HYDROSENSE

A Capstone Project

Presented to the Faculty of the

College of Information Technology

University of Negros Occidental - Recoletos

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science in Information Technology

by

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The capstone project entitled:

HYDROSENSE

submitted by Bernard Anton J. Millaro, Marvin Jomel O. Felipe, and Thalea Prince P. Baladhay has been examined and is recommended for Oral Defense.

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HYDROSENSE

submitted by Bernard Anton J. Millaro, Marvin Jomel O. Felipe, and Thalea Prince P. Baladhay in partial fulfillment of the requirements for the degree of Bachelor of Science in Information Technology.

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HydroSense

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ABSTRACT

The United Nations' Sustainable Development Goal (SDG) 6 guarantees universal and equitable access to safe, affordable drinking water. Despite global initiatives, many rural, remote, and underserved communities still struggle to secure clean water, leading to elevated risks of waterborne illnesses from contaminated sources. In response, HydroSense was developed as a comprehensive monitoring solution. Powered by Arduino, it employs sensors to measure Total Dissolved Solids (TDS), turbidity, pH, and temperature. Real-time data is relayed to a web application, allowing users to visualize water quality metrics and receive tailored purification guidance. Beyond monitoring, HydroSense also offers educational hydrology materials to increase awareness of water management and safety practices. By combining sensor-driven analysis with a user-friendly interface, HydroSense makes direct strides toward SDG 6, promoting access to clean, safe water and underscoring the vital role of technology in safeguarding public health and sustainable water usage.

INFORMATION TECHNOLOGY CONCEPTS

•IoT-based Water Management •Sensor Integration •Real-time Water Quality Monitoring •Data Logging and Analysis

KEYWORDS

Water Quality, TDS, pH Levels, Turbidity, Arduino, Data Visualization, Web Application, Hydrology Resources, Real-time Monitoring

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1 INTRODUCTION

Clean water is essential to life, as hydration is the most basic function of water, necessary to keep the body of a living organism hydrated. It is important to preserve and sustain water availability for bodies that rely on water for digestion, metabolism, transportation of nutrients, and temperature regulation.[1] One of the Sustainable Development Goals (SDG) is SDG 6, clean water and sanitation, adopted by the United Nations (UN). SDG 6 clean water and sanitation goal is to ensure the availability and sustainable management of water sanitation for all and achieve universal and equitable access to safe and affordable drinking water for all. [2]

Billions of people worldwide still live without safely managed drinking water, safely managed sanitation, and basic hygiene services, especially in rural areas and least developed countries. Globally, 44 percent of all household wastewater flows are not safely treated. Thus, access to clean water is fundamental to human health and well-being. They are essential to improving nutrition, preventing disease, and enabling health care. [3]

In 2020, 47.46% of Filipinos need access to clean drinking water.[4] Contaminated water and poor sanitation are linked to the transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio.[5] Based on an article reported by the Department of Health (DOH) in 2023, there is a 101% rise in the number of people who suffer from typhoid fever. 3,285 compared to 1,633 from the same period in 2022.[6]

Access to safe water and adequate sanitation is a basic human right. While progress has been made towards achieving the Sustainable Development Goal on water and sanitation (SDG 6), the trends and status of access to water and sanitation cause concern. There is an urgent need to devise solutions that accelerate progress and ensure no one is left behind.[7] This leads the team to propose a software and hardware project that integrates sensors to determine the waters safety level to ensure drinking waters safety and quality. Sensors provide valuable insights into contaminants such as heavy metals, organic pollutants, pathogens, and other harmful substances in drinking water. HydroSense is a software-hardware integration application essential in preventing waterborne diseases and ensuring water safety for communities worldwide.

HydroSense goes beyond a mere technological breakthrough, offering a crucial solution for communities battling waterborne illnesses linked to insufficient access to clean water. It does more than detect contaminants; it facilitates informed, data-driven decisions. By providing trustworthy resources and guides on hydrology, it equips users with essential knowledge of water management and purification strategies. These materials serve as invaluable references for understanding and effectively managing water resources. Through its integrated software and hardware components, HydroSense empowers communities to monitor and maintain water quality proactively, mitigating risks and safeguarding public health.

1.1 Project Scope

The HydroSense project aims to deliver a comprehensive solution for assessing and improving water quality. To collect essential data, an Arduino-powered device equipped with advanced sensors—measuring TDS, turbidity, temperature, and pH—was developed. A dedicated web application analyzes and visualizes this information, offering real-time insights and suggestions for improving water quality. Ultimately, the goal is to empower individuals to make informed decisions about their water sources and take effective steps to preserve or enhance water quality.

2 METHODOLOGY

The HydroSense project methodology emphasizes creating an accessible and efficient real-time water quality monitoring system by integrating sensors with user-friendly software. The system utilizes an Arduino-based microcontroller and sensors to measure essential water parameters such as Total Dissolved Solids (TDS), pH, turbidity, and temperature. These sensors continuously collect data, which is processed and transmitted to a web application, providing users real-time insights into water quality. This approach ensures dependable data collection and ease of use, particularly for communities with limited resources.

The web application is the primary interface, featuring intuitive data visualization through graphs and charts. Users monitor trends, receive personalized water treatment recommendations, and log or export historical data in CSV format for further analysis. Additionally, the system includes a comprehensive library of hydrology resources, offering educational materials on water management and purification techniques.

2.1 Design and Implementation Controls

The design and functionality of HydroSense are shaped by several key considerations. Ensuring continuous device operation and accurate data collection for reliable water quality monitoring is fundamental to achieving its objectives. Environmental influences on sensor accuracy and durability are also carefully assessed to maintain system reliability. Furthermore, dependable internet connectivity is crucial for transmitting real-time data, underscoring the importance of a stable network. By proactively recognizing and addressing these challenges, the team ensures that HydroSense remains practical and effective over the long term.

2.2 Technology Deployment

HydroSense relies on both hardware and software to function seamlessly. The hardware consists of an Arduino platform paired with various sensors, while the software is a web application dedicated to data visualization and recommendations. A stable internet connection is critical for real-time transmission of sensor readings to the web server, allowing users to access and analyze water quality data from any internet-connected device.

Effective hardware selection is vital for implementing the HydroSense system. Essential components include the ESP32-WROOM-32D and Arduino Nano, sensors for TDS, pH, turbidity, and water temperature, a 0.96-inch OLED display, a microSD storage module, and an external 5V power source. Table 1 summarizes all required components and their respective models for building HydroSense.

Components	Model	
Microcontrollers	Arduino UNO	
	ESP32-WROOM-32D	
Sensors	SEN0422	TDS
	SEN0161	pH
	TSW-20M	Turbidity
	DS18B20	Water Temperature
Device Screen	SSD1306	0.96-inch OLED
Storage	HW-125	mSD module
Power	External 5v Power Supply	

Table 1: Hardware Requirements.

HydroSense relies on a stable internet connection and WiFi compatibility to facilitate seamless communication. This connectivity enables the device to link with the web application, transmitting real-time water quality data and receiving updates or recommendations. Various browsers are critical for deploying and testing the web application. At the same time, a dependable internet connection is essential for integrating the device and ensuring smooth access to online services, such as APIs. (see table 2)

Component	Specification
Mode of Connection	Wi-Fi
Wi-Fi Range	~15 – 20 meters in line of sight
Internet Speed	10 Mbps

Table 2: Connectivity Requirements.

2.3 Features and Functionalities

The web application guides users through the interfacing process with step-by-step prompts. Successful interfacing guarantees smooth data transmission from the sensors to the web application. Figure 1 provides an overview of HydroSense features and functionalities in a simplified format.

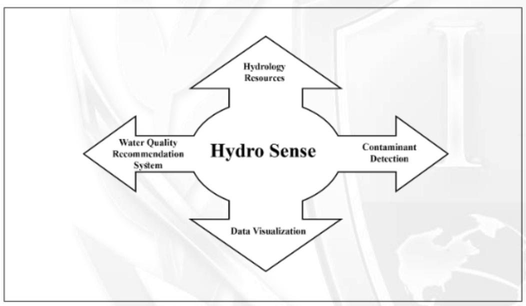

Figure 1: Features and Functionalities of HydroSense.

The water quality recommendation system measures key parameters such as TDS, pH, and turbidity in a water sample. Once these readings are collected, the system integrates them to assess overall water quality, identify potential health risks, and deliver targeted treatment recommendations. Users view the test results, associated health concerns, and suggested interventions through the contaminant detection module.

Data collection begins with immersing a sensor in the water and confirming successful data transmission. Users start and stop data logging using a user-friendly interface with data visualization features. The gathered information is stored in a CSV file, providing real-time and historical data views. An export option allows users to download data for further analysis or documentation.

Including comprehensive hydrology resources within the system is crucial for offering thorough and practical insights. These resources deliver detailed information about water characteristics and treatment methods, enhancing users' understanding of water quality issues and potential solutions.

2.4 Interface and Interactions

HydroSense provides a comprehensive platform divided into four main sections: Homepage, Data Insights, Hydrology Resources, and About. The Homepage features real-time water quality monitoring, interactive gauges displaying pH, TDS, turbidity, and temperature, and options for data logging and receiving recommendations. The Data Insights section offers detailed analyses and historical data visualization through interactive graphs and tables, enabling users to track water quality trends over time. The Hydrology Resources section serves as an educational hub, providing valuable information on water safety, pH levels, and treatment methods through articles and videos. Lastly, the About section introduces the HydroSense project, its development team, and its technical framework.

2.5 Performance Testing and Evaluation

The ISO/IEC 9126[8] software quality model was applied to evaluate the software components of HydroSense, focusing on usability, efficiency, and functionality. Particular emphasis was placed on the usability attribute to assess the user experience quality across features such as hydrology resources, data visualization, and the water quality recommendation system. Table 3 outlines the criteria used for evaluating the software aspects of HydroSense.

Product Features	Software Quality Models and Attributes	Software Quality Criteria
Hydrology Resources	Usability (ISO/IEC-9126)	Understandability
		Learnability
		Operability
		Attractiveness
		Compliance
Contaminant Detection	Functionality (ISO/IEC-9126)	Accuracy
		Interoperability
		Compliance
Data Visualization	Efficiency (ISO/IEC-9126)	Resource Utilization
		Time Behavior
		Compliance
Water Quality Recommendation	Usability (ISO/IEC-9126)	Understandability
		Learnability
		Operability
		Compliance

Table 3: Software Quality Model.

The ISO/IEC 30141[9] IoT system reference architecture model was utilized to evaluate the hardware aspects of HydroSense, emphasizing trustworthiness, architecture, and functional characteristics. Trustworthiness was measured by availability, confidentiality, integrity, reliability, resilience, and safety, ensuring continuous operation, secure data transmission, accurate sensor readings, and system recovery from environmental challenges. Regarding architecture, HydroSense was assessed for composability, heterogeneity, modularity, and scalability, enabling seamless integration or replacement of sensors, compatibility across various sensor types, and the system ability to expand by incorporating additional sensors. (see table 4)

Hardware	Characteristics of IoT System	Related Characteristics
Hydrosense	IoT system trustworthiness characteristics	Availability
		Confidentiality
		Integrity
		Reliability
		Resilience
		Safety
	IoT system architecture characteristics	Heterogeneity
		Modularity
		Network Connectivity
	IoT system functional characteristics	Compliance
		Data Characteristics
		Real-time Capability

Table 4: Hardware Quality Model.

3 RESULTS

The results for HydroSense were derived from a one-day collection of water quality data using multiple sensors that measured TDS, pH, turbidity, and temperature. The system logged data every five minutes, resulting in over 86,400 data points. These readings were processed and displayed through the web application, enabling real-time trend visualization and the generation of water quality recommendations based on predefined sensor thresholds. The system demonstrated consistent performance, accurately detecting changes in water quality and delivering actionable insights to users. All data was stored in CSV format to facilitate further analysis and validation.

3.1 Data Visualization and Historical Data Logging

HydroSense addresses the need for continuous monitoring and historical tracking of water quality data. Over one day, the system collected more than 86,400 data points by logging sensor readings at one-minute intervals. These data points, including TDS, pH, Turbidity, and temperature measurements, were processed and presented through the web application, offering users clear, real-time visualizations in graphs and charts. There is a slight deviation in water temperature as it is affected by the room temperature where the test occurred.

3.2 Water Quality Recommendation

The hydrology resources feature of HydroSense enhances real-time data collection and recommendations by providing educational materials to help users interpret test results more effectively. With over 86,400 data points collected during the one-day test, these resources offered vital background knowledge on managing and treating water based on observed trends and anomalies. They enabled users to look beyond immediate sensor readings, fostering an understanding of the long-term implications of water quality management. These resources guided users through best practices for purification and sustainable water management during and after the testing phase.

3.3 Hydrology Resources

The hydrology resources feature of HydroSense enhances real-time data collection and recommendations by providing educational materials that assist users in interpreting test results more effectively. During the one-day test period, which generated over 86,400 data points, these resources offered crucial background knowledge on managing and treating water based on observed trends and anomalies. They allowed users to move beyond immediate sensor readings, gaining insights into the long-term implications of water quality management. These resources guided users in adopting best practices for water purification and sustainable management during and after the testing phase.

4 CONCLUSION AND RECOMMENDATIONS

The conclusion of this capstone provides a summary of the solutions developed to tackle the identified challenges in water quality monitoring and highlights potential opportunities for future improvements. This section consolidates the results obtained during the testing phase and emphasizes the systems' overall achievements. Its objective is to present a clear and comprehensive overview of the project findings and outcomes, demonstrating its effectiveness in real-time water quality monitoring and user support.

4.1 Conclusion

HydroSense effectively achieves the objectives outlined in its design and implementation, delivering an integrated system that combines hardware, software, and user-friendly interfaces to facilitate water quality monitoring and awareness.

4.1.1 Device Development. An Arduino-based system with sensors to measure TDS, pH, turbidity, and temperature was developed. The device was designed to provide real-time water quality data, prioritizing accessibility and operability in various environments.

4.1.2 Web Application Integration. A web application was implemented to grant users access to real-time water quality data through a centralized platform. The application displayed data visually using graphs and charts, enabling easy interpretation while supporting historical data logging and analysis.

4.1.3 Data Visualization and Historical Data Logging. The system recorded over 86,400 data points during a one-day test. These data were processed, visualized, and stored in CSV format, offering users a detailed record of water quality trends and anomalies over time.

4.1.4 Water Quality Recommendations. The system successfully analyzed sensor data to provide specific water treatment suggestions. Recommendations were tailored to TDS, pH, turbidity, and temperature levels, offering actionable guidance to users for improving water quality.

4.1.5 Hydrological Resources. Addressed by integrating educational materials into the system. Users were provided with articles, guides, and tutorials on water purification and management, allowing them to better understand their water quality data and adopt sustainable water practices.

In conclusion, HydroSense presents a system that incorporates real-time monitoring, data visualization, personalized recommendations, and educational resources, aligning with the projects design objectives.

4.2 Recommendations

A good way to improve HydroSenses ability to assess a wider range of water quality parameters is to integrate additional sensors that are able to detect contaminants such as dissolved oxygen, nitrates, and heavy metals. HydroSense has the potential to provide a more comprehensive water quality analysis by expanding the range of measurable parameters, making it suitable for use in more diverse environments.

Also, having a dedicated mobile application is more convenient for users than accessing HydroSense through a browser. One positive of having a dedicated mobile application is the capability of using push notifications to alert users when the water quality exceeds safe limits.

Lastly, shifting to cloud-based data storage offers several advantages, including remotely monitoring HydroSense data or storing large volumes of historical data. This allows users to access their data from multiple devices and perform more advanced data analysis over longer periods.

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CHAPTER I

INTRODUCTION

Clean water is essential to life, as hydration is the most basic function of water, necessary to keep the body of a living organism hydrated. It is important to preserve and sustain water availability for bodies that rely on water for digestion, metabolism, transportation of nutrients, and temperature regulation [PM2024]. One of the Sustainable Development Goals (SDGs) is SDG 6, clean water and sanitation, adopted by the United Nations (UN). SDG 6 clean water and sanitation goal is to ensure the availability and sustainable management of water sanitation for all and achieve universal and equitable access to safe and affordable drinking water for all. [OD2021]

Billions of people worldwide still live without safely managed drinking water, safely managed sanitation, and basic hygiene services, especially in rural areas and least developed countries. Globally, 44 percent of all household wastewater flows are not safely treated. Thus, access to clean water is fundamental to human health and well-being. They are essential to improving nutrition, preventing disease, and enabling health care. [UN2021]

In 2020, 47.46% of Filipinos had no access to clean drinking water [BC2021]. Contaminated water and poor sanitation are linked to the transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio [WH2023]. According to an article by the Department of Health (DOH), the number of people suffering from typhoid fever rose 101% to 3,285 compared to 1,633 in the same period in 2022 [DV2023].

To ensure safe water and proper sanitation is widely recognized as a fundamental human right. Although there has been some advancement toward meeting the Sustainable Development Goal on water and sanitation (SDG 6), current trends and levels of access remain troubling, highlighting the urgent need for solutions that accelerate progress and include everyone. In light of these concerns, the team proposes a combined software-hardware initiative that uses sensors to evaluate water safety levels, ensuring safe and high-quality drinking water. These sensors offer critical insights into contaminants such as heavy metals, organic pollutants, pathogens, and other harmful substances. As a fully integrated solution, HydroSense plays a pivotal role in preventing waterborne diseases and safeguarding drinking water quality for communities around the globe.

HydroSense goes beyond a mere technological breakthrough, offering a crucial solution for communities battling waterborne illnesses linked to insufficient access to clean water. It does more than detect contaminants; it facilitates informed, data-driven decisions. By providing trustworthy resources and guides on hydrology, it equips users with essential knowledge of water management and purification strategies. These materials serve as invaluable references for understanding and effectively managing water resources. Through its integrated software and hardware components, HydroSense empowers communities to proactively monitor and maintain water quality, mitigating risks and safeguarding public health. HydroSense user-friendly interface ensures accessibility for users of all skill levels, encouraging widespread adoption. By raising awareness about waterborne diseases and prevention, it empowers communities to manage their water resources. Its scalable design enables integration with regional systems, creating pathways for more robust and comprehensive solutions.

1.1 Purpose

This project focuses on creating an Arduino-based device equipped with TDS, turbidity, temperature, and pH sensors to evaluate water quality and transmit real-time data to a web application. By doing so, HydroSense contributes to the United Nations' Sustainable Development Goal 6, which aims to ensure safe water and sanitation for everyone. The web application displays the collected data and provides tailored recommendations for water purification methods based on detected contaminants and raises awareness about health risks linked to consuming contaminated water. By integrating hardware and software, HydroSense empowers individuals and organizations to make informed decisions about water safety and take appropriate steps to secure access to clean, safe water, ultimately supporting the broader goal of achieving sustainable development worldwide.

1.1.1 Device Development

HydroSense was developed to address individuals' concerns about the quality of their drinking water at home. By providing a reliable and user-friendly device, HydroSense ensures accessibility for all users, empowering them to assess and maintain their water quality effectively. This user-centric approach promotes informed decision-making and proactive management of water resources.

