]. The employability of multiple sensors allows a more accurate remote analysis due to more complete data, which can predict more accurately the area, emphasizing the unguided transmission medium such as radiofrequency waves used for internet connection through local telephone provider [9]. Being the communication structure where the system adapts to voltages no higher than 12V due to the low consumption equipment, thus obtaining solar energy in areas where there is no commercial energy and giving way to the installation in the required independent area. RiverCore's research and development lays the foundation for a flood disaster prevention system.

B. MQTT PROTOCOL

MQTT represents a non-closed public/private protocol conceived for limited devices used in remote measurement applications; however, it does not take into account the Autonomous System device scenario; its extension for data collection networks [10]. The broker (central device), clients (Internet of Things nodes), subject and payload are the four main components of the MQTT communication protocol, consequently the subject of the MQTT protocol also includes information about the source and destination of messages transmitted between networks; they are organized using the forward slash separator (/), and the payloads contain information collected by Internet of Things sensors [11]. The MQTT protocol has a space for the communication between networks.

The MQTT protocol has a very small storage space compared to other protocols, such as HTTP, as mentioned above, this protocol is best for resource constrained environments, although the MQTT protocol has many benefits, not all MQTT based brokers have the necessary skills to perform authentication or encryption of entities [12]. Determining a very important point as far as sending information is concerned, the relevance of the application of the stations lies in sending information which makes the data much more reliable in internal processing capability. It addresses the need for the proper functioning of a system capable of transmitting information, connecting through the cellular network, there are these cellular routers In previous research, the researchers achieved the goal of their study: to merge several water level sensors in distant areas in a single system. This demonstrates great efficiency, as it covers a wide area over the cellular communication infrastructure used in mobile devices. The researchers use a wireless connectivity configuration that is rooted in the web architecture, which guarantees the availability of a unique IP address [13]. There are many models that can be perfectly used in general IoT applications, as well as cellular modules that require a number of extra slots for implementation in this area, consisting of choosing the right one for the required application, taking into account network redundancy, data availability (even when the ISP network fails), response speed, data security (encrypted), QoS, among others.

The Internet of Things, also known as the "Internet of Things," is the most recent emerging trend in the field of information and communications technology (ICT) that realizes the idea that any object can be connected to the entire world virtually [14]. Several communications infrastructure specifications for 4G LTE networks have been proposed to meet the diverse needs of Internet of Things (IoT) devices. These regulations include both large-scale applications, such as precision agriculture, and critical applications, such as traffic control and security. In contrast to the latter, the former prioritize economic efficiency, reduced power consumption, and transmission of small amounts of data, while the latter require extremely high levels of reliability, low response times, and high availability [15].

C. CELLULAR TECHNOLOGY

The ubiquitous connectivity of cellular technologies is a great advantage compared to other unauthorized LPWA access technologies. Even in remote locations, mobile networks are always available. Cellular Internet of Things (IoT) technologies (CIoT) are highly reliable, secure and adaptable, making them suitable technologies for use in large areas where there are a large number of smart devices connected to the Internet (up to one million devices per kilometer). In addition, the development of cellular communications enables interoperability in the global CIoT ecosystem [16]. Connectivity for IoT consists of a basic structure on which connectivity is based, described by implementing layers together (as divided in the OSI model), So far, no consensus has been reached on the IoT architecture to fully understand how it works. However, the three-tier model is widely accepted. In other words, as shown in the Figure, IoT is generally divided into three levels: one of perception, one of connectivity and one of application [17]. Correspondingly, the levels and applications to be taken into account in the development are listed as: cloud systems, cellular communication and Sensor, listed from the first layer to the last, generationally developing improvements in connectivity with the incorporation of 5G and NB-IoT that seek direct machine-to-machine connection thus streamlining processes without human intervention.

D. ULTRASONIC SENSORS

Ultrasonic sensors emit sequences of signals from an emitter. As the signals bounce off the target surface and return to the receiver, their travel intervals and speed of sound are translated into distance measurements and depending on the user's needs, these devices can be integrated with information storage components, data transmission modules, power supplies, position aligners, etc.[18]. As a water level sensor, the ultrasonic sensing device uses ultrasonic frequency sound waves to measure the height of the water level by evaluating the time lapse between the emission of the high frequency signal and capturing the feedback from the water surface, in addition; it can also use the data provided by the sensor itself to determine the height of the water level [19]. A conventional measurement system is composed of one or more transducers that emit and receive ultrasonic waves; a stage that amplifies and filters the receiver signal; a level identifier circuit that is based on a voltage comparator; a stage that boosts the trigger signal and stimulates the emitter; and, finally, a control and measurement logic [20]. The application in conjunction with the ultrasonic sensor to measure the water level of the flow establishes the fundamental part as the main tool, which requires physical measurements in space, in order to mathematically determine the depth and transmit this data accurately.