1.1.2 Web Application Integration

The integration of web applications into HydroSense aims to create a centralized platform for real-time water quality monitoring and data visualization. This integration provides users access to sensor data from any smartphone or computer, facilitating timely decision-making and intervention. The web application features an intuitive interface, personalized water purification recommendations, and educational resources on water safety. It also supports historical data analysis and remote monitoring, adding value for individual and institutional users. Overall, this integration enhances HydroSense usability and effectiveness, advancing the goal of ensuring clean and safe drinking water.

1.1.3 Data Visualization

By enabling users to interpret water quality data collected by the sensors effectively, data visualization plays a crucial role in HydroSense. Users are able to quickly grasp key water quality parameters, identify trends, and spot anomalies. This visual representation facilitates informed decision-making and helps users take appropriate actions to ensure water safety. Additionally, it enhances user engagement and understanding, making complex data accessible to individuals with varying levels of technical expertise. Data visualization supports proactive water management and maintains clean and safe water sources.

1.1.4 Water Quality Analysis

Evaluating water safety and suitability for consumption and other purposes is vital in HydroSense. By examining data gathered from TDS, turbidity, temperature, and pH sensors, users gain a well-rounded view of water quality, helping to identify contaminants and pollutants such as dissolved solids and uncover potential health risks. Early detection of these risks enables swift and appropriate measures to ensure safe water. Additionally, the water quality analysis feature generates tailored recommendations for purification based on real-time sensor data. For instance, high TDS levels prompt a recommendation for filtration, whereas elevated turbidity suggests sedimentation. These customized suggestions help users effectively address specific contaminants and maintain safe drinking water. Ultimately, water quality analysis and the accompanying recommendations empower individuals to make informed decisions about water treatment.

1.1.5 Hydrology Resources

In HydroSense, hydrology resources supply users with extensive information and educational content on water quality and management, helping them understand various treatment methods. By offering a comprehensive selection of articles, guides, and tutorials, these resources broaden users' knowledge of water safety, sources of contamination, and effective purification strategies. This equips individuals to make informed decisions about water consumption and treatment. Additionally, hydrology resources encourage awareness of the importance of maintaining clean water and adopting sustainable water management practices. Ultimately, they are essential in promoting water safety and sustainability, supporting the project goal of ensuring clean and safe water is accessible to everyone.

1.2 Technical Review of Related Systems

The existing water quality system and devices, such as Yinmik Bluetooth Multi-Parameter Water Analyzer [YM2009], Gain Express WQM-341 [GE2003], and Lepmerk Mini 991W Bluetooth Remote Monitoring App [LM2021], have been a reference in the project. The current applications' systems and devices differ from those in the applications the developers plan to develop. The concept distinguishes itself by integrating Arduino-based sensors and a companion web application for real-time monitoring and data transmission. The features include water treatment advice and support structured decision-making processes to ensure water safety. The developers project outlines criteria for the system and device objectives, addressing challenges, data transmission, data visualization, hydrology resources, and power source. Evaluation against existing devices highlights HydroSense advanced comprehensive water quality monitoring capabilities. Achieving these goals effectively relies on completing the prerequisites, as indicated in Table 1.

HydroSense Criteria	Yinmik Bluetooth Multi-Parameter Water Analyzer	Gain Express WQM-341	Lepmerk Mini 991W Bluetooth Remote Monitoring App	HydroSense
Sensor Used	pH, TDS, EC	pH, EC, TDS, Salinity, SG, Water Temperature	pH, EC, TDS, SG, Water Temperature	TDS, pH level, Turbidity, Water Temperature
Data Transmitted	Bluetooth	Wi-Fi	Bluetooth	Wi-Fi
Data Visualization	Sensor Variables	Sensor Variables	Sensor Variables	Sensor Variables, Graphs, Charts and Recommendation
Hydrology Resources	Does not apply	Does not apply	Does not apply	Provides hydrology resources
Power Source	Internal, External	External	External	Internal, External

Table 1. Comparative Matrix of Related Systems.

1.2.1 Sensor Used

This criterion employs sensor technology to gather essential water parameters, forming the cornerstone for detailed water quality analysis. The system integrates sensors and collects data on crucial metrics such as pH levels, Total Dissolved Solids (TDS), and Electrical Conductivity (EC). This enables users to obtain precise measurements of diverse water quality indicators vital for monitoring and assessment.

The Yinmik Bluetooth Multi-Parameter Water Analyzer utilizes sensors for pH, TDS, EC, and other pivotal parameters, facilitating a thorough water quality analysis. In contrast, the Gain Express WQM-341 incorporates sensors for pH, EC, TDS, Salinity, SG (Specific Gravity), and water temperature, offering a wider range of data for comprehensive assessment. Similarly, the Lepmerk Mini 991W Bluetooth Remote Monitoring App integrates pH, EC, TDS, SG, and water temperature sensors, ensuring a comprehensive grasp of water quality dynamics.

These sensor-equipped systems significantly enhance the efficiency of data collection, empowering users to access accurate and diverse information crucial for informed decision-making and environmental monitoring. On the other hand, HydroSense employs sensors for TDS, pH level, Turbidity, and water temperature, providing vital insights into various aspects of water quality.

1.2.2 Data Transmitted

This aspect addresses data transmission via Bluetooth and Wi-Fi in various water analyzers and monitoring applications, serving as a key indicator of these devices' connectivity capabilities. Bluetooth and Wi-Fi facilitate seamless interaction between the devices and user interfaces, enabling users to monitor water parameters remotely and in real-time, thus enhancing accessibility and convenience. Ultimately, this feature ensures that users effectively employ water quality monitoring and analysis tools, leading to more efficient data collection, management, and analysis processes.

The Yinmik Bluetooth Multi-Parameter Water Analyzer transmits data using Bluetooth, allowing users to connect the device to compatible smartphones or tablets for real-time monitoring and analysis of water parameters. Similarly, the Lepmerk Mini 991W Bluetooth Remote Monitoring App employs Bluetooth for transmitting data, enabling users to monitor water quality remotely using their smartphones or tablets. On the other hand, the Gain Express WQM-341 and HydroSense utilize Wi-Fi for data transmission, enabling users to connect the devices to local networks for centralized data management and analysis.

This criterion ensures that water analyzers and monitoring applications offer versatile connectivity options catering to users' diverse needs and preferences. The devices facilitate seamless data transmission through Bluetooth or Wi-Fi for efficient water quality monitoring and analysis applications.

1.2.3 Data Visualization

This criterion assesses the quality of data visualization in water analyzers and monitoring applications. It evaluates how effectively these tools present sensor variables through graphs, charts, and recommendations. Data visualization is crucial for aiding users in comprehensively interpreting and analyzing water parameters.

The Yinmik Bluetooth Multi-Parameter Water Analyzer, Gain Express WQM-341, and Lepmerk Mini 991W Bluetooth Remote Monitoring App primarily concentrate on data collection and transmission. However, they do not include features for graphical visualization or provide any recommendations based on the collected data. As a result, users rely solely on raw data readings without visual aids like graphs or charts to support interpretation. Moreover, these devices do not offer suggestions for potential actions drawn from data analysis.

In contrast, HydroSense distinguishes itself through its robust data visualization features. It displays sensor measurements via graphs and charts, complemented by in-depth recommendations based on thorough analysis. This all-encompassing strategy ensures that users not only understand the current water quality status but also gain actionable guidance on steps to improve or maintain water quality effectively.

1.2.4 Hydrology Resources

This criterion evaluates the presence of hydrology resources within the water analyzers and monitoring applications considered. While the Yinmik Bluetooth Multi-Parameter Water Analyzer, Gain Express WQM-341, and Lepmerk Mini 991W Bluetooth Remote Monitoring App do not offer a hydrology resource, HydroSense distinguishes itself by providing users with access to one.

The Yinmik Bluetooth Multi-Parameter Water Analyzer, Gain Express WQM-341, and Lepmerk Mini 991W Bluetooth Remote Monitoring App prioritize data collection, transmission, and visualization functionalities without incorporating a hydrology resource. Users primarily rely on these devices to monitor and analyze water parameters.

On the other hand, it goes beyond basic functionality by offering users a hydrology resource. These components potentially include tutorials, guides, or articles to enhance users' understanding of water quality management principles, sensor technology, and best practices for interpreting data. By providing a hydrology resource alongside its core features, it contributes to users' knowledge and proficiency in water quality monitoring and management.

1.2.5 Power Source

This criterion pertains to the power sources utilized by the water analyzers and monitoring applications considered. It addresses whether these devices rely on both internal, external, or a combination. Understanding the power source is crucial for users in determining the flexibility and reliability of these tools in various operational environments.

The Yinmik Bluetooth Multi-Parameter Water Analyzer and the Lepmerk Mini 991W Bluetooth Remote Monitoring App offer flexible power source options, allowing operation from an internal or external supply. This adaptability makes it easy for users to accommodate different environments, plugging into available power outlets when possible or using internal batteries for convenient portability.

Similarly, the Gain Express WQM-341 relies solely on external power sources, ensuring consistent and reliable operation if connected to a power supply. On the other hand, HydroSense offers flexibility between internal and external power sources, providing users with options based on their specific needs and preferences.

1.3 Project Scope

The HydroSense project scope provides a holistic solution for monitoring and improving water quality. It involves creating an Arduino-based device equipped with advanced sensors to measure TDS, turbidity, water temperature, and pH. In tandem, a web application visualizes and analyzes the collected data, delivering real-time insights into water quality and offering suggestions for improvement. Ultimately, the project objective is to empower individuals to make informed decisions about their water sources and take action to maintain or enhance water quality.

1.3.1 Arduino-Powered Device

The HydroSense project involves designing and constructing a water quality monitoring device based on the Arduino platform. This device integrates sensors for measuring TDS, Turbidity, water temperature, and pH levels to ensure accurate data acquisition. It includes a screen for displaying real-time data, making it easy for users to monitor water quality directly from the device. This setup ensures that users are able to effectively assess and maintain water quality.

1.3.2 Sensor Types

The HydroSense water quality monitoring device incorporates high-quality sensors specifically selected to measure essential parameters such as TDS, turbidity, water temperature, and pH. These sensors, chosen for their precision and sensitivity, ensure accurate and dependable data collection, offering crucial insights into water quality. By using these advanced sensors, the device thoroughly evaluates water conditions, enabling users to detect contaminants and respond effectively. Incorporating advanced sensors is fundamental to achieving efficient water quality monitoring and management.

1.3.2.1 TDS (Total Dissolved Solids) Sensor

This sensor quantifies the concentration of dissolved solids in water, including salts, minerals, metals, and organic compounds. This measurement provides valuable information about the waters overall mineral content and purity. High TDS levels potentially indicate the presence of contaminants or pollutants, such as heavy metals or agricultural runoff, which are able to affect water quality and pose health risks to consumers. Health risks include gastrointestinal problems, such as stomach pain and diarrhea, and in extreme cases, cause kidney disease, liver disease, and even death. [TD2022]

1.3.2.2 pH Sensor

The pH sensor is essential for determining the acidity or alkalinity of the water, providing critical information about its chemical balance. Monitoring pH levels helps detect potential contaminants or pollutants, such as acids or bases, that potentially affect the water safety for consumption. This sensor ensures that users are aware of any water quality changes that may require intervention. The pH sensor plays a crucial role in maintaining water safety and purity.

1.3.2.3 Turbidity Sensor

The turbidity sensor measures the cloudiness or haziness of the water, indicating suspended particles. By monitoring turbidity levels, users are able to assess the aesthetic quality and potential contamination of the water. High turbidity levels potentially suggest the presence of pollutants or pathogens, prompting necessary treatment actions. This sensor is vital for ensuring the waters clarity and overall safety.

1.3.2.4 Water Temperature Sensor

The water temperature sensor tracks the water temperature during testing, an essential factor for accurate water quality evaluations. Because temperature affects various chemical and physical properties including TDS readings monitoring, the device can refine TDS measurements for greater precision. As a result, users obtain reliable water quality data, enhancing the overall effectiveness of the monitoring system.

1.3.3 Web Application and Device Compatibility

The software development process includes building a web application as a unified hub for displaying and analyzing real-time water quality measurements gathered by the Arduino-powered device. Users can examine and interpret this data from any internet-capable device such as a smartphone, tablet, or computer, access recommendations to enhance water quality, and consult various hydrology resources. By offering a user-friendly interface, the application facilitates seamless interaction with the Arduino device and delivers valuable insights into water sources.

1.3.4 Data Visualization Features

In the context of the water quality monitoring project, the data presented in the web application include various visualizations to represent water quality parameters effectively. These visualizations potentially include graphs and color-coded indicators to comprehensively overview TDS, Turbidity, water temperature, and pH levels. By using these visual aids, users are able to interpret the data intuitively and make informed decisions regarding water quality management. The goal is to present the data in a format that is easy to understand for users with varying levels of expertise and to facilitate quick insights into the quality of the water being monitored.

1.3.5 Water Quality Recommendation System

Based on the collected sensor data, the water quality recommendation system is designed to offer tailored guidance for water purification methods based on real-time sensor data analysis. This system analyzes the collected data from TDS, Turbidity, water temperature, and pH sensors, identifying specific contaminants and their concentrations in the water. By gathering this information through the water, the system generates personalized recommendations for effective water treatment strategies, such as filtration or sedimentation. These recommendations be integrated into the web application interface, providing users with actionable insights to address water quality issues promptly and ensure access to clean and safe drinking water. The Water Quality Recommendation System equips users with tools for effective water management and sustainable practices.

1.3.6 Hydrology Resources

This project develops a hydrology resource to provide users with knowledge and insights into water safety practices and sustainable water management. Integrated into the web application, this resource offers articles and guides that cover a range of topics—including the importance of monitoring water quality, the impact of contaminants on human health and the environment, and best practices for water purification and conservation. Through HydroSense, users are equipped with the tools and information to enhance awareness, foster engagement, and ensure global access to clean water.

This chapter underscores the critical importance of water quality management and highlights the health risks of inadequate water supplies. HydroSense combines Arduino devices and a web application to provide real-time monitoring, data analysis, and actionable recommendations, ensuring clean, safe water access. By integrating sensors, data visualization, and targeted guidance, HydroSense enables users to confront water quality challenges effectively. Moreover, it directly advances SDG 6, which focuses on clean water and sanitation, by curbing the spread of waterborne illnesses and improving public health outcomes.

CHAPTER II

PRODUCT SPECIFICATIONS

This chapter delved into the technical specifications essential for developing and implementing HydroSense. It aimed to comprehensively understand the system framework by detailing the hardware and software components, operating environment, and connectivity requirements. The chapter also addressed crucial design and implementation constraints, such as power needs and data accuracy, to ensure reliable and efficient system performance. Additionally, it outlined the assumptions and dependencies underpinning the project success, ensuring that each aspect of the system was robust and well-integrated.

2.1 Product Perspective and General Features

The device powered by Arduino, equipped with essential sensors and interfacing with a web application, offered a comprehensive solution for monitoring water quality. This integrated system provided users with real-time data on TDS, turbidity, water temperature, and pH, enabling informed decision-making regarding water safety. HydroSense multiple sensors ensured accurate data collection, while the web application intuitive interface presented actionable insights, water puri cation recommendations, and hydrology resources to empower users in managing water quality effectively. The combination of hardware and software components made HydroSense a reliable tool for personal and professional water quality monitoring. This holistic approach bridged the gap between technology and water safety. It fostered proactive water management for healthier communities. Figure 1 shows the four general features of HydroSense.

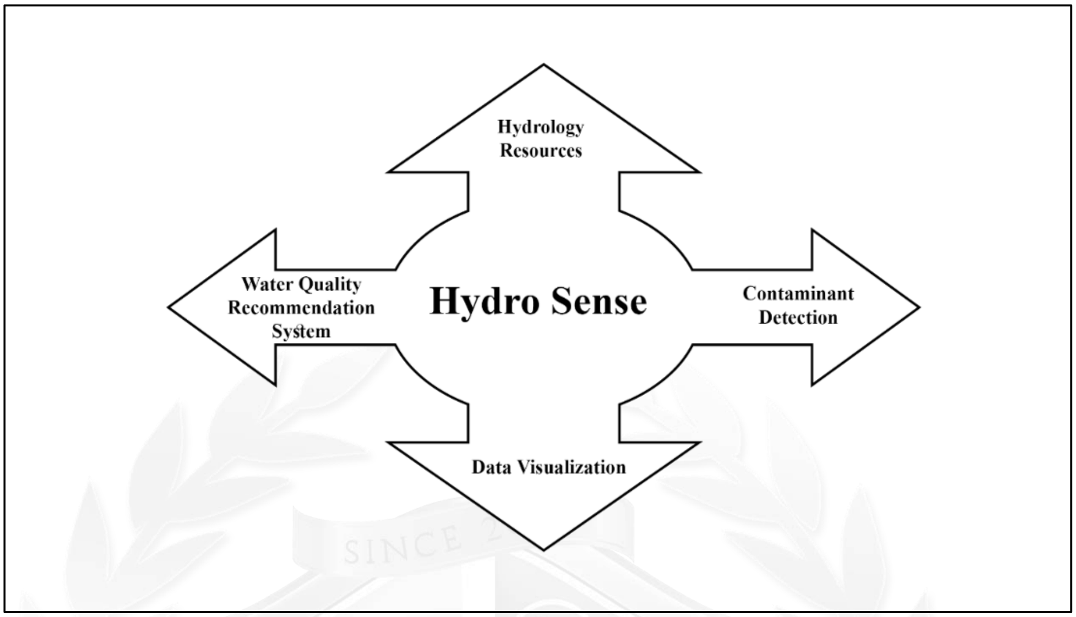


Figure 1. HydroSense General Features.

2.1.1 Contaminant Detection

It is a pivotal aspect of HydroSense, ensuring the accurate identification and assessment of harmful substances in the water. Using sensors like TDS, Turbidity, water temperature, and pH in the device offered a comprehensive view of water quality. These sensors provided real-time data on key parameters, enabling users to accurately monitor water condition changes. By utilizing these sensors, the device assesses water cleanliness and offers tailored recommendations for water purification methods. This feature empowered users to make informed decisions about water safety, ensuring access to clean and healthy water sources while promoting proactive measures for water quality management. It simplifies water monitoring while supporting sustainable water management practices. It also encourages informed actions for cleaner water sources.

2.1.2 Data Visualization

It offered a detailed insight into water quality parameters. Each sensor, including TDS, Turbidity, temperature, and pH, was accompanied by a real-time graph displaying data. This allowed users to track the historical trends of each parameter over time, facilitating a deeper understanding of water quality dynamics. Moreover, users view the real-time values of each sensor, providing immediate feedback on current water conditions. Additionally, the web application enabled users to download historical data in CSV format if they decided to save the sensor data, empowering them to conduct further analysis or share information with relevant stakeholders. This comprehensive functionality enhanced users' ability to monitor and manage water quality effectively, ensuring the continuous provision of clean and safe water resources.

2.1.3 Water Quality Recommendation

It provide users with guidance on how to purify their contaminated water based on sensor readings was a feature of the water quality recommendation system in the web application. It offered tailored suggestions for water purification methods by leveraging data collected from TDS, Turbidity, water temperature, and pH sensors. By analyzing these sensor readings, the recommendation system advised users on specific actions to clean their water effectively. This ensured that users addressed detected contaminants appropriately and maintained access to clean and safe water sources. This system enhanced user confidence in managing water safety. It promoted informed, timely actions for better water quality.

2.1.4 Hydrology Resources

This component feature of the web application provided a diverse collection of materials to enhance user understanding of water quality and safety. This feature included articles, guides, and videos addressing water quality monitoring, the health effects of contaminants like heavy metals and bacteria, and water purification and conservation strategies. Notable sources included the World Health Organization (WHO) guidelines for drinking water quality, the United States Geological Survey insights on turbidity and water temperature, and educational content from the Safe Drinking Water Foundation on TDS and pH. These resources ensured users had access to accurate, practical, and up-to-date information, empowering them to make informed water management and safety decisions.

2.2 Operating Environment

HydroSense operated with both hardware and software components to ensure seamless functionality. The hardware included the Arduino platform and various sensors, while the software encompassed the web application used for data visualization and recommendations. A stable internet connection was essential for real-time data transmission between the device and the web server. This integration allowed users to access and analyze water quality data from any internet-enabled device. This enables timely, informed decisions on water safety and management. By combining these elements, HydroSense provides a comprehensive and accessible solution for continuous water quality monitoring.

2.2.1 Hardware Requirements

As outlined in Table 2, the hardware requirements for HydroSense were crucial for its successful development and implementation. Identifying the necessary components and specifications ensured the system effectively performed its intended operations. The foundation provided by these components was essential for building a robust and functional system. The ESP32-WROOM-32D and Arduino Uno microcontrollers included sensors for measuring TDS, pH, Turbidity, and water temperature, a 0.96-inch OLED device screen, and a microSD storage module. Additionally, the system required an external 5V power source for operation. The project achieved accurate data collection and reliable performance by addressing these hardware needs.

Function Components	Development		Implementation	
Arduino / Microcontroller	ESP32-WROOM-32D		ESP32-WROOM-32D	
	Arduino Uno		Arduino Uno	
Sensors	SEN0244	TDS	SEN0244	TDS
	SEN0161	pH	SEN0161	pH
	TSW-20M	Turbidity	TSW-20M	Turbidity
	DS18B20	Water Temperature	DS18B20	Water Temperature
Device Screen	SSD1306	0.96-inch OLED	SSD1306	0.96-inch OLED
Storage	HW-125	microSD Module	HW-125	microSD Module
Power	External 5v Power Supply		External 5v Power Supply	

Table 2. Hardware Requirements.

2.2.1.1 ESP32-WROOM-32D Microcontroller

Figure 2 highlights the ESP32-WROOM-32D microcontroller, primarily used to serve the web server in HydroSense. It facilitated real-time data transmission and communication between the sensors and the web application. This microcontroller built-in Wi-Fi capabilities enabled seamless connectivity, allowing users to access and monitor water quality data remotely. By leveraging the ESP32 powerful processing and connectivity features, the system ensured efficient and reliable performance.

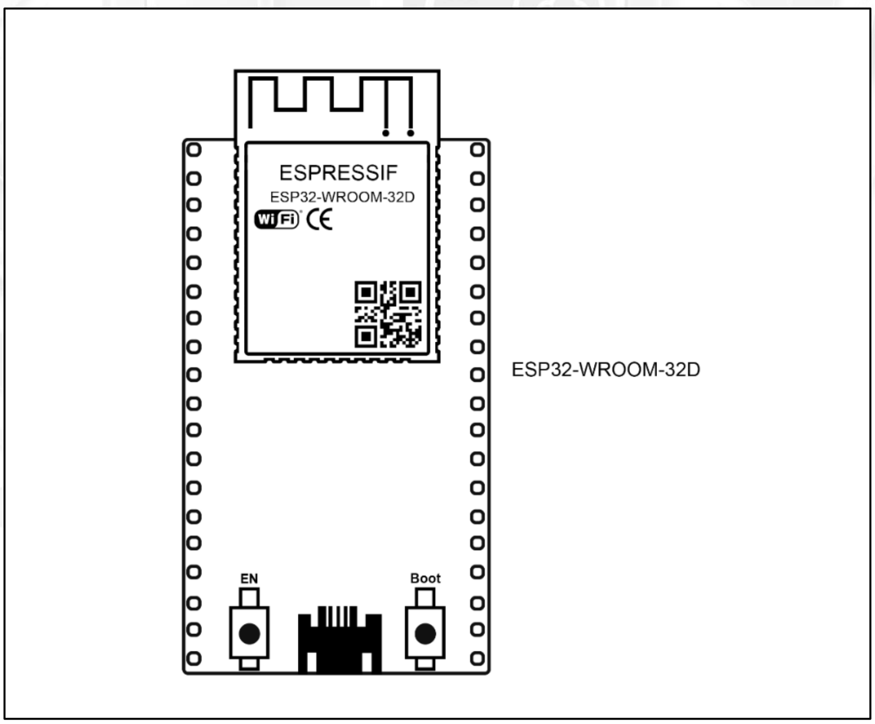


Figure 2. ESP32-WROOM-32D Microcontroller.

2.2.1.2 Arduino UNO

Figure 3 highlights the Arduino Uno microcontroller, primarily used for interfacing with the sensors in HydroSense. It facilitated real-time data acquisition from the Turbidity, pH, TDS, and temperature sensors. This microcontroller versatility and ease of use enabled seamless integration, allowing users to collect and process water-quality data efficiently. By leveraging the Arduino Uno robust features and extensive support community, the system ensured reliable and accurate performance in monitoring water safety.

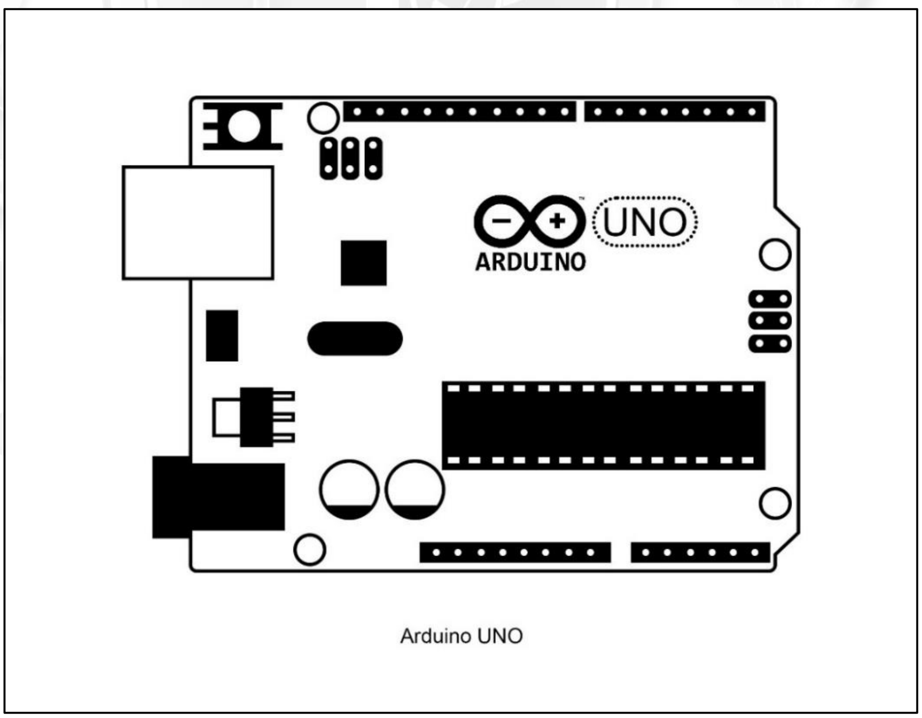


Figure 3. Arduino UNO.

2.2.1.3 Sensor and Interface Boards

Figure 4 presents a detailed view of the individual sensors and their respective interface boards used in HydroSense. The sensors included the TDS sensor (SEN0244), temperature sensor (DS18B20), turbidity sensor (TSW-20M), and pH sensor (SEN0161), along with their interface boards for proper connectivity. Additionally, the diagram included the microSD card module (HW 125) to illustrate the storage solution for the system. The diagram helped users identify each component and understand their role in the overall system. This figure was essential for troubleshooting and ensuring correct sensor installation.

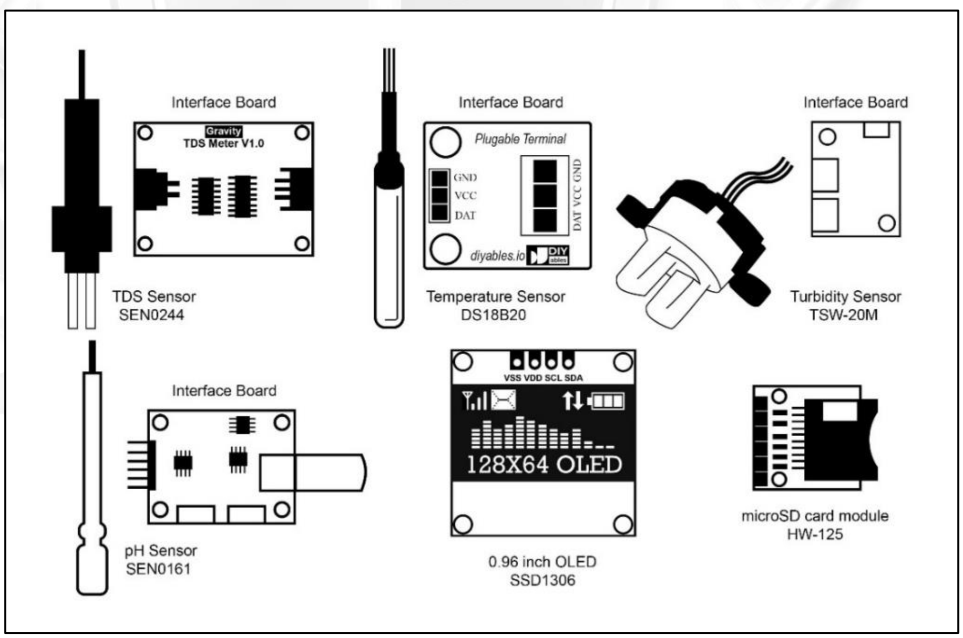


Figure 4. Sensor and Interface Boards.

2.2.1.4 Hardware Wiring Diagram

Figure 5 illustrates the connections between the ESP32-WROOM-32D microcontroller and the Arduino Uno, along with the various sensors used in HydroSense. The TDS, Turbidity, temperature, and pH sensors were interfaced with the Arduino Uno via specific interface boards. The Arduino Uno was connected to the ESP32-WROOM-32D microcontroller via a serial connection to transmit sensor data. Additionally, the diagram showed the microSD card module and the OLED display connected to the ESP32 for data storage and device interfacing.

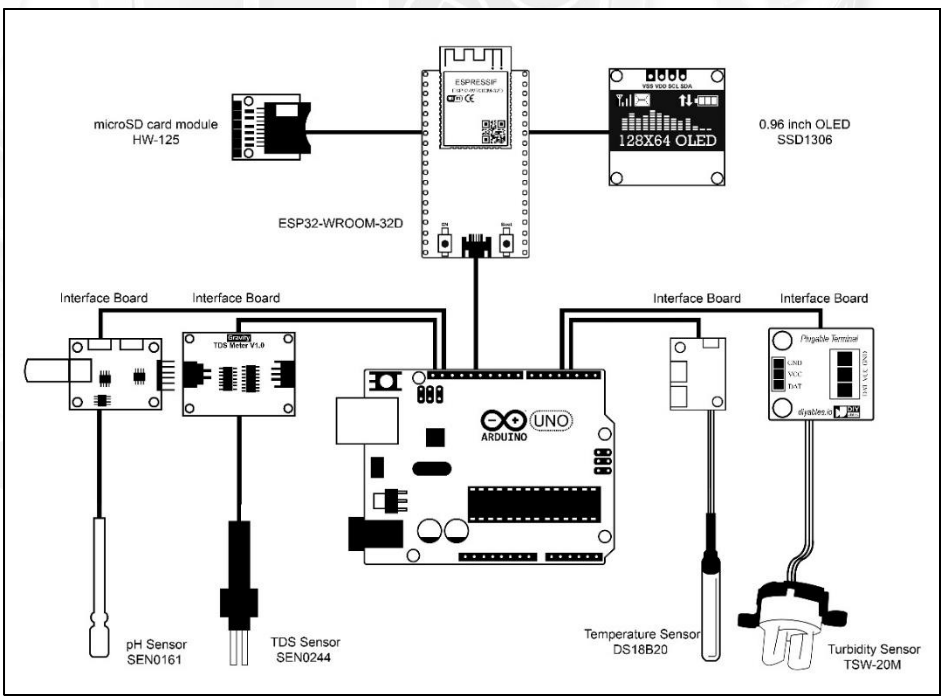


Figure 5. Hardware Wiring Diagram.

2.2.1.5 Sensor Placement in Water

Figure 6 demonstrates the HydroSense operation within a water environment, illustrating the placement of various sensors when submerged. The pH sensor measured the water acidity or alkalinity, the TDS sensor monitored dissolved substances, the temperature sensor tracked water temperature, and the turbidity sensor assessed water clarity. Each sensor was connected to the Arduino Uno via its respective interface board, facilitating proper data transmission. The Arduino Uno sent the collected sensor data to the ESP32-WROOM-32D microcontroller via a serial connection. The microcontroller collected and processed the data, displaying it on the OLED screen and storing it on the microSD card for real-time monitoring and logging.

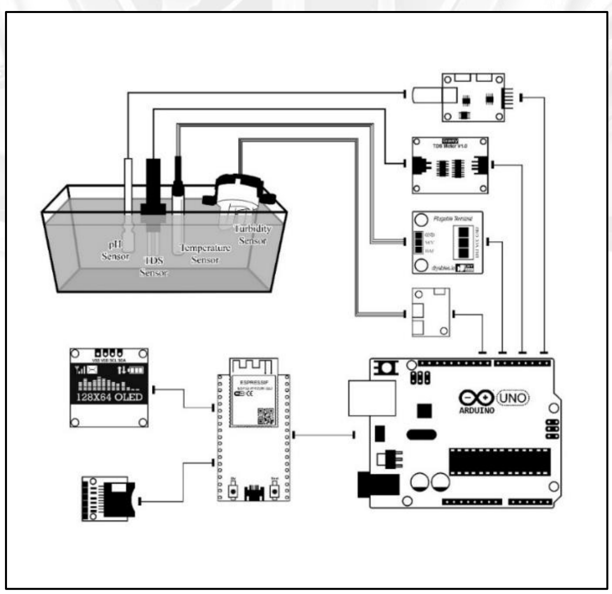


Figure 6. Sensor Placement in Water Diagram.

2.2.2 Software Requirements

Visual Studio Code and Arduino IDE were employed as the primary code editors. The operating system used was Windows 11, ensuring compatibility with the latest software applications during the project development. The programming languages C++ and JavaScript were integrated for robust backend functionality, while HTML and CSS were utilized for front-end development to create a dynamic and user-friendly interface. Communication among the developers was streamlined through platforms like Facebook Messenger and Microsoft Teams, facilitating virtual meetings. The web application underwent rigorous testing on multiple browsers, including Google Chrome, Firefox, and Brave, to ensure broad compatibility. The software specifications for the project were outlined in Table 3 and accessible to the project team.

Component	Software Tool
Code Editor	Visual Studio Code, Arduino IDE
Operating System	Windows 11
Programming Languages	C++, JavaScript
Front-end Development	HTML, CSS
Communication Platforms	Facebook Messenger, Microsoft Teams
Browser	Google Chrome, Firefox, Brave

Table 3. Software Requirements.

2.2.3 Connectivity Requirements

HydroSense requires a stable internet connection and compatibility with Wi-Fi for seamless communication. This ensured the device connected to the web application to transmit real-time water quality data and receive updates or recommendations. Just as different browsers were essential for deploying and testing web applications, a reliable internet connection was crucial for integrating the device and enabling easy access to online services like web hosting. Table 4 shows the prerequisites fundamental for the development and successful implementation of the project.

Component	Specification
Mode of Connection	Wi-Fi
Wi-Fi Range	~15 – 20 meters in line of sight
Internet Connection	10 Mbps

Table 4. Connectivity Requirements.

2.3 Design and Implementation Constraints

The developers acknowledged critical factors that shaped the system development and functionality by outlining the design and implementation constraints. These constraints encompass power requirements, crucial for sustaining device operation, and data accuracy requirements, essential for reliable water quality monitoring. To address these constraints ensured the project aligned with its objectives and fostered user confidence in the system performance. The project also had to consider environmental factors that affect sensor accuracy and durability. Additionally, the reliance on a stable internet connection for real-time data transmission posed a constraint, necessitating dependable network availability. Understanding and mitigating these constraints were vital for the successful implementation and long-term effectiveness of HydroSense.

2.3.1 Power Requirement

The device primarily operated using a 5V power supply via a USB connection, ensuring compatibility and ease of access to power. Additionally, the device utilized an off-the-shelf battery bank rated at 5000mAh for scenarios where portability or uninterrupted operation was essential. This battery bank was estimated to provide enough power for about seven days of continuous operation, ensuring prolonged functionality without frequent recharging or replacing power sources. The charging time of the battery bank was about three to four hours. These specifications underscored the device adaptability to various environments and its capability to maintain reliable operation while addressing power constraints effectively.

2.3.2 Sensor Data Accuracy

Table 5 provides a comparison based on the accuracy of data gathered by different sensors used in HydroSense and the formula for assessing water quality based on sensor data. Ensuring data accuracy posed a significant constraint, especially considering the variability in environmental conditions and potential sources of interference. Achieving reliable and accurate sensor readings was crucial for building user trust and confidence in the device functionality. This constraint necessitated thorough testing and calibration of sensors during both the manufacturing and deployment phases to guarantee consistent performance. Regular maintenance and recalibration were also required for sensor drift and wear.

Additionally, the system had to account for potential inaccuracies caused by temperature fluctuations, electromagnetic interference, and physical obstructions.

+Sensor Type	Range	Description	Accuracy
TDS Sensor	Data < 300ppm	Excellent	±2% ppm
	Data between 300ppm – 600ppm	Good	
	Data between 600ppm – 900ppm	Fair	
	Data between 900ppm – 1,200ppm	Poor	
	Data > 1,200ppm	Unacceptable	
Turbidity Sensor	Data ≤ 1 NTU	Ideal Turbidity	±5% NTU
	Data ≤ 5 NTU	Drinkable Water	
	Data > 5 NTU	Dirty Water	
pH Sensor	Data < 6.5pH	Not Acceptable	±0.1 pH
	Data between 6.5pH – 8.5pH	Acceptable	
	Data > 8.5pH	Not Acceptable	
Water Temperature Sensor			±0.5°C

Table 5. Ranges and its Description.