The scope of this research is limited to the assembly and transmission of the data, also considered are the calculations that determine the margin of error and its percentage in approximation of the data to the reality of the water currents in its totality. A similarity analysis applied to the study under development uses the presented cellular connection and addresses the GPRS-based remote river water level monitoring system, which consists of a water level sensor, a wireless module, a user device and a single-chip microcomputing unit.

Physical phenomena such as water monitoring, due to flooding and processing data in immediate response time, represent a challenge; due to unexpected changes, in the case of flows in Honduras, these carry currents that converge at one point and form the main rivers causing natural disasters, the location of the stations will depend very much on important details, on which cellular coverage stands out. Cellular systems can provide connectivity for mobility needs or to extend coverage. As a result of the widespread adoption of LTE, many cellular operators are considering machine type communications (MTC) over LTE.

E. COMPARISON WITH PREVIOUS RESEARCH

Although there is previous research between articles and projects, the projected functions are described in this development, which also have the same application and systems, where the different methods to interconnect with these field sensors are briefly described. In the study called "Development of a bridge safety monitoring system based on IoT" In the context of the Internet of Things (IoT), a system for monitoring the structural integrity of bridges has been created using ZigBee technology. This system consists of the following elements: (1) monitoring sensors installed in the bridge environment; (2) communication devices that connect the bridge monitoring sensors to the server hosted in the cloud; and (3) a dynamic database that stores information about the bridge monitoring sensors. The system can monitor in real time the conditions of the bridge and its environment, including water levels, pipelines, air quality, and other safety-related factors.

The collected images and data are transmitted to the server and stored in the database, allowing users to monitor bridge conditions in real time via mobile telecommunication devices [21]. Zigbee is a network with an excellent boom a few years ago and very good evolution in IoT applications.

The hydrological monitoring system of the project "Design of a GPRS-based monitoring system" Mainly, it is to obtain and collect real traffic parameters and water levels in real time. This data is collected and sent via SMS or GPRS to the terminal data receiver, which then transmits the information to a computer via RS232 serial port. This involves comprehensive monitoring of data extraction, data analysis and complete intelligent water control. In its overall structure, the water level monitoring system is divided into four levels.

The first level involves the measurement of water level parameters, gate level, precipitation and flow through sensors, the second level is simple and deals with data acquisition, processing and storage from the sensor terminal unit (RTU), the third layer is the hydrological station center, which uses GPRS and GSM to collect, store, display, process, tabulate, preliminary analyze and print measurement data and the fourth layer is the monitoring center, which receives the move schedule data and processes it. The second layer is the hydrological station center, which uses GPRS and GSM to collect, store, display, process, tabulate, preliminary analyze and print measurement data and the fourth layer is the monitoring center, which receives the move schedule data and processes it [22].

The article The "Development of flood monitoring system" The text is composed of three main parts: information collection, data processing and warning system. Sensors such as flow and ultrasonic sensors are crucial for obtaining input data such as liquid level and velocity during the information acquisition phase. In terms of data processing, current data is analyzed here and compared to historical records to determine if the warning system should be activated to notify the community. This is the main function of the warning system [23].

In the research: "LoPy4 Microcontroller Based Water Level Monitoring System with LoRa Technology" Current atmospheric stations allow monitoring of multiple atmospheric magnitudes in real time. Wireless sensor networks (WSN) help the nodes and the network coordinator (gateway) to communicate. The information generated by the stations is transmitted through transceivers in this system. Due to the absence of cellular signal or network access, the implementation of WSN in distant areas requires the installation of repeaters. This paper presents the development of a data logger for stations assessing river water levels in the Andean region.

The LoPy4 microcontroller is used. This solution combines Wifi and a wide range transceiver with LoRa (Long Range) technology to simplify the sensor configuration [24].

III. Methodology

This section describes the resources and methods used to carry out the development of the telemetric watershed monitoring station, in order to provide a broad explanation of its operation and tools that led to the success of the project. Different research on flow level readings were taken into account, thinking about the implementation of strategic plans for early action in neighboring areas that are at a higher risk of impact in terms of flooding due to the constant natural phenomena to which Honduras is exposed due to its geographic location.

IMPLEMENTATION OF A TELEMETRIC STATION IN A RIVER BASIN

The design is composed of a voltage inverter with its solar panel structure, a cellular modem/router with connection capacity up to 4G, which incorporates the usual functions in a single mechanism, considerably reducing equipment usage, connectivity problems and environmentally able to withstand weather changes without affecting its operation, added to these, a data security with the MQTT protocol through GSM, with storage memory included, and a data processing memory wider in capacity, compared to the use of modules as a whole.

The MB7386 ultrasonic water level sensor is used to measure the distance between the water surface and the sensor location, noting the instantaneous reading. This data is then transmitted over 4G, 3G, and 2G mobile networks to servers and stored in a database for further calculations and then used in predictive networks.