2.3.3 Water Quality Parameter Ranges

This section elaborated on the specific ranges and descriptions of water quality parameters measured by HydroSense. Understanding these ranges was crucial for accurately assessing water quality and making informed decisions regarding water treatment. Each parameter measured by the system had a specific range that indicated different water quality levels. These ranges provided valuable insights into the overall health of the water source, allowing for appropriate corrective actions when necessary.

2.3.3.1 TDS Sensor Ranges

The TDS sensor measured the concentration of dissolved solids in water. High levels of TDS indicate the presence of various contaminants, including salts, minerals, and metals. The following table provides the ranges and corresponding descriptions for TDS levels. Table 6 shows the descriptions that helped users understand the potential impact of TDS on water quality.

TDS Range	Description
Data < 300ppm	Lowest amount of dissolved solids
Data between 300ppm – 600ppm	Low to moderate amount of dissolved solids
Data between 600ppm – 900ppm	Moderate amount of dissolved solids
Data between 900ppm – 1200ppm	High amount of dissolved solids
Data > 1200ppm	Very high amount of dissolved solids

Table 6. TDS Sensor Ranges and Descriptions.

2.3.3.2 Turbidity Sensor Ranges

The turbidity sensor measured the cloudiness or haziness of water caused by suspended particles. High turbidity levels indicate the presence of pollutants, pathogens, or organic matter, which affect water safety. Understanding these ranges helped users evaluate the aesthetic and health-related quality of the water. Table 7 shows the ranges and their descriptions.

Turbidity Range	Description
Data ≤ 1 NTU	Low amount of suspended particles
Data ≤ 5 NTU	Moderate amount of suspended particles
Data > 5 NTU	High amount of suspended particles

Table 7. Turbidity Sensor Ranges and Descriptions.

2.3.3.3 pH Sensor Ranges

The pH sensor measured the acidity or alkalinity of the water. It was crucial for assessing water corrosiveness and chemical balance. Proper pH levels ensured water safety and protected plumbing. Table 8 outlines the pH ranges and their descriptions.

pH Range	Description
Data between 0pH – 2.3pH	Strongly acidic water
Data between 2.4pH – 4.6pH	Moderately acidic water
Data between 4.7pH – 6.4pH	Weakly acidic water
Data between 6.5pH – 8.5pH	Neutral water
Data between 8.6pH – 10pH	Weakly alkaline water
Data between 10.1pH – 12pH	Moderately alkaline water
Data between 12.1pH – 14pH	Strongly alkaline water

Table 8. pH Sensor Ranges and Descriptions.

2.3.4 Hardware to Software Interfacing

Efficient interfacing between hardware components and the software application was pivotal for displaying Arduino sensor readings. The system relied on a stable internet connection with a minimum speed of 10 Mbps to transmit sensor data from the Arduino-powered device to the web server for real-time display. Utilizing a dedicated web server facilitated seamless communication between the device and the web application, ensuring that sensor readings were accurately displayed to users. This integration optimized the system functionality, allowing users to access timely sensor data and simplifying the monitoring process while maintaining real-time data visualization.

2.3.5 Graphical Data Visualization

This played a crucial role in interpreting the results of the data collected by the sensors. Graphical representation of water quality parameters, such as TDS, Turbidity, pH, and temperature, allowed users to easily comprehend trends and variations. By incorporating interactive graphs and charts into the web application interface, users were able to visualize real-time data clearly and intuitively, facilitating informed decision-making regarding water management practices. These visualizations provided valuable insights into water quality dynamics, enabling users to identify patterns and anomalies effectively and contributing to maintaining clean and safe water sources. Moreover, the ability to customize visualizations according to user preferences enhanced the overall user experience and usability of the system.

2.3.6 Water Treatment Recommendation

The system faced challenges in providing accurate water treatment recommendations due to the varying levels and types of contaminants detected by the sensors. Sensors detected diverse contaminants, making it necessary to consider the type, concentration, and water quality standards for suitable treatment recommendations. The system had to analyze real-time data from TDS, Turbidity, water temperature, and pH sensors to generate specific and effective treatment methods. Environmental factors, such as temperature and pH, influenced the effectiveness of certain treatments, adding complexity to the recommendation process. Additionally, the system needed to provide easy-to-understand, actionable steps for users, which required simplifying complex data into user-friendly guidance. Despite these challenges, the system offered easy, homemade treatments that required no specialized equipment.

Furthermore, the system had to account for regional water quality variations and regulatory differences affecting treatment efficacy and safety. Integrating machine learning algorithms to predict treatment outcomes based on historical data enhances recommendation accuracy. User feedback loops were essential to continuously re-evaluate and improve the treatment suggestions provided by the system. The system must regularly update its database with the latest water treatment research and emerging contaminants to ensure reliability. Table 9 illustrates how the system analyzes sensor data, environmental factors, and user feedback to generate accurate water treatment recommendations.

TDS Range	Turbidity Range	pH range	Recommendation
TDS < 300ppm	Turbidity ≤ 1 NTU	6.5pH – 8.5pH	Water is safe to drink.
TDS < 300ppm	Turbidity ≤ 1 NTU	4.7pH – 6.4pH	Gradually add small amounts of baking soda to increase pH to neutral range. (0.1g)
TDS < 300ppm	Turbidity ≤ 1 NTU	8.6pH – 10pH	Gradually add a few drops of lemon juice or vinegar to decrease pH to neutral range. (1 drop)
TDS < 300ppm	Turbidity ≤ 5 NTU	6.5pH – 8.5pH	Let water settle (Sedimentation) then use a cloth filter (Filtration).
TDS < 300ppm	Turbidity ≤ 5 NTU	4.7pH – 6.4pH	Let water settle (Sedimentation) then use a cloth filter (Filtration). Gradually add small amounts of baking soda to increase pH to neutral range. (0.1g)
TDS < 300ppm	Turbidity ≤ 5 NTU	8.6pH – 10pH	Let water settle (Sedimentation) then use a cloth filter (Filtration). Gradually add a few drops of lemon juice or vinegar to decrease pH to neutral range. (1 drop)
301ppm - 900ppm	Turbidity ≤ 1 NTU	6.5pH – 8.5pH	Boil the water and collect its condensation (Distillation).
301ppm - 900ppm	Turbidity ≤ 1 NTU	4.7pH – 6.4pH	Boil the water and collect its condensation (Distillation). Gradually add small amounts of baking soda to increase pH to neutral range. (0.1g)
301ppm - 900ppm	Turbidity ≤ 1 NTU	8.6pH – 10pH	Boil the water and collect its condensation (Distillation). Gradually add a few drops of lemon juice or vinegar to decrease pH to neutral range. (1 drop)
301ppm - 900ppm	Turbidity ≤ 5 NTU	6.5pH – 8.5pH	Boil the water and collect its condensation (Distillation). Let water settle (Sedimentation) then use a cloth filter (Filtration).
301ppm - 900ppm	Turbidity ≤ 5 NTU	4.7pH – 6.4pH	Boil the water and collect its condensation (Distillation). Let water settle (Sedimentation) then use a cloth filter (Filtration). Gradually add small amounts of baking soda to increase pH to neutral range. (0.1g)
301ppm - 900ppm	Turbidity ≤ 5 NTU	8.6pH – 10pH	Boil the water and collect its condensation (Distillation). Let water settle (Sedimentation) then use a cloth filter (Filtration). Gradually add a few drops of lemon juice or vinegar to decrease pH to neutral range. (1 drop)
TDS > 900 ppm	Any	Any	No homemade treatment can safely treat this water.
Any	Turbidity > 5 NTU	Any	No homemade treatment can safely treat this water.
Any	Any	0pH – 4.6pH	No homemade treatment can safely treat this water.
Any	Any	10.1pH – 14pH	No homemade treatment can safely treat this water.

Table 9. Formula for Recommending Water Treatments.

2.3.7 Hydrology Resources

The hydrology resources component of HydroSense was designed to provide users with access to a comprehensive repository of educational materials on water quality and management practices. Drawing from reputable sources such as the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), National Library of Medicine, and other scholarly and governmental organizations, the application included articles, guides, videos, and studies. These resources covered topics like pH, turbidity, total dissolved solids (TDS), water temperature, and various water treatment methods such as boiling, filtration, and aeration. By presenting accurate and up-to-date information, the component aimed to enhance user awareness and understanding of water safety, the health effects of contaminants, and best practices for water conservation and purification. The references and detailed breakdown of sources are listed in Appendix Q through AB, categorizing the information by topic and type.

2.3.8 Sensor Durability Against High Acidity and Alkalinity

HydroSense faced constraints related to the durability and accuracy of sensors when exposed to highly acidic (low pH) or highly alkaline (high pH) environments. Extreme pH levels corrode or damage the sensors, leading to inaccurate readings or sensor failure. As a result, the system cannot reliably monitor water quality in conditions where the pH falls outside the optimal range for sensor operation. This limitation must be acknowledged, and users potentially be informed of the potential impact on sensor performance when water pH levels are too high or too low. To mitigate this issue, regular calibration and maintenance of the sensors are essential to extend their operational lifespan and improve accuracy. Ensuring sensor protection and accuracy was crucial for maintaining the reliability of the water quality data provided by the system.

2.3.9 Health Risk Evaluation System

The Health Risk Evaluation System provides a framework for analyzing water safety based on key parameters: TDS, turbidity, and pH. This system uses sensor data to interpret these parameters and generate detailed health risk assessments and treatment recommendations tailored to specific water quality conditions. By offering in-depth explanations of potential health risks associated with various water quality scenarios, it empowers users to make informed decisions about water consumption and treatment. The system enhances user understanding by correlating specific water quality ranges with associated health risks, providing actionable insights for mitigation. It integrates real-time data processing with a robust algorithm to deliver timely alerts about unsafe water conditions. This comprehensive approach not only alerts users to potential dangers but also educates them about the importance of water quality in maintaining health. This system ensures users take proactive steps to safeguard their health. Additionally, it provides users with practical guidance on improving water quality to mitigate identified risks. Table 10 presents a comprehensive overview of potential health risks associated with various combinations of water quality parameters, offering a valuable reference for risk assessment.

TDS Range	Turbidity Range	pH Range	Potential Health Risk
TDS < 300ppm	Turbidity ≤ 1 NTU	6.5pH – 8.5pH	Generally safe, minimal health risks
TDS < 300ppm	Turbidity ≤ 1 NTU	4.7pH – 6.4pH	Mild gastrointestinal irritation. Potential for dental erosion
TDS < 300ppm	Turbidity ≤ 1 NTU	8.6pH – 10pH	Mild gastrointestinal irritation
TDS < 300ppm	Turbidity ≤ 5 NTU	6.5pH – 8.5pH	Increased risk of waterborne diseases (bacterial, viral, parasitic). Gastrointestinal issues (diarrhea, vomiting)
TDS < 300ppm	Turbidity ≤ 5 NTU	4.7pH – 6.4pH	Increased risk of waterborne diseases. Gastrointestinal issues. Potential for dental erosion.
TDS < 300ppm	Turbidity ≤ 5 NTU	8.6pH – 10pH	Increased risk of waterborne diseases. Gastrointestinal issues.
301ppm - 900ppm	Turbidity ≤ 1 NTU	6.5pH – 8.5pH	Potential for mild gastrointestinal issues. Possible mineral imbalances.
301ppm - 900ppm	Turbidity ≤ 1 NTU	4.7pH – 6.4pH	Gastrointestinal issues. Dental erosion. Possible mineral imbalances.
301ppm - 900ppm	Turbidity ≤ 1 NTU	8.6pH – 10pH	Gastrointestinal issues. Possible mineral imbalances.
301ppm - 900ppm	Turbidity ≤ 5 NTU	6.5pH – 8.5pH	Increased risk of waterborne diseases. Gastrointestinal issues. Possible mineral imbalances.
301ppm - 900ppm	Turbidity ≤ 5 NTU	4.7pH – 6.4pH	Increased risk of waterborne diseases. Gastrointestinal issues. Dental erosion. Possible mineral imbalances.
301ppm - 900ppm	Turbidity ≤ 5 NTU	8.6pH – 10pH	Increased risk of waterborne diseases. Gastrointestinal issues. Possible mineral imbalances.
TDS > 900 ppm	Any	Any	Severe gastrointestinal distress. Kidney problems. Cardiovascular issues. Mineral toxicity or deficiency.
Any	Turbidity > 5 NTU	Any	High risk of waterborne diseases (cholera, typhoid, hepatitis A). Parasitic infections (giardiasis, cryptosporidiosis). Severe gastrointestinal issues.
Any	Any	0pH – 4.6pH	Severe chemical burns to mouth, throat, and digestive tract. Dental erosion. Metabolic acidosis.
Any	Any	10.1pH – 14pH	Severe chemical burns to mouth, throat, and digestive tract. Metabolic alkalosis.

Table 10. Health Risk Evaluation System.

2.3.10 Use of Web Server

The project used a dedicated web server to integrate hardware and software components seamlessly. The reliability of the web server was essential for the continuous operation of the system. Additionally, users had to have compatible devices and browsers to interact with the web-based application. Table 11 lists the compatible browsers and their versions for desktop and Android platforms.

Browser	Desktop Version	Android Version
Google Chrome	Minimum version 125.0	Minimum version 125.0
Firefox	Minimum version 126.0	Minimum version 126.0
Brave	Minimum version 1.66.115	Minimum version 1.66.113

Table 11. Compatible Browsers and their Versions.

2.4 Assumptions and Dependencies

The project assumed that the chosen sensors and Arduino platform accurately measured water quality parameters within acceptable tolerances. Additionally, it depended on the availability of compatible development tools and technologies for hardware and software aspects. Furthermore, dependencies included access to reliable data sources and resources for validation, ensuring the system functionality and accuracy.

2.4.1 Assumptions

This section outlined the key assumptions fundamental to the development and functionality of Hydrosense. These assumptions encompassed various aspects, ranging from sensor accuracy to the functionality of formulas used for assessing water quality parameters and recommending treatments. Each assumption played a critical role in ensuring the reliability, effectiveness, and seamless operation of the system. By acknowledging and addressing these assumptions, the project aimed to mitigate potential risks and challenges, thereby enhancing the overall success and impact of the water quality monitoring endeavor.

2.4.1.1 Sensor Accuracy

The project assumed that the selected sensors, including TDS, Turbidity, pH, and water temperature sensors, accurately measured water quality parameters within acceptable tolerances. This was crucial for the reliability and effectiveness of the data collected. The accuracy of these sensors underpinned the project ability to provide actionable insights. Ensuring precise measurements was fundamental to achieving the project goals.

2.4.1.2 Availability of Development Tools

It was assumed that there be access to compatible development tools and technologies for both hardware and software aspects of the project. This included access to Arduino IDE for programming the Arduino platform and Visual Studio Code for developing and debugging the web application. Ensuring the availability of these tools streamlined the development process and facilitated efficient implementation of system functionalities. Comprehensive documentation and community support offered valuable guidance, reducing troubleshooting time and improving project efficiency.

2.4.1.3 Access to Reliable Data Sources

The project relied on access to reliable data sources and resources for validation purposes. This included datasets for calibrating sensors, historical water quality data for comparison and analysis, and authoritative sources for validating recommendations and hydrology resources. The availability of these resources was crucial for verifying the accuracy and effectiveness of the system in monitoring water quality and providing actionable insights to users.

2.4.1.4 Functionality of Formulas

The project also assumed that the formulas above for assessing water quality parameters and recommending water treatments were accurate and functional. These formulas provided users with actionable insights and recommendations based on sensor readings. Regular validation and testing were conducted to ensure the accuracy and reliability of these formulas in real-world scenarios.

2.4.1.5 Hardware-Software Compatibility

Another assumption was the compatibility of chosen hardware and software components, which minimized integration challenges during development. This entailed ensuring that the sensors, Arduino platform, and web application were seamlessly integrated and communicated effectively. Compatibility testing was conducted to identify and resolve any compatibility issues, ensuring the smooth operation of the entire system.

2.4.2 Dependencies

The success of the water quality monitoring project hinged on a series of dependencies vital for its seamless operation and effectiveness. These dependencies encompassed critical elements ranging from integrating sensor technologies to visualizing data on the web platform. Each dependency played a crucial role in ensuring the accuracy, reliability, and accessibility of water quality information to users. By understanding and addressing these dependencies, the project aimed to create a robust infrastructure capable of effectively delivering actionable insights and promoting awareness about water safety practices.

2.4.2.1 Seamless Sensor Integration

The project success relied on the seamless integration between various sensors utilized for water quality monitoring. Sensors such as DS18B20 for water temperature, TSW-20M for Turbidity, SEN0244 for TDS measurement, and SEN0161 for pH assessment played pivotal roles in gathering accurate data across multiple parameters. This integration ensured that the system provided reliable and comprehensive insights into the quality of water sources being monitored. This integration boosts the system effectiveness. Users trust the data collected and make informed decisions regarding water safety and management by ensuring that each sensor communicates effectively with the system. Additionally, the system real-time alerts empower users to respond swiftly to any water quality issues and this ensures proactive management of water resources.

2.4.2.2 Interoperability with Web Server

The project success depended on the interoperability of the web server for interfacing with the Arduino device. The web server facilitated seamless communication between the device and the web application, enabling real-time data transmission and visualization. This integration streamlined data management processes and ensured that users had access to up-to-date information on water quality parameters. With the web server, users monitor changes in water conditions promptly and take appropriate actions to address any issues detected.

2.4.2.3 Web Server for Data Visualization

The project dependency on the web server extended to data visualization, enabling the generation of graphical and chart-based representations of water quality parameters. This functionality facilitated intuitive analysis and interpretation of data, empowering users to identify trends and anomalies effectively. With visualizations generated through the web server, users gain deeper insights into water quality dynamics and make informed decisions regarding water management practices. By leveraging data visualization capabilities, the project enhanced the user experience and promoted proactive measures for ensuring clean and safe water sources.

2.4.2.4 Access to External Data Sources

The project relied on external data sources for hydrology resources. Access to comprehensive information on water safety practices and management was essential for empowering users to make informed decisions regarding their water sources. The project aimed to enhance awareness and understanding of water quality issues by providing users with access to reputable and authoritative hydrology resources. Users leverage this knowledge to implement effective water purification methods and contribute to maintaining clean and safe water sources.

2.4.2.5 Dependency on Hardware for Data Collection

The software component of HydroSense depended on the hardware for accurate data collection. The sensors integrated with the Arduino platform measured key water quality parameters such as TDS, Turbidity, pH, and temperature. Without reliable data from these sensors, the software does not process, visualize, or provide meaningful insights regarding water quality. This dependency highlighted the critical role of the hardware in ensuring the overall functionality of the system. Any hardware failure or malfunction directly impacts the software ability to deliver accurate and timely information to the users. Therefore, maintaining the hardware performance and ensuring proper integration with the software was essential for successfully operating the entire system.

This chapter outlined the technical specifications for the HydroSense water quality monitoring system, detailing its essential components and operational requirements. The system, powered by an Arduino microcontroller and equipped with TDS, Turbidity, temperature, and pH sensors, interfaced with a web application to provide real-time water quality data. Key features included contaminant detection, data visualization, tailored recommendations, and hydrology resources. The chapter also covered hardware and software needs, connectivity, design constraints, and dependencies. This comprehensive examination ensured the system effective development, accurate monitoring, and user-friendly interface for maintaining water safety. Moreover, it highlighted the system adaptability to varying environmental conditions and its ability to provide actionable insights for improving water quality. By combining advanced sensor technology with an intuitive web interface, HydroSense empowers users to make informed decisions, ensuring clean and safe water access. This thorough technical foundation paves the way for future enhancements and scalability of the system.

CHAPTER III

PRODUCT FEATURES

This chapter presents the product features of HydroSense, offering a detailed overview of its various modules and components. It included a decomposition chart that visualized the primary product features and their interconnections. Each module was briefly explained, focusing on user interactions, activity diagrams, and the steps prompted within the web application. Additionally, the chapter listed the functional requirements defined by the developers for each module, ensuring the system goals were met upon development. This comprehensive introduction gave readers a clear understanding of HydroSense capabilities and how they enabled effective water quality monitoring and management.

3.1 Product Decomposition

HydroSense comprised several main functionalities that ensured comprehensive water quality monitoring and management. The interfacing functionality included initial setup, connecting devices to the HydroSense access point, and ensuring Wi-Fi connectivity. For a thorough assessment, water quality analysis used sensors to measure dissolved particles, pH, and suspended particles. This function displayed water quality data and suggested purification methods based on contaminants. It included real-time data visualization, historical trend analysis, and data export. The hydrology resources section offered articles and guides on water safety and purification, enhancing users' understanding and managing water quality. The integration of these functionalities streamlined HydroSense operations, as depicted in Figure 7.

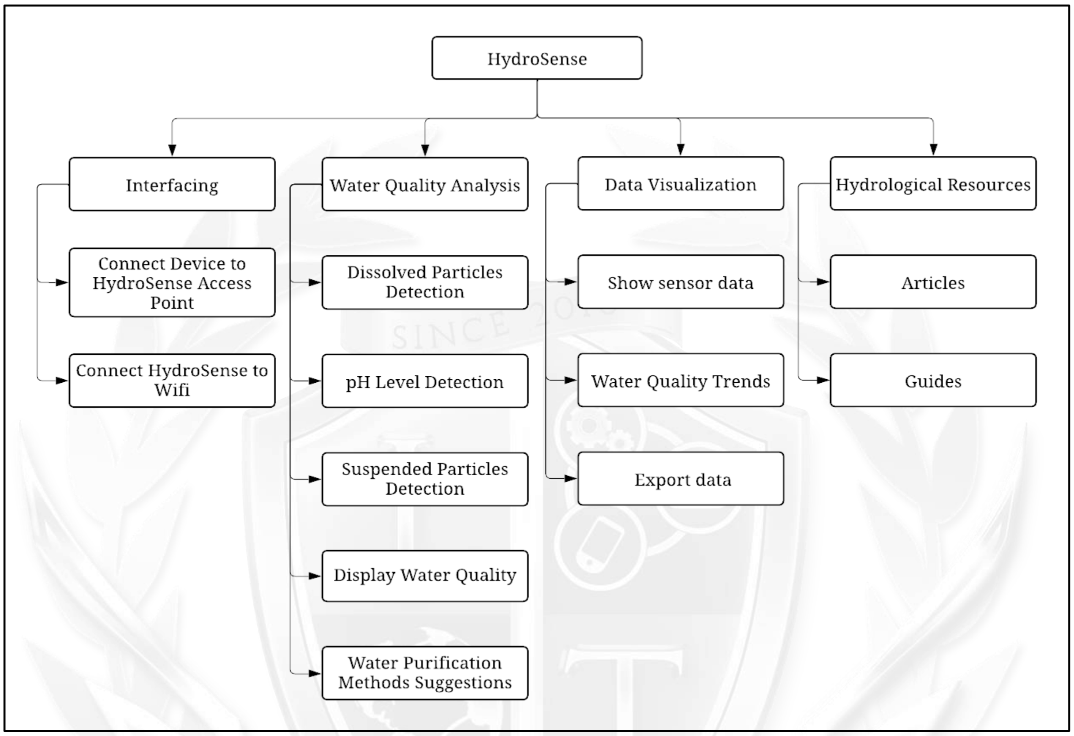


Figure 7. HydroSense Decomposition Chart.

3.2 System Functionalities

The developers provided a detailed explanation of the creation and integration of each module within HydroSense. The following subsections describe how the functionalities operated when users interacted with the web application, detailing the system response based on user actions and the interconnectivity of its modules on the backend. Developers used activity diagrams to illustrate each module data and command flow. Each module description included a list of functional requirements to ensure alignment with overall project goals.

3.2.1 Interfacing

This module handled the initial setup process, including connecting HydroSense to the network and ensuring all devices were paired correctly. Users were guided through the interfacing process via a series of prompts within the web application. Successful interfacing ensured seamless data flow from the sensors to the web application.

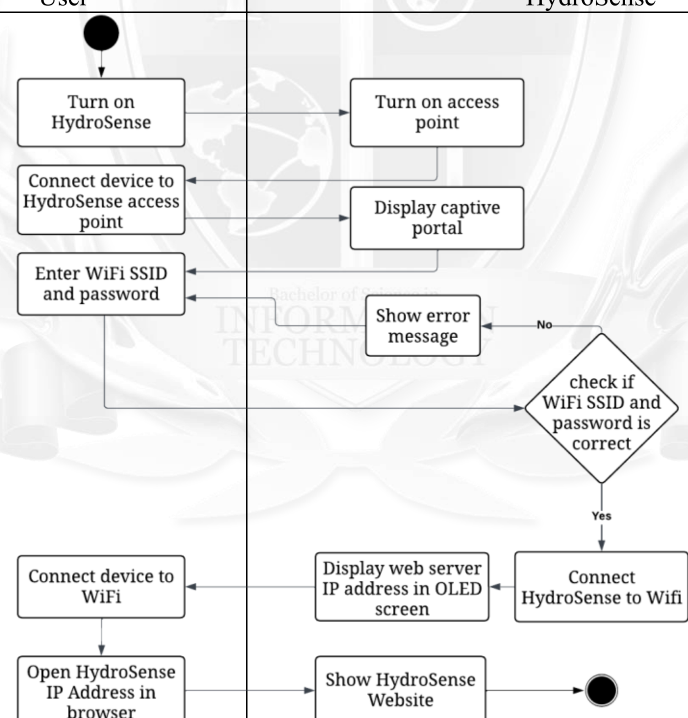
3.2.1.1 Description and Priority

To interface was crucial for establishing a reliable connection between HydroSense and the network. Users were required to connect the Arduino to an internet router, connect their device to the same router, and then open the Internet Protocol (IP) address of the Arduino device in a browser. The system checked if the Arduino was connected to Wi-Fi, and the web server interface was displayed upon confirmation. By ensuring the HydroSense system collect and transmit data effectively was a high priority, as it was foundational for the system operation.

3.2.1.2 Stimulus/Response Sequence

Users began interfacing by powering on the HydroSense device and turning on the access point. The device displayed a captive portal. Users connected their devices to the HydroSense access point and entered the Wi-Fi Service Set Identifier (SSID) and password. The system checked if the Wi-Fi SSID and password were correct. If correct, HydroSense connected to Wi-Fi and displayed the web server IP address on the OLED screen. Users then connected their devices to the same Wi-Fi network, opened a web browser, and entered the Internet Protocol (IP) address to access the HydroSense website. An error message prompted the user to re-enter the details if the Wi-Fi name and password were incorrect. This ensured the proper setup and operation of the HydroSense system. Table 12 indicates the sequence of tasks that the user performed for interfacing.

Function Name	Interfacing
Function Description	
Precondition	○ HydroSense device and access point are powered on. ○ User has access to a device connected to the same network as the HydroSense device.
Post Condition	○ HydroSense is connected to the WiFi network. ○ The web server interface is accessible, allowing data transmission from sensors to the web application.
Activity Flow	
User	HydroSense



Alternate Flow	○ The Wi-Fi SSID and password are incorrect.
Exception	○ The access point did not turn on.

Table 12. Interfacing Activity Diagram.

3.2.1.3 Functional Requirements

The developers outlined the tasks needed to interface HydroSense with the network and ensure its proper setup. The interfacing process was essential for accurate data collection. Users had to connect the Arduino to the network and access the web server interface, guided by the system to ensure all connections were established. Once connected, users remotely monitor and manage the system through the web interface. Users also had to power on the HydroSense device.

a. Users must connect the Arduino to the internet router.
b. The system checks if the Arduino is powered on and attempts to establish a network connection.
c. Users then connect their device (laptop, smartphone, etc.) to the same internet router.
d. The system verifies that the user device is connected to the same network as the Arduino.
e. Users open a web browser and enter the IP address of the Arduino device.
f. The system checks if the Arduino is connected to Wi-Fi.
g. If the Arduino is successfully connected, the system displays the web server interface.
h. If the Arduino is not connected to Wi-Fi, the system prompts the user to check the Wi-Fi settings and retry the connection.

i. The system ensures that the web server interface is accessible only after a successful interfacing process.

3.2.2 Water Quality Analysis

The water quality analysis system employed sensors to measure various parameters, including TDS, pH, and Turbidity of a water sample. If needed, the system combined these measurements to assess water quality and displayed treatment recommendations. Users easily view both the results and the suggestions, ensuring accurate monitoring and management.

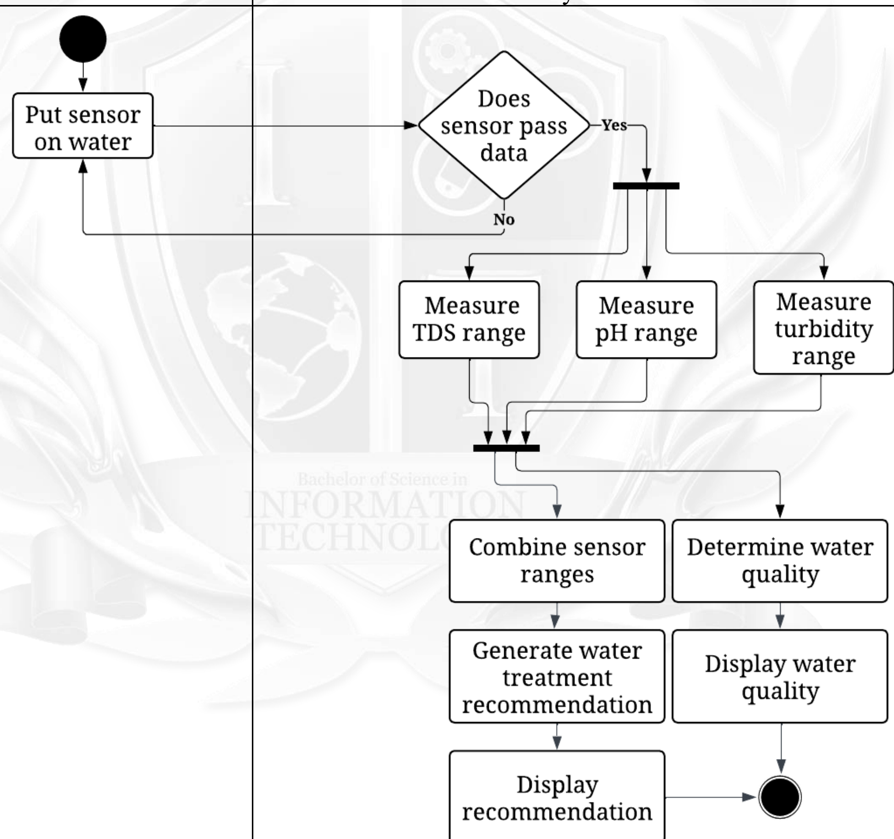
3.2.1.1 Description and Priority

The water quality analysis system was designed to measure and evaluate water quality using sensors that detected TDS, pH levels, and Turbidity. The sensor data was transmitted and combined to comprehensively assess the water condition. The system generated and displayed specific water treatment recommendations based on the data, offering accurate and actionable information on water quality.

3.2.1.2 Stimulus/Response Sequence

The water quality analysis system operated by placing a sensor in a water sample, which initiated the data transmission check. The system measured the TDS, pH level, and Turbidity upon successful data transmission. These measurements were then combined to assess the overall water quality. The system generated and displayed a water treatment recommendation based on the combined data, ensuring users received accurate and actionable information on water quality. Table 13 indicates the sequence of tasks during water quality analysis.

Function Name	Water Quality Analysis
Function Description	This function measures and evaluates the quality of water by using sensors to provide a comprehensive assessment of the water condition and generate treatment recommendations
Precondition	o The sensor is properly connected. o The water sample is available for testing.
Post Condition	o The system displays the water quality results. o The system provides water treatment recommendations based on the analysis.
Activity Flow	
User	HydroSense



Alternative Flow	o Sensor fails to submit data. o System prompts user to check sensor connection and retry.
Exception	o The sensor does not pass data, the system prompts the user to check the sensor and retry the detection process.

Table 13. Water Quality Analysis Activity Diagram.

3.2.2.3 Functional Requirements

The developers outlined the tasks necessary to function correctly for the water quality analysis process. Users placed the sensor in the water, and the system checked if the sensor was passing data. If data was being passed, the system measured the TDS, pH, and turbidity ranges. The system then combined these measurements to determine the overall water quality and generated a water treatment recommendation for the user. Finally, the system displayed the water quality results and the treatment recommendation to the user, ensuring comprehensive and actionable feedback.

a. Users place the sensor in the water to start the detection process.
b. The system checks if the sensor is passing data.
c. If the sensor passes data, the system measures the TDS range of the water.
d. The system measures the pH range of the water.
e. The system measures the turbidity range of the water.
f. The system combines the sensor measurements to determine the overall water quality.
g. The system generates a water treatment recommendation based on the combined data.
h. The system displays the determined water quality and the treatment recommendation to the user.

i. If the sensor does not pass data, the system prompts the user to check the sensor and retry the detection process.

3.2.3 Data Visualization

The Data Visualization system for water quality analysis was crucial in effectively monitoring and managing water quality. The system-initiated data collection and verified successful data transmission by placing a sensor in the water. Users start and stop data logging through an intuitive interface. The collected data was compiled into a CSV file, providing live and historical views. CSV export enabled easy data download for analysis.

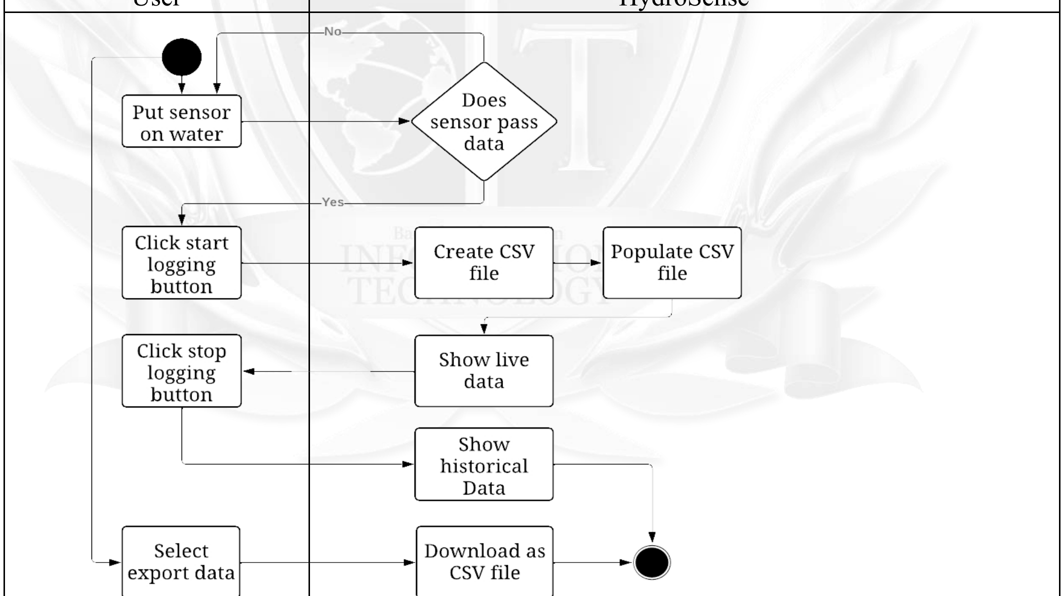
3.2.3.1 Description and Priority

The Data Visualization system for water quality analysis is designed to provide accurate and comprehensive monitoring through real-time data collection and visualization. Developers chose the CSV le format for data export due to its wide compatibility and ease of use with various data analysis tools, ensuring that users seamlessly integrate the collected data into their existing workflows. By visualizing the data is essential for quickly identifying trends and anomalies in water quality, allowing for immediate corrective actions if necessary.

3.2.3.2 Stimulus/Response Sequence

When users placed the sensor in the water, the system checked if data was being transmitted. Upon successful data transmission, users clicked the start logging button, initiating data collection. The system created and populated a CSV le while displaying live data. Users stop logging by clicking the stop logging button, after which they select the export data option. The system allowed users to download the collected data as a CSV file for further analysis. Table 14 shows how data visualization worked.

Function Name	Data Visualization
Function Description	The Data Visualization system for water quality analysis collects, logs, and visualizes data from the sensors. It allows users to view live and historical data and export the data.
Precondition	○ The sensor is properly connected. ○ The water sample is available for testing.
Post Condition	○ The system displays live and historical water quality data. ○ The data is logged and saved in a CSV file. ○ Users export and download the CSV file containing the collected data.
Activity Flow	
User	HydroSense



Alternate Flow	○ Sensor fails to submit data. ○ System prompts user to check sensor connection and retry
Exception	○ The sensor does not pass data, the system prompts the user to check the sensor and retry the detection process.

Table 14. Data Visualization Activity Diagram.

3.2.3.3 Functional Requirements

The developers outlined the tasks necessary to function correctly for the data visualization process. Users placed the sensor in the water, and the system checked if the sensor was passing data. If data was being passed, users started and stopped data logging, and the system measured the water quality parameters. The system then created and populated a CSV file displaying live and historical data. Finally, the system allowed users to export the data in CSV format by selecting the export data option.

a. The user places the sensor in the water to start the data collection process.
b. The system checks if the sensor is passing data.
c. If the sensor passes data, the user clicks the start logging button to initiate the data logging.
d. The system measures water quality parameters and displays live data.
e. The user clicks the stop logging button to stop data collection.
f. The system compiles the collected data into a CSV file, providing historical data views.
g. The user selects the export data option to download the data as a CSV file.
h. If the sensor does not pass data, the system prompts the user to check the sensor and retry the data collection process.