The use of the cellular network is the most relevant for this type of stations, it is the one that provides greater coverage throughout the country, allowing its location in remote places, in addition, another benefit of the structure of the monitoring station presented in this research is the self-sustainability of the same, since it is powered by its own solar panel and has battery backup, it should be noted that its charge durability is 4 days.

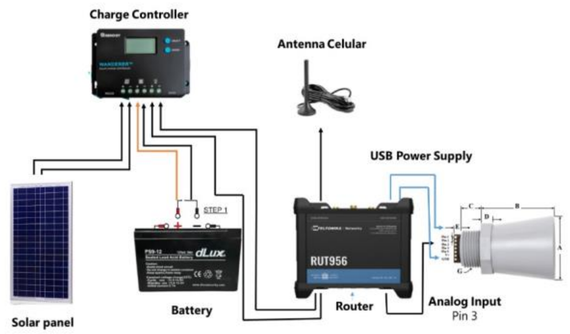

Fig. 1 General Diagram.

A. BLOCK DIAGRAM

Figure (2) shows the general block diagram of the system. The data obtained by the sensor are sent to the ROUT956, this works with an internal communication protocol called "Modbus", which is an internal communication protocol in the router, which allows obtaining information from a client to the server; Modbus has the ability to read all sensor inputs connected to the router. This information is passed to the MQTT Broker where the users and topics are hosted to which information is requested and sent, MQTT Broker is a server that is hosted in EMQX cloud in the cloud.

The Broker sends the information to the Python application where it is processed and displays the graphs with the data in real time.

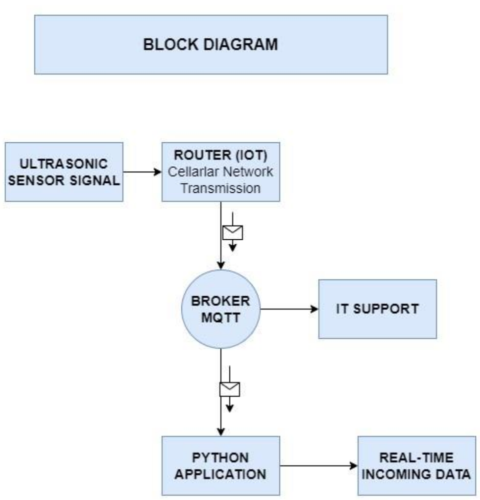

Fig. 2 Block Diagram.

B. MQTT MESSAGING PROTOCOL

MQTT is a messaging protocol that works on the basis of a subscription by a client, it creates a kind of request topics that can be sent to the publisher and receive a response from it (the Router). The information that the sensor will send is through request commands reflected in numerical parameters. The data request process is programmed to take place every two (2) to five (5) seconds, finally this data is processed and displayed graphically.

C. PHYTON APPLICATION

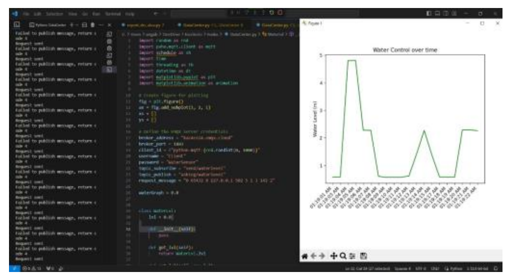

Fig. 3 Python Application.

The Web Platform was created in Python and the Paho Python library is used, in this program the status graphs and information processing are generated. Python is an application that offers to process the information, display it graphically and store it, within this application you can program the time in which you want to take the reading and where you want to save the information, you can even add the conditions that you want to have in the monitoring system.

D. LOW DIAGRAM

According to the flow chart, the ultrasonic sensor will detect the flooding level through 3 conditions generating alerts.

Level 1: When the water level is between 0 - 2.50 meters, the graph will remain in its normal state, showing green.

Level 2: When the water level is between 2.51 - 3.70 meters, it will be considered a yellow alert, therefore, the graph will be shown in yellow.

Level 3: When the water level is between 3.71 - 5 meters, it will be considered a red alert, therefore, the graph will be shown in red.

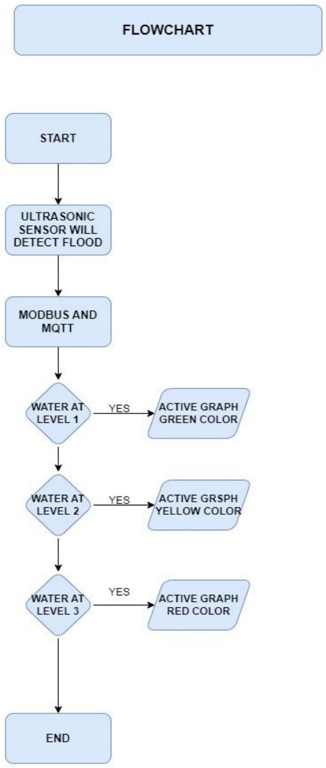

Fig. 4 Flow Diagram.