3.2.4 Hydrology Resources

The inclusion of hydrology resources in the water quality analysis system was crucial for providing comprehensive and actionable information to users. These resources offered knowledge on water properties and treatment methods, enhancing user understanding. The system provided treatment recommendations based on suspended, pH, and dissolved particles. Users check water safety, access purification tutorials, and make informed decisions with integrated definitions and content.

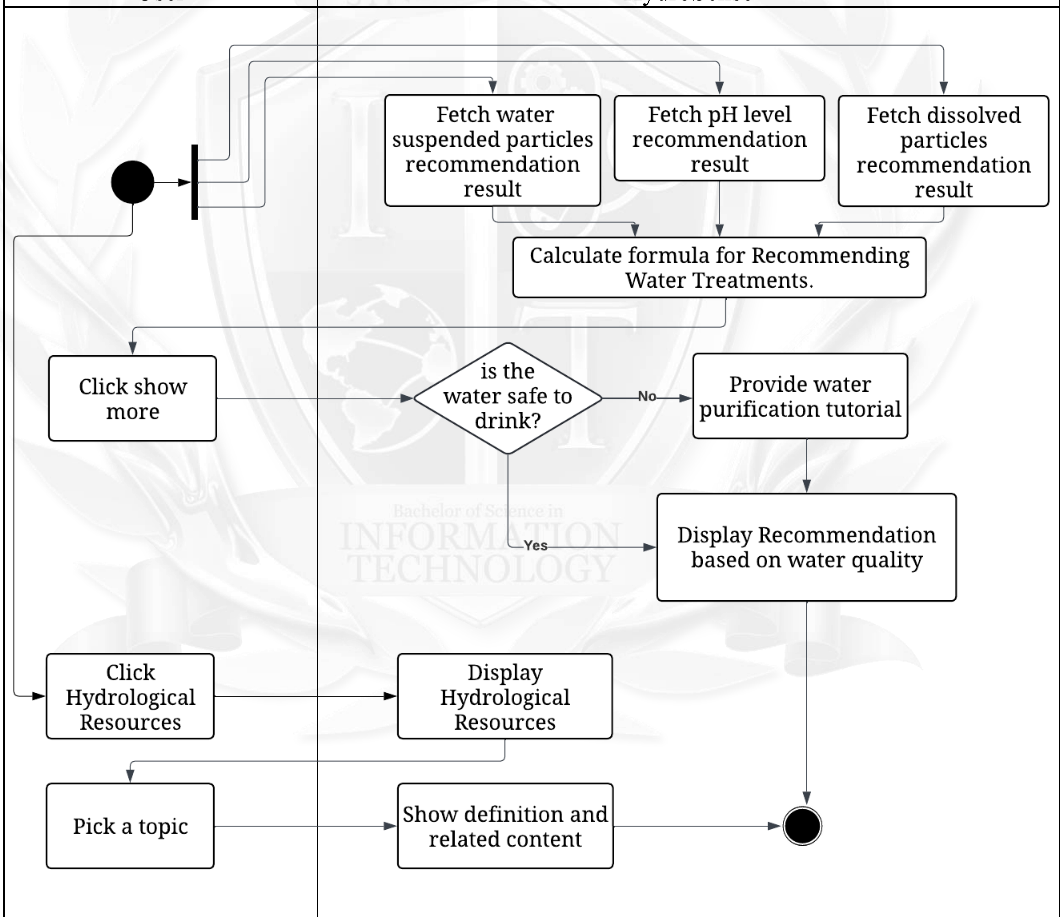
3.2.4.1 Description and Priority

The integration of hydrology resources in the water quality analysis system is essential for delivering detailed and practical insights into water quality. These resources provide valuable information on water properties and treatment techniques, aiding users in interpreting sensor data. The system offers accurate recommendations by calculating optimal treatment solutions based on parameters like suspended particles, pH, and dissolved particles. Hydrology resources support effective water quality management through informed actions.

3.2.4.2 Stimulus/Response Sequence

When the user clicked the option to fetch recommendations for suspended particles, pH level, and dissolved particles, the system retrieved the necessary data. It calculated the optimal water treatment formula and provided a tutorial if the water was unsafe. If the water was safe, it showed recommendations and allowed users to access hydrological resources for related content and definitions. Table 15 indicates the tasks that enabled the hydrology resources to be displayed to users.

Function Name	Hydrology Resources
Function Description	The hydrology resources provide users with detailed information on water quality, recommended treatment methods and educational resources.
Precondition	○ The sensor data is available and accurate. ○ The user has access to the hydrology resources interface.
Post Condition	○ Hydrology studies and articles are displayed to the user. ○ Users are informed about water quality and treatment methods.
Activity Flow	
User	HydroSense



Alternate Flow	○ Users navigate through various hydrology topics to gain more insights. ○ User returns to the previous Page.
Exception	○ The system fails to fetch recommendation results.

Table 15. Hydrology Resources Activity Diagram.

3.2.4.3 Functional Requirements

The developers outlined the tasks necessary for the hydrology resources feature in the water quality analysis system to function correctly. The system fetched recommendation results for water-suspended particles, pH levels, and dissolved particles and calculated the optimal formula for recommending water treatments. It determined if the water was safe to drink and, if not, provided a water purification tutorial. Users access hydrological resources to view definitions, related content, and detailed information on various topics by clicking the "learn more about water quality" option. Users access the hydrology resources interface to start the process.

a. The system fetches recommendation results for water suspended particles, pH levels, and dissolved particles.
b. The system calculates the optimal formula for recommending water treatments.
c. The system determines if the water is safe to drink.
d. If the water is safe to drink, the system displays a recommendation based on water quality.
e. If the water is not safe to drink, the system provides a water purification tutorial.
f. Users click “Show More” to access additional information and resources.
g. Users click on hydrological resources to display definitions and related content.

h. Users select topics within the hydrological resources to view detailed information and definitions.

i. If the system fails to fetch recommendation results or if data is incomplete, it notifies the user and provides troubleshooting steps.

This chapter presents the product features of HydroSense, offering a detailed overview of its various modules and components. It included a decomposition chart that visualized the primary product features and their interconnections. Each module was briefly explained, focusing on user interactions, activity diagrams, and the steps prompted within the web application. Additionally, the chapter listed the functional requirements defined by the developers for each module, ensuring the system goals were met upon development. In summary, HydroSense extensive functionalities ensured a comprehensive approach to water quality monitoring and management. Each module, from interfacing and water quality analysis to data visualization and hydrology resources, was designed to provide accurate and actionable insights.

CHAPTER IV

EXTERNAL INTERFACE REQUIREMENTS

This chapter discusses the interfaces of HydroSense, focusing on the interaction between hardware and software components. It outlines the web applications screen layouts and corresponding purposes, providing a detailed overview of the user interface elements and their functionalities. Additionally, this chapter identifies the hardware interfaces, explaining how sensors and microcontrollers work together to gather and process water quality data. The chapter covers the software interfaces, detailing the programming languages and development tools that facilitate seamless data integration and visualization. Furthermore, it elaborates on the communication interfaces, highlighting the critical role of the ESP32 web server in delivering real-time water quality information to users over a network.

4.1 User Interfaces

HydroSense offers a comprehensive platform with four sections: homepage, data insights, hydrology resources, and about. First, the homepage provides real-time water quality monitoring, interactive pH, TDS, turbidity, temperature gauges, and logging and recommendation features. Second, the data insights section presents detailed analysis and historical data through interactive graphs and tables, allowing users to track water quality trends. Third, the hydrology resources section serves as an educational hub, offering information on water safety, pH levels, and treatment methods through articles and videos. Lastly, the About section introduces the HydroSense project and its developers, explaining the systems mission and technical setup. Each section shares a consistent layout with a top navigation bar for seamless access, ensuring a user-friendly experience across the application.

4.1.1 Setup Interface

Figure 8 shows the setup interface for connecting HydroSense to the Wi-Fi network. At the top, it lists the available networks with respective signal strengths. Below the list is a form to input the SSID and password for the selected network, with an option to show the password input. Two "Save" and "Refresh" buttons are provided to save the settings or refresh the network list. At the bottom, a red message indicates that the device is "Not connected" to the network with SSID "1234568," stating "AP not found." It means that the previous Wi-Fi that HydroSense is connected to is not present. The interface is accessed when connecting to the HydroSense Wi-Fi AP at the local IP address '192.168.4.1'.

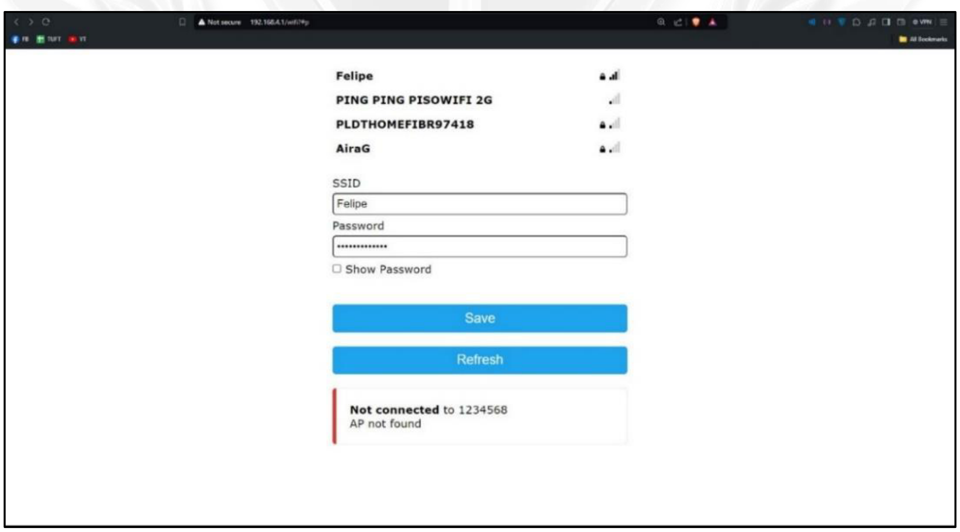


Figure 8. Setup Interface.

Figure 9 shows the process of saving Wi-Fi credentials and attempting to connect the HydroSense device to a network. A message box on the page states, "Saving Credentials" and "Trying to connect ESP to network." It also advises, "If it fails reconnect to AP to try again," suggesting that if the connection attempt is unsuccessful, the user has to reconnect to the Access Point (AP) and try again.

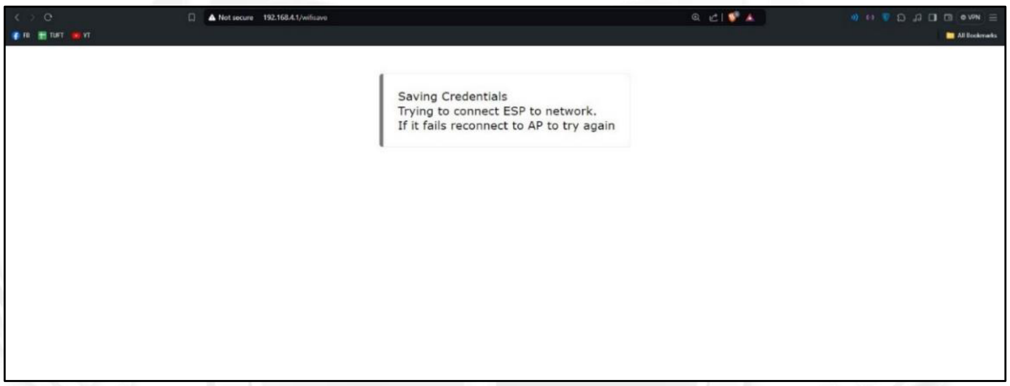


Figure 9. Saving Credentials.

4.1.2 Homepage Interface

The HydroSense homepage interface is designed for real-time water quality monitoring, showing four gauges that display key measurements: pH level, TDS level, turbidity level, and temperature. Each gauge is color-coded for quick visual assessment and is clearly labeled to enhance user understanding. Below the gauges are two functional buttons: "Start Logging" and "Show More." The "Show More" button provides detailed recommendations for water treatment, explaining the significance of each parameter. The interface also includes a navigation menu with links to "Data Insights," "Hydrological Resources," and "About Us," offering users access to additional information and resources. The "Start Logging" button in Figure 10 creates a .csv le that records the sensor data and then redirects the user to the Live Data page.

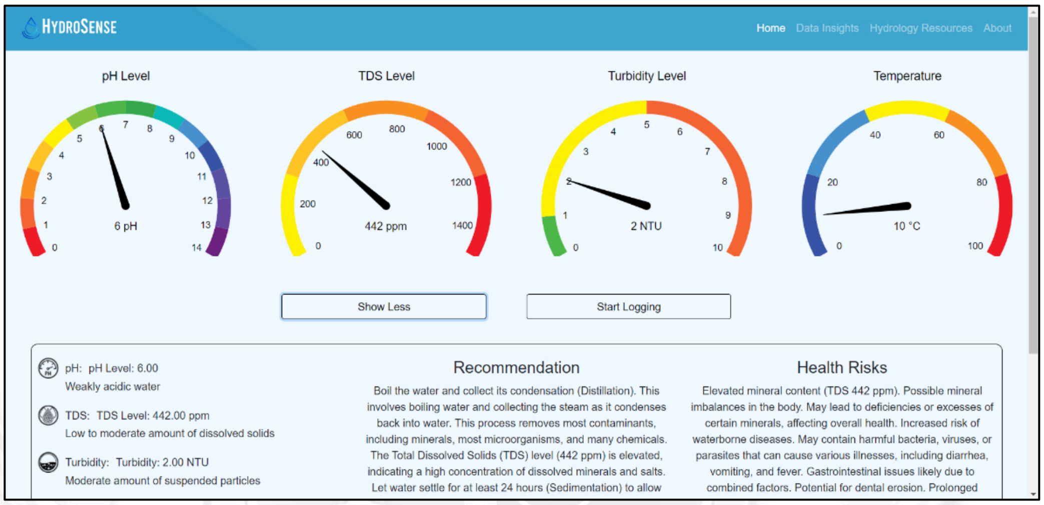


Figure 10. Homepage.

Figure 11 depicts the Live Data page. The page features a line graph labeled "Sensor Data" at the top, which plots measurements of temperature (°C), TDS (ppm), turbidity (NTU), and pH over time, with each parameter represented by a unique color. The page also includes a "Recommendation" section, which states that the water is safe to drink, summarizing the current water quality status. A table below the graph lists recent measurements, showing timestamps alongside the corresponding temperature, TDS, turbidity, and pH values. A recommendation section indicates that the water is safe to drink, summarizing the current water quality status. The "Stop Logging" button stops data logging, saves it to a .csv le, and redirects to the Data Insights page.

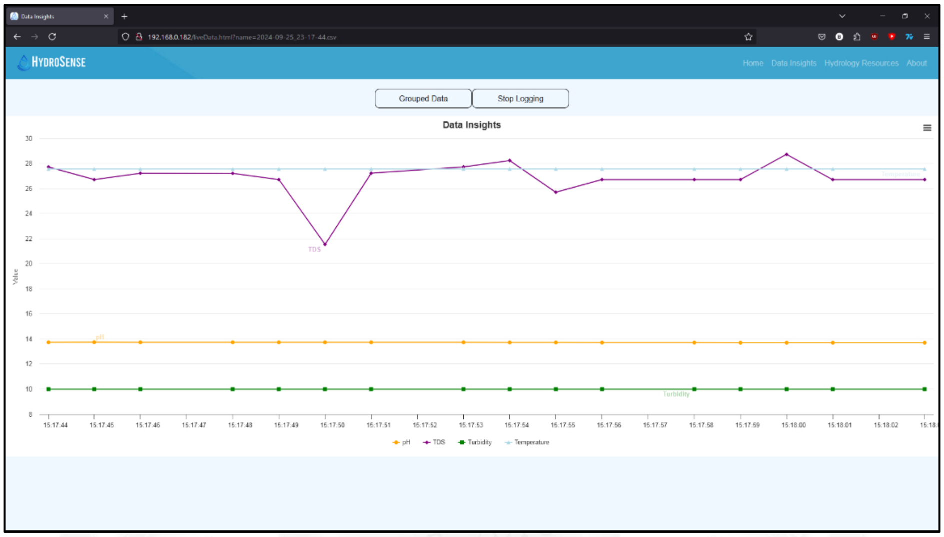


Figure 11. Live Data.

4.1.3 Data Insights Interface

Figure 12 displays the Data Insights interface of HydroSense, showcasing a comprehensive view of water quality data. At the top, a line graph titled "Sensor Data" presents historical measurements of temperature (°C), TDS (ppm), turbidity (NTU), and pH over time, each represented by a distinct color. A menu in the upper right corner offers options to view the chart in full screen, print it, or download it in various formats, including .csv. Below the graph, is a recommendation section summarizing the water quality status. The interface also includes a table listing recent sensor data with columns for time, temperature, TDS, turbidity, and pH values. On the left side, a panel labeled "Saved Data Files" lists previously recorded data files with options to delete them. This interface allows users to monitor real-time trends and access historical data for better decision-making. The intuitive layout ensures easy navigation and quick access to critical information.

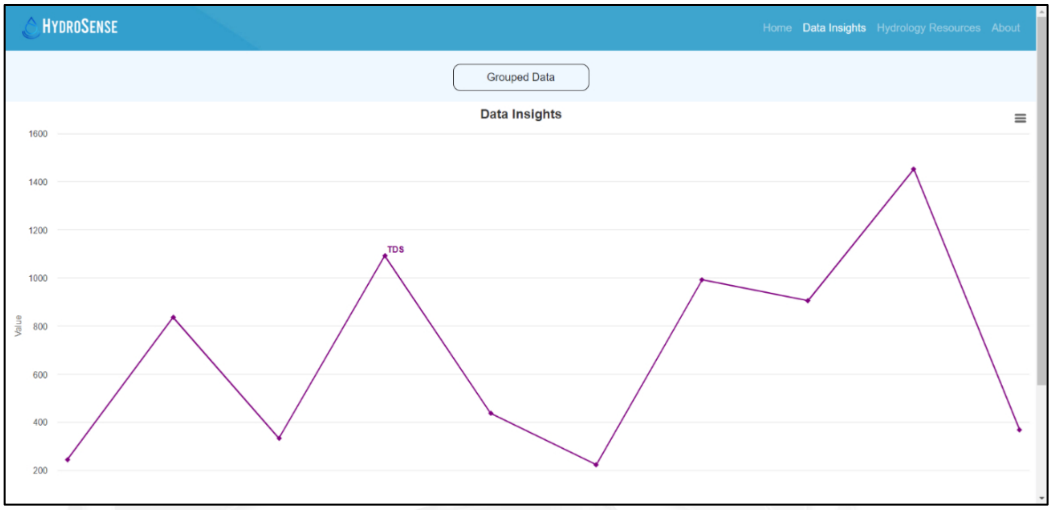


Figure 12. Data Insights Interface.

4.1.4 Hydrology Resources Interface

Figure 13 shows the Hydrology Resources page. It reveals a comprehensive list of topics related to water quality and treatment. Below the search bar and filter buttons, the page includes expandable sections for "Water Safety," "pH Level," "Turbidity Level," "TDS Level," "Water Temperature," and several methods of water treatment, such as "Filtration," "Aeration," "Water Distillation," "Sedimentation," "Boiling Water," "Water Treatment," and "Alkaline Water." Each section contains detailed information and resources to educate users on these specific aspects of hydrology. This layout provides a structured way for users to access and explore various topics related to water quality and treatment techniques. This makes it a practical resource for water quality education. The page also provides links to external resources, such as articles and video tutorials, for further learning. Its user-friendly design ensures easy navigation and accessibility for users at all knowledge levels.

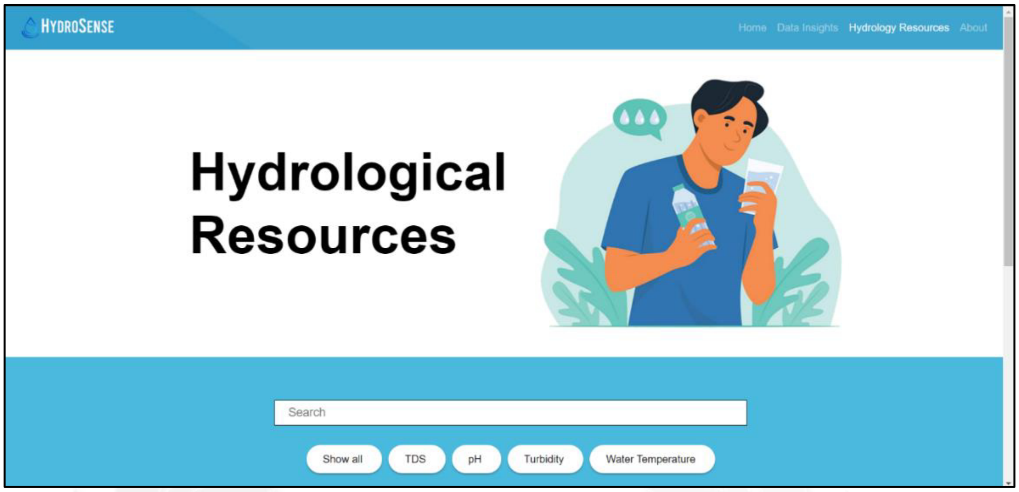


Figure 13. Hydrology Resources Interface.

Figure 14 shows a pop-up window when clicking on the "Water Safety" section on the Hydrology Resources page of HydroSense. The window briefly describes water safety, explaining its importance in ensuring that water used for drinking, recreation, and environmental purposes meets quality standards and is free from contaminants. The pop-up includes an embedded YouTube video offering an educational resource. Below the video, there are buttons labeled "Guide," "Article 1", "Article 2", and "Article 3", which provide additional resources for users to explore for more in-depth information about water safety. This feature enhances the user experience by integrating multimedia content that supports varied learning styles and preferences. HydroSense provides easy access to valuable resources on water safety. This promotes informed decision-making for safer water practices. This allows users to explore various topics in more depth. As a result, users enhance their understanding of essential water safety measures directly from the Hydrology Resources page.

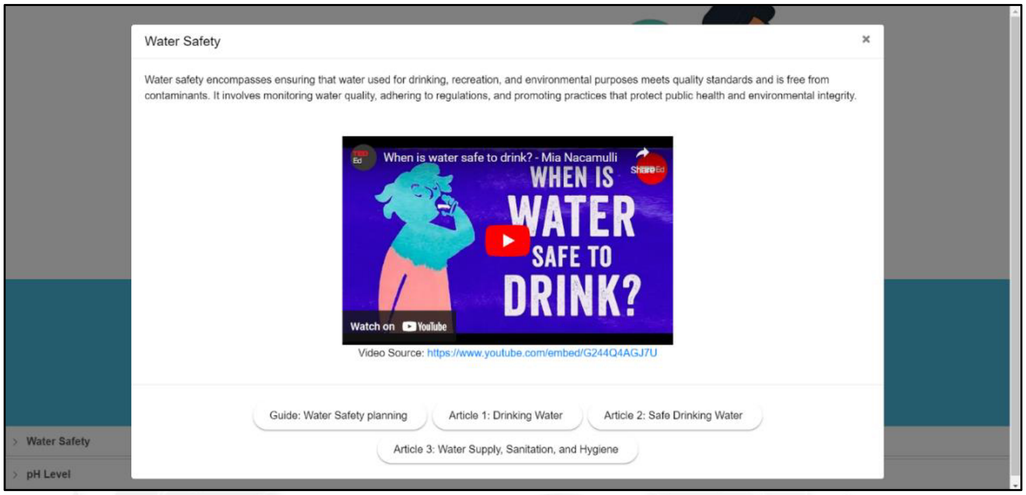


Figure 14. Hydrology Resources Popup.

Figure 15 provides a detailed view of the Hydrology Resources page after selecting the "pH" filter button just below the search bar. When this filter is activated, the page dynamically updates to showcase content specifically related to pH, streamlining the users focus on this aspect of water quality. The updated page layout features two prominent expandable sections labeled "Water Safety" and "pH Level." These sections are designed to house content pertinent to the pH filter, ensuring that all displayed information and resources are directly related to the pH of water. Users are able to interact with these expandable sections to reveal in-depth material on how pH levels affect water quality and safety, including details on the significance of maintaining appropriate pH levels, common issues associated with pH imbalances, and best practices for monitoring and adjusting pH. This targeted filter functionality enhances the user experience by providing a streamlined path to explore relevant topics, facilitating a more efficient and focused search for information about pH and its implications for water safety.

Figure 15. Hydrology Resource Toggle.

Figure 16 displays the Hydrology Resources page after using the search bar to look for the keyword "tds." The search results are filtered to display only the "TDS Level" section at the bottom, indicating that this section contains information relevant to the Total Dissolved Solids (TDS) keyword. This functionality allows users to quickly locate, and access specific topics related to their search query, streamlining the process of finding detailed information on water quality parameters. Users are able to refine their search with additional keywords further or explore related topics through the filter buttons provided. This interface design enhances user efficiency by offering intuitive search and navigation features within the HydroSense application. Additionally, tooltips and concise descriptions are integrated to assist users in understanding the context and significance of the displayed results, promoting a user-friendly experience.

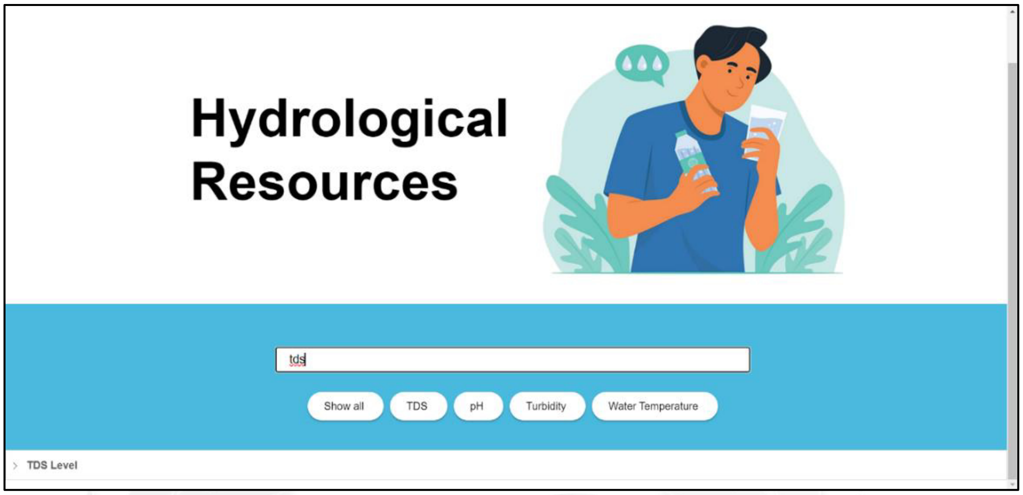


Figure 16. Hydrology Resources Search.

4.1.5 About Interface

Figure 17 shows the About page of HydroSense. It introduces the project with a visually engaging banner featuring clear water and the system "Clean Water, Clear Knowledge," emphasizing its focus on providing accurate water quality information. The page outlines HydroSense as an innovative web application offering tailored water purification suggestions based on real-time sensor readings, analyzing data such as TDS, turbidity, temperature, and pH. The technical setup includes an ESP32-WROOM-32D microcontroller connected to an Arduino Nano and various sensors, facilitating efficient data processing and visualization through a microSD card and OLED display. Additionally, the page highlights the developers, "Stealthy Kitten," showcasing the developers with their respective roles. This section provides a comprehensive overview of HydroSense mission, technological framework, and the developers behind its creation.

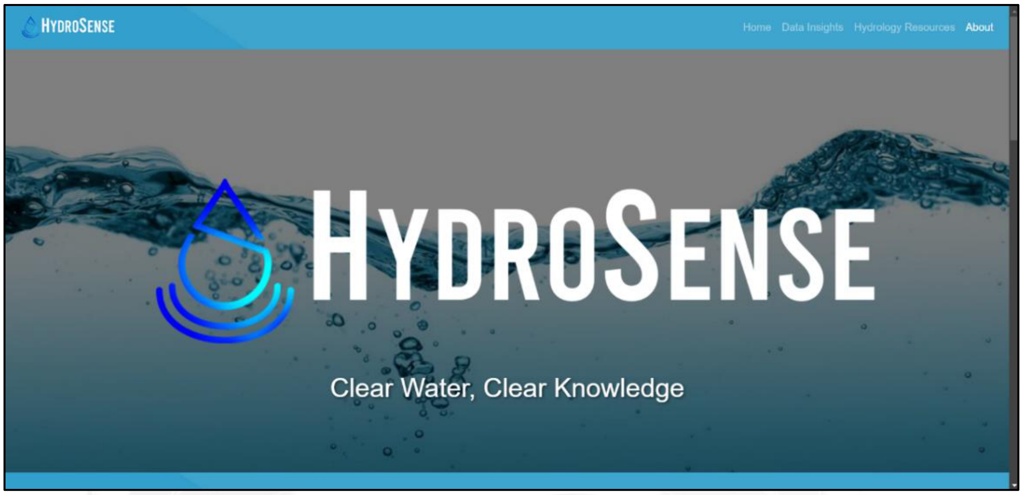


Figure 17. About Interface.

4.2 Hardware Interfaces

HydroSense is a sophisticated system that integrates software and hardware components to provide real-time water quality monitoring and analysis. The hardware interface of HydroSense includes an ESP32-WROOM-32D microcontroller connected to an Arduino Nano, which serves as the core processing unit for sensor data collection. Various sensors are integrated into the system to measure key parameters such as pH, TDS, turbidity, and temperature, transmitting data through interface boards. This setup enables precise and continuous monitoring of water quality. The microcontroller interfaces with an OLED display for real-time data visualization and a microSD card for logging sensor data and storing web server les. While HydroSense is accessible via a web-based application, the hardware components are essential for capturing accurate water data. This makes the system suitable for deployment in various locations where monitoring is critical. Users are able to access the application through any device with a web browser, although using a desktop or tablet with a larger screen enhances the visualization of complex data and graphs.

4.2.1 OLED Screen Interface

Figure 18 shows that the OLED screen of the HydroSense system provides a convenient and immediate way to view real-time water quality metrics directly from the hardware, offering a critical interface for on-site monitoring. This compact display prominently shows the device IP address, facilitating network communication and enabling seamless data monitoring from remote locations through the web application. In addition to the IP address, the screen presents crucial water quality parameters, including the current temperature, Total Dissolved Solids (TDS) level, turbidity, and pH level, giving users comprehensive insights into water conditions at a glance. By consolidating this information into a single, easily accessible display, users efficiently monitor essential water quality metrics on the spot without needing to go into the web interface, enhancing both usability and convenience. This capability is especially valuable in remote or eld settings, where quick access to water quality data is able to inform immediate decision-making and ensure timely interventions. Furthermore, the straightforward presentation of data on the OLED screen supports users of all technical levels, making HydroSense a versatile tool for various applications in water quality management. Its robust design and clear readability under diverse environmental conditions make it a reliable solution for field professionals.

Figure 18. OLED Screen Interface.

4.3 Software Interfaces

The developers carefully integrated software interfaces that efficiently interact with the underlying hardware to provide accurate water quality monitoring and analysis. The system utilizes programming languages like C++ and Javascript to manage sensor data collection, processing, and transmission. The use of .csv les to store sensor data and Highcharts for charting .csv les to be viewed in the application. Internet protocols, including Hypertext Transfer Protocol (HTTP) and web servers, facilitate real-time data exchange between the hardware and the web-based application, enabling users to access current and historical water quality data through a user-friendly interface.

4.3.1 Browser

HydroSense is a web-based application designed to operate seamlessly on any device equipped with a modern web browser. The application has been thoroughly tested on popular browsers, including Google Chrome, Firefox, and Brave, to ensure compatibility and performance across different platforms.

Developers used these browsers to verify that the web application maintains consistent functionality and interface quality, regardless of the users' browser choice. Internet connectivity is critical to application performance, relying on real-time data transmission from the hardware to the web interface. A stable and fast internet connection enhances the applications responsiveness and user experience, providing accurate and timely water quality insights.

4.4 Communication Interfaces

This section discusses the components and technologies facilitating data transmission between the HydroSense web application and its users. It explains how data transmission is initiated and delivered, ensuring efficient interaction. Additionally, the section covers the hosting platform that supports seamless user access to the application. Overall, it provides an overview of the communication processes that enable real-time data exchange within HydroSense.

4.4.1 ESP32 Web Server

HydroSense utilizes an integrated web server hosted directly on the ESP32 microcontroller, enabling local data processing and web application hosting. The application is developed using C++ and JavaScript to create interactive features and real-time data visualization. By hosting the web application on the ESP32, HydroSense operates independently of external servers, ensuring data security and immediate access. The ESP32 web server handles requests from connected devices, delivering water quality data efficiently to users' browsers via HTTP and WebSocket protocols.

This chapter outlines the various interfaces designed and utilized by the HydroSense application. The team has explored the screen layouts, presenting a graphical representation of what users are able to expect when accessing and navigating through the system. The developers have provided detailed descriptions of hardware and software interfaces, illustrating how they work together to deliver accurate water quality data. Each section has highlighted the importance of these interfaces in ensuring a seamless user experience, focusing on real-time data processing and accessibility. The chapter also emphasizes the role of intuitive design in minimizing the learning curve for users of diverse technical backgrounds. Detailed case studies demonstrate how the interfaces facilitate quick decision-making and enhance operational efficiency.

Additionally, future recommendations for interface improvements are provided to address scalability and evolving user needs. The integration of feedback from initial users has been instrumental in refining the systems usability and performance. Looking ahead, the development team plans to incorporate advanced features, such as predictive analytics, to further empower users in proactive water quality management.

CHAPTER V

OTHER NONFUNCTIONAL REQUIREMENTS

This chapter outlines the nonfunctional requirements of HydroSense, emphasizing the quality attributes of the hardware and software components. It includes performance metrics, software and hardware quality attributes, safety, security, and testing requirements. Performance requirements focus on system efficiency, sensor data accuracy, real-time data visualization, and responsiveness under varying environmental conditions. The quality attributes section defines the criteria for evaluating system performance, while safety and security requirements address data integrity and sensor reliability. Additionally, this chapter covers the testing protocols to ensure HydroSense meets its operational and safety goals.

5.1 Performance Requirements

This section outlines the efficiency and effectiveness of the performance requirements of HydroSense, encompassing both hardware and software components. These requirements include various measurements used to evaluate system performance, aiding developers in identifying necessary improvements to ensure optimal functionality. The key features of HydroSense have been evaluated using quality attributes to measure system performance. These features include real-time water quality monitoring, data visualization, sensor data logging, and hydrology resources. The water quality monitoring feature, powered by sensors for Total Dissolved Solids (TDS), turbidity, pH, and temperature, provides real-time feedback through the web interface, while the hardware components, such as the ESP32-WROOM-32D and Arduino Uno, ensure accurate data collection and reliable transmission. Data visualization presents sensor readings in graphical formats, enabling users to track trends and anomalies efficiently. The data logging function allows users to store historical sensor data in CSV format for further analysis. The system hydrology resources feature provides users with educational materials and water management guidelines. Performance evaluations include the response time of sensor readings, accuracy and speed of data transmission from the hardware to the web application, real-time updates, and the system ability to handle continuous monitoring under varying environmental and operational conditions. The hardware is also evaluated for power efficiency, durability, and ability to sustain long-term use without compromising sensor accuracy.

The ISO/IEC 9126 [GFG2024] software quality model was used to evaluate the software aspects of HydroSense, focusing on usability, efficiency, and functionality. The usability attribute was emphasized to assess the quality of the user experience with the hydrology resources, data visualization, and water quality recommendation system. This includes evaluating the understandability, learnability, operability, and attractiveness of the web interface, ensuring users are able to interpret water quality data and access educational materials easily. The efficiency attribute examines how well the web application processes and displays sensor data, linking it to the real-time data visualization and contaminant detection features. This involves measuring the system response times, resource utilization, and compliance. Lastly, the functionality attribute was applied to evaluate the contaminant detection and water quality recommendation system, focusing on accuracy, interoperability, security, and suitability. These assessments ensure that HydroSense delivers reliable and actionable data on water quality. Table 16 shows the product features of the application and their respective software quality models, attributes, criteria, mean scores, and feature mean scores.

Product Features	Software Quality Models and Attributes	Software Quality Criteria	Mean Score	Feature Mean Score
Hydrology Resources	Usability (ISO/IEC-9126)	Understandability	100%	95%
		Learnability	100%	
		Operability	100%	
		Attractiveness	100%	
		Compliance	75.00%	
Contaminant Detection	Functionality (ISO/IEC-9126)	Accuracy	100%	95.90%
		Interoperability	100%	
		Compliance	85.71%	
Data Visualization	Efficiency (ISO/IEC-9126)	Resource Utilization	75.00%	91.67%
		Time Behavior	100%	
		Compliance	100%	
Water Quality Recommendation	Usability (ISO/IEC-9126)	Understandability	100%	95%
		Learnability	100%	
		Operability	80%	
		Compliance	100%	

Table 16. Summary of Features, Attributes, and Results in Software Quality Model.

The score results are interpreted using Table 17. In addition, the equations used to solve the scores are discussed. It allows the developers to interpret the quality attribute scores using narrative descriptions. The software quality model provides some significant benefits to standard users by specifying the effectiveness of each feature. The developers identified and provided a conclusion to each attribute score of the product features. This comprehensive evaluation ensures that users make informed decisions based on the performance of the system across various attributes.

Percentage Range	Interpretation	Interpretation Description
80.20% -100.00%	Very Good	The quality of performance of the application feature is on the desired and excellent level.
60.40% – 80.19%	Good	The quality of performance of the application is on a satisfactory level and a little improvement
40.60% – 60.39%	Average	The quality of performance of the application is on a fair level, some improvements are recommended.
20.80% – 40.59%	Poor	The quality of performance of the application feature is on the undesired level, more improvements are recommended.
1.00% – 20.79%	Very Poor	The quality of performance of the application feature is not acceptable, A re-design is highly recommended.