E. VALIDATION METHOD

This segment shows the process evaluated to confirm with concrete evidence of the operation of the telemetry watershed monitoring station.

1. PACKET´S GRAPH: The first graph shows the data of the different packets sent in the validation process, resulting in an excellent connection between publisher and the client.

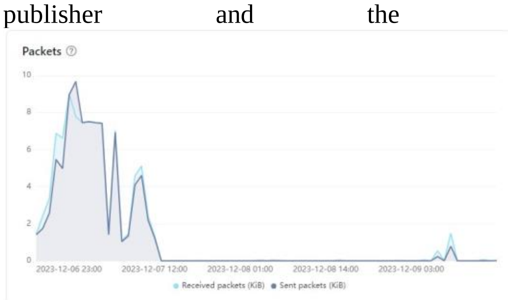

Fig. 5 Packet Graph.

2. MEASUREMENT GRAPHS: The following graphs show a series of measurements made from multiple distances to verify that the measurements that the sensor is making are correct and to observe that there is no delay in sending the data.

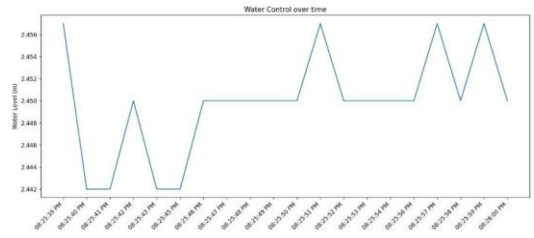

Fig. 6 River‘s level.

IV. RESULTS

In the physical implementation of the telemetric monitoring station of watersheds it was observed that the implementation of IOT is very helpful to develop technologies that integrate multiple functions in a single computer, in the development of this project the use of plates to make the communication modules was avoided, Cellular network was used for wireless communication since it is what provides more coverage in the country, and the data obtained are of great relevance to generate historical data, and to be informed instantly about the water level.

A. MEASUREMENT RESULTS

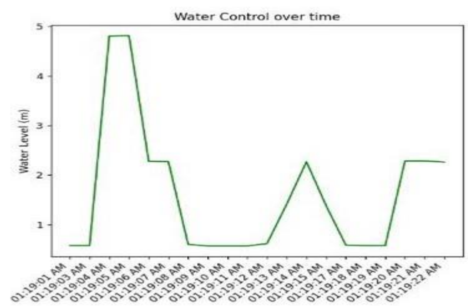

Fig. 6 Level 1.

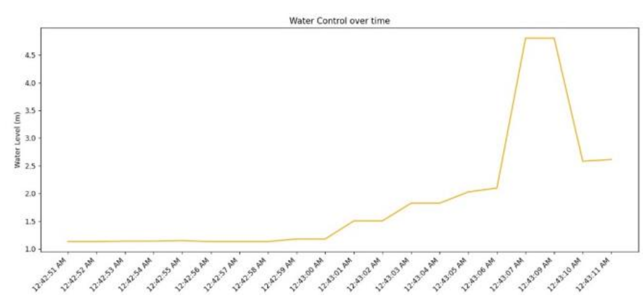

Fig. 6 Level 2.

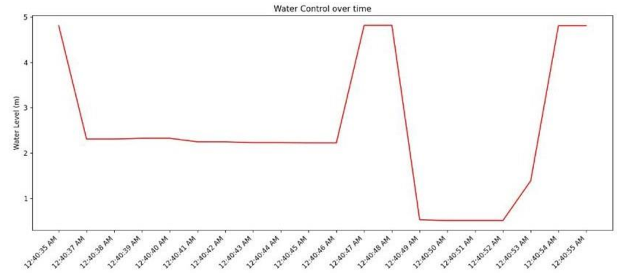

Fig. 6 Level 3.

V. CONCLUSIONES

The "Development of Telemetric Watershed Monitoring Station" project, which focuses on wireless data transmission and the implementation of Internet of Things solutions, obtains real-time data, which will facilitate the efficient management of the country's water resources. This is especially important in Honduras, which is susceptible to extreme hydro-climatic conditions. Evidence-based data collection management relies on efficient data communication from monitoring stations to control centers. In addition, the integration of solar power systems ensures that the stations operate autonomously and sustainably, even in remote areas. The use of MQTT supports timely and accurate water resource management by transmitting data securely and efficiently to control centers. This project not only helps authorities make informed decisions, but also protects the well-being of communities, safeguards aquatic ecosystems, and reduces risks in crucial watersheds in Honduras. This creates a safer and more sustainable future.

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