Table 17. Validation Testing Results Interpretation in Software Quality Model.

The ISO/IEC 30141 [ISO2018] IoT system reference architecture model was used to evaluate the hardware aspects of HydroSense, focusing on trustworthiness, architecture, and functional characteristics. Trustworthiness was assessed through availability, confidentiality, integrity, reliability, resilience, and safety, ensuring continuous uptime, secure data transmission, accurate sensor readings, and system recovery from environmental challenges. In terms of architecture, HydroSense was evaluated for composability, heterogeneity, modularity, and scalability, ensuring easy integration or replacement of sensors, compatibility among different sensor types, and the system ability to scale by adding more sensors. Functional characteristics such as accuracy, compliance, data handling, manageability, and real-time capability were also emphasized. This ensured precise water quality measurements, adherence to standards, efficient data processing, easy maintenance, and live data transmission. By applying ISO/IEC 30141, the developers ensured HydroSense is a secure and reliable IoT water monitoring solution capable of effectively handling real-world conditions. Table 18 shows the product, its characteristics, and the mean and feature mean scores.

Hardware	Characteristics of IoT Systems	Related Characteristics	Mean Score	Characteristic Mean Score
HydroSense	IoT system Trustworthiness characteristics (ISO/IEC-30141)	Availability	100.00%	97.22%
		Confidentiality	83.33%	
		Integrity	100.00%	
		Reliability	100.00%	
		Resilience	100.00%	
		Safety	100.00%	
	IoT system architecture characteristics (ISO/IEC-30141)	Heterogeneity	100.00%	91.67%
		Modularity	75.00%	
		Network Connectivity	80%	
	IoT system functional characteristics (ISO/IEC-30141)	Compliance	100.00%	95.24%
		Data Characteristics	100.00%	
		Real-time Capability	85.71%	

Table 18. Summary of the Product and Characteristic of the Hardware Quality Model.

The score results are interpreted using Table 19. the equations used to calculate the scores are discussed to allow developers to assess the quality attributes of the system quantitatively. This interpretation provides developers with narrative descriptions for each score range, helping them assess the system performance in areas like availability, confidentiality, integrity, scalability, and real-time capabilities. The ISO/IEC 30141 model used in this evaluation offers significant benefits to both developers and users by outlining the system effectiveness across its trustworthiness, architecture, and functional characteristics. Developers are able to use the table to identify and interpret the attribute scores of each characteristic, determining which areas of HydroSense excel and which require further improvements. This structured approach helps prioritize development efforts, ensuring a targeted enhancement of the system overall performance and reliability.

Percentage Range	Interpretation	Interpretation Description
80.20% -100.00%	Very Good	The system performs excellently, meeting all IoT system trustworthiness, architecture, and functional requirements effectively.
60.40% – 80.19%	Good	The system performs satisfactorily, though some minor improvements enhance performance.
40.60% – 60.39%	Average	The system meets functional requirements, but significant improvements are recommended for better performance and reliability.
20.80% – 40.59%	Poor	The system performs below expectations; improvements in several areas are necessary to meet quality standards.
1.00% – 20.79%	Very Poor	The system is inadequate, with major issues in performance and security, requiring urgent redesigns or overhauls.

Table 19. Validation Testing Results Interpretation in Software Quality Model.

5.2 Software Quality Attributes and Metrics

The software quality attributes and metrics for HydroSense focus on evaluating functionality, usability, and efficiency attributes from the ISO/IEC 9126 model. Each attribute is measured using specific formulas to determine the system effectiveness. These calculations allow developers to evaluate the system performance, pinpoint areas for improvement, and ensure that the application meets industry standards. The attributes evaluated include accuracy, attractiveness, compliance, interoperability, learnability, operability, resource utilization, and time behavior. The calculation details are found in Appendix D, where the developers applied the formulas or metrics of software quality attribute discussed in this section. This thorough evaluation ensures the system is aligned with quality benchmarks.

5.2.1 Accuracy

It measures how precisely the system sensors collect and process water quality data. It evaluates whether the measurements from the sensors (such as pH, TDS, turbidity, and temperature) meet the required precision. The method involves counting the number of data items with incorrect precision and comparing it to the total number of items requiring precise measurements. A higher accuracy score reflects fewer errors in the system calculations, ensuring reliable data for real-time analysis. Formula 1 shows the accuracy formula. It contains one subtracted from the number of data items with incorrect precision divided by the total number of data items requiring precision, then multiplied by 100 to convert it to a percentage form.

$$\boxed{AC = \left(\frac{number\ of\ data\ items\ with\ incorrect\ precision}{total\ number\ of\ data\ items\ requiring\ precision}\right) x100}$$

Formula 1. Accuracy Formula.

The accuracy of HydroSense was evaluated, focusing on the precision of the sensor data. The accuracy criterion scored 100%, as outlined in Appendix M in contaminant detection, showing that the system accurately detects water contaminants such as pH, TDS, and turbidity levels. This high score reflects the sensors reliability and the system's ability to provide precise and actionable data. Users are able to trust the system to deliver accurate measurements, which is essential for monitoring water quality and ensuring safety. The contaminant detection system performs exceptionally well, providing accurate data that supports informed decision-making.

5.2.2 Attractiveness

It evaluates the visual design and organization of the HydroSense interface, ensuring it is appealing and intuitive to users. The metric assesses how many interface elements, such as dashboards and visualizations, are customizable by the user. The attractiveness score is calculated by comparing the number of customizable interface elements to the required elements. A high score indicates a visually appealing and user-friendly interface that enhances user interaction and experience. Formula 2 shows the attractiveness formula, which contains the number of customizable interface elements divided by the total number of interface elements, then multiplied by 100 to convert it to a percentage form.

$$AT = \left(\frac{number\ of\ customized\ interface\ elements}{total\ number\ of\ interface\ elements}\right) x100$$

Formula 2. Attractiveness Formula.

The attractiveness of the HydroSense interface was evaluated across all features. The attractiveness criterion received a score of 100%, indicating that the interface visual design is appealing and engaging. Users find the system layout clean, modern, and visually pleasing, which enhances the overall user experience. This score, presented in Appendix M in the part of hydrology resources, reflects the effective design of the interface, which contributes to user satisfaction by presenting water quality data intuitively and aesthetically pleasingly.

5.2.3 ISO/IEC-9126 Compliance

It assesses the extent to which the system adheres to the specifications, standards, and requirements during development. It measures the number of correctly implemented features and compares it to the required compliance items. A high compliance score reflects that the system meets the necessary usability, functionality, and efficiency standards. By ensuring compliance guarantees that the HydroSense system operates as expected, providing reliable water quality monitoring and data management. Formula 3 shows the compliance formula. It contains the number of correctly implemented compliance items divided by the total number of required compliance items, then multiplied by 100 to convert it to a percentage form.

$$CPL = \left(\frac{number\ of\ correctly\ implemented\ compliance\ items}{total\ number\ of\ compliance\ items}\right) x100$$

Formula 3. ISO/IEC-9126 Compliance Formula.

The compliance of HydroSense features was evaluated using the ISO/IEC 9126 models, assessing usability, functionality, and efficiency standards. The hydrology resources scored 75% under the usability model, meeting most usability standards while leaving room for improvement. The contaminant detection feature scored 85.71% under the functionality model, indicating reliable and precise performance with partial adherence to functional requirements. The data visualization feature achieved a score of 100% under the efficiency model, demonstrating full compliance in resource utilization and real-time responsiveness. The water quality recommendation feature also scored 100% under the usability model, fully meeting standards for understandability, learnability, operability, and attractiveness. As highlighted in Appendix M of hydrology resources, contaminant detection, data visualization, and water quality recommendation, these scores assess the system adherence.

5.2.4 Interoperability

It evaluates the system ability to exchange and integrate data between sensors and subsystems. It assesses whether the system correctly implements data formats and communication protocols, ensuring seamless data exchange between components such as pH, TDS, and turbidity sensors. The score is determined by comparing the number of correctly implemented data formats to the required formats. A high interoperability score indicates the system functions efficiently with external systems and devices, ensuring smooth data transmission and integration. Formula 4 shows the interoperability formula. It contains the number of correctly implemented data formats divided by the required data formats, then multiplied by 100 to convert it to a percentage form.

$$IO = \left(\frac{number\ of\ correctly\ implemented\ data\ formats}{total\ number\ of\ required\ data\ formats}\right) x100$$

Formula 4. Interoperability Formula.

Interoperability of HydroSense was assessed across all its features, measuring the system ability to integrate and communicate with various sensors and components. The interoperability criterion scored 100%, as displayed in Appendix M in contaminant detection, indicates that the system successfully implements all required data formats and protocols, ensuring seamless data exchange between sensors. This score reflects the system ability to integrate multiple sensor types and transmit data without issues effectively.

5.2.5 Learnability

It evaluates how easily users are able to understand and use the system. It measures the completeness and clarity of help topics, documentation, and tutorials, ensuring users quickly learn how to operate the system. The score is calculated by comparing the number of fully understood help topics to the required topics. A high learnability score indicates that users potentially navigate the system with minimal training or assistance, improving overall user satisfaction. Formula 5 shows the learnability formula. It contains one subtracted from the number of incomplete help topics divided by the total number of help topics, then multiplied by 100 to convert it to a percentage form. This formula provides a straightforward way to quantify the system ease of learning and highlights areas where user support enhanced.

$$LA = 1 - \left(\frac{number\ of\ incomplete\ help\ topics}{total\ number\ of\ help\ topics}\right) x100$$

Formula 5. Learnability Formula.

The learnability of HydroSense hydrology resources and water quality recommendation features was evaluated using the usability model, scoring 100%, as shown in Appendix M in hydrology resources and water quality recommendation. This indicates full compliance with learnability standards, allowing users to operate these features with minimal effort or training. The hydrology resources enable users to access educational materials and water management guidelines efficiently, while the water quality recommendation feature provides intuitive guidance for interpreting water quality data.

5.2.6 Operability

Operability assesses how easily users are allowed to operate and customize system functions during regular use. It evaluates how many system functions, such as data displays or sensor settings, potentially be adjusted by the user compared to the total functions requiring customization. A high operability score suggests that users have control over key system features, improving their experience by allowing them to adjust the system to their needs. This attribute ensures that HydroSense is easy to use and is able to personalize to meet user preferences. Formula 6 shows the operability formula. It contains the number of customizable functions divided by the total number of functions requiring customization, then multiplied by 100 to convert it to a percentage form.

$$OA = \left(\frac{number\ of\ customizable\ functions}{total\ number\ of\ function\ requiring\ customization}\right) x100$$

Formula 6. Operability Formula.

The operability of HydroSense hydrology resources and water quality recommendation features was evaluated using the usability model. The hydrology resources scored 100%, indicating full compliance with operability standards and allowing users to interact with and control the features easily. The water quality recommendation feature scored 80%, meeting most operability standards and enabling effective navigation and task execution with room for improvement. These scores, as indicated in Appendix M, in hydrology resources and water quality recommendation, provide a clear assessment of the operability of both features.

5.2.7 Resource Utilization

It measures how efficiently the system uses computational resources, such as memory and processing power, during operation. It evaluates the number of input/output errors relative to the number of system calls made, such as accessing sensor data or generating reports. Few errors lead to a higher resource utilization score, indicating that the system operates efficiently without unnecessary resource consumption. This attribute ensures HydroSense runs smoothly and effectively, even under heavy workloads. Formula 7 shows the resource utilization formula, which contains the number of I/O errors divided by the number of lines of code related to system calls, then multiplied by 100 to convert it to a percentage form.

$$\boxed{RU = \left(\frac{number\ of\ I/O\ errors}{number\ of\ lines\ of\ code\ related\ to\ system\ calls}\right) x100}$$

Formula 7. Resource Utilization Formula.

The developers assessed the resource utilization of HydroSense, The developers assessed the resource utilization of HydroSense, particularly in the data visualization feature. The resource utilization criterion scored 75% as depicted in Appendix M in data visualization, indicates that the system meets most efficiency standards but has room for improvement. This score reflects that HydroSense manages system resources effectively under typical workloads, though optimization is needed to handle larger volumes of water quality data without potential performance degradation. Enhance resource management able to improve the system ability to operate smoothly and efficiently under all conditions.

5.2.8 Time Behavior

It evaluates the system responsiveness, particularly in time-sensitive operations such as live data streaming. It measures how many delays or lags occur during data processing and compares this to the total number of time-sensitive operations. A higher time behavior score reflects that the system responds quickly, providing users with up-to-date information on water quality without delays. This attribute ensures that HydroSense meets real-time monitoring requirements and delivers accurate, timely data to users. Formula 8 shows the time behavior formula, which contains the time delays divided by the total number of data streams, then multiplied by 100 to convert it to a percentage form.

$$TB = \left(\frac{number\ of\ time\ delays}{total\ number\ of\ data\ streams}\right) x100$$

Formula 8. Time Behavior Formula.

The time behavior of HydroSense was evaluated across all features, with a particular focus on real-time data visualization. The time behavior criterion scored 100% as provided in Appendix M in data visualization, shows that the system responds instantly to user inputs and provides real-time data updates without delays. This high score reflects the system efficiency in processing and displaying data, ensuring that users receive up-to-date information promptly. The fast response times ensure HydroSense is highly effective in real-time water quality monitoring.

5.2.9 Understandability

It evaluates how well users comprehend the purpose and functions of HydroSense. It measures how easily users are able to interpret the system user interface and features, ensuring that they use the system without confusion. The score is calculated by comparing the number of fully understood interface functions to the total number of required interface functions. A high understandability score indicates that users easily navigate the system and interact with its features, improving the user experience. Formula 9 shows the understandability formula, which contains the number of UI functions whose purpose is understood by the user divided by the total number of user interface functions, then multiplied by 100 to convert it to a percentage form.

$$\boxed{UA = \left(\frac{number\ of\ UI\ functions\ whose\ purpose\ is\ understood\ by\ user}{total\ number\ of\ user\ interfaces\ functions}\right) x100}$$

Formula 9. Understandability Formula.

The understandability of HydroSense hydrology resources and water quality recommendation features was evaluated using the usability model, with both scoring 100%, as provided in Appendix N. These scores indicate full compliance with understandability standards, demonstrating that users easily comprehend both features purpose and functionality. The hydrology resources provide clear and intuitive information, while the water quality recommendation feature offers concise and easily interpretable guidance. These evaluations confirm that both features meet the defined usability criteria for understandability.

5.3 Hardware Quality Attributes and Metrics

The hardware quality attributes and metrics for HydroSense focus on evaluating key aspects of system performance, reliability, and resilience using the ISO/IEC 30141 model. Each attribute is measured using specific formulas to assess the effectiveness of the hardware components, including sensors and communication modules. These calculations in Appendix N help developers identify areas of improvement and ensure that the system adheres to IoT industry standards. The evaluated attributes include availability, confidentiality, integrity, reliability, resilience, safety, heterogeneity, modularity, network connectivity, compliance, data characteristics, and real-time capability. As discussed in this section, detailed calculations and evaluation metrics are provided to ensure that the hardware components meet the necessary performance and operational standards. This comprehensive evaluation supports developing a robust, high-performance system that meets current and future IoT needs.

5.3.1 Availability

The availability criterion in this internal quality measurement relates to the operational uptime of the hardware. The procedure counts the number of operational instances when the sensors or devices were online and compares it to the total operational time. The availability attribute was measured to determine whether the hardware elements, including the pH, TDS, turbidity, and temperature sensors, were functioning without interruptions. As indicated in Formula 10, one is subtracted from the number of unplanned hardware downtimes, divided by the total number of operational instances, and then multiplied by 100 to get the percentage.

$$A = \left(1 - \frac{number\ of\ unplanned\ hardware\ downtimes}{total\ number\ of\ operational\ instances}\right) x100$$

Formula 10. Availability Formula.

The developers evaluated the HydroSense hardwares availability based on its sensors' operational uptime. The availability criterion received a score of 100.00%, as referenced in Appendix N in IoT system trustworthiness characteristics, indicating that the sensors and devices remained operational without any unplanned downtimes. This signifies that the system consistently performed its functions, ensuring that data collection and transmission were uninterrupted. This high availability reinforced user trust in the reliability of the system. It also demonstrated HydroSense suitability for continuous water quality monitoring.

5.3.2 Confidentiality

It measures the security of transmitted data to ensure it is encrypted and protected. The procedure counts the number of secure transmissions from the sensors to the server and compares it to the total number of transmissions made. The confidentiality attribute was measured to ensure sensor data security, such as pH, TDS, turbidity, and temperature readings. As shown in Formula 11, the number of secure transmissions is divided by the total number of data transmissions and then multiplied by 100 to convert it to a percentage. This metric provides a clear indicator of the system reliability in safeguarding sensitive data against potential breaches or unauthorized access.

$$CY = \frac{number\ of\ secure\ transmissions}{total\ number\ of\ data\ transmissions}$$

Formula 11. Confidentiality Formula.

The confidentiality of HydroSense was assessed by evaluating the security of data transmissions from the sensors. This criterion received a score of 83.33%, as highlighted in Appendix N in IoT system trustworthiness characteristics, indicating that most data transmissions were securely encrypted, with some areas requiring improvement. The result shows that the system-maintained data privacy for most transmissions, though there is room to enhance security measures. To address these gaps, ensured that all sensitive information was transmitted securely and without breaches.

5.3.3 Integrity

It refers to the accuracy of the data transmitted from the sensors to the system, ensuring no data is corrupted or altered. The procedure compares the number of data packets transmitted correctly to the total number of packets sent by the sensors. This criterion was measured for pH, TDS, turbidity, and temperature data integrity. As indicated in Formula 12, the number of correctly transmitted data packets is divided by the total number of transmitted packets, then multiplied by 100 to obtain the percentage.

$$\boxed{I = \frac{number\ of\ correctly\ transmitted\ data\ packets}{total\ number\ of\ transmitted\ packets} x100}$$

Formula 12. Integrity Formula.

The integrity criterion was evaluated to determine the accuracy and reliability of the data transmitted from HydroSense sensors to the system. This assessment ensures that the data collected by sensors, such as pH, turbidity, and temperature readings, remains accurate and unaltered during transmission. The integrity criterion received a score of 100.00%, as shown in Appendix N in IoT system trustworthiness characteristics, indicating that no data corruption, loss, or alteration occurred throughout the transmission process. This result highlights the systems robust design and adherence to integrity standards, ensuring that the data remains precise and reliable for analysis and decision-making. It is crucial to maintain this level of integrity to provide users with dependable water quality monitoring, as any errors in data transmission compromise the system effectiveness and user trust.

5.3.4 Reliability Sensor

The reliability criterion relates to the consistency of sensor data collection and processing over time. It involves comparing the number of consistent readings to the total readings obtained. This ensures that pH, TDS, turbidity, and temperature sensors provide consistent data across different conditions. As described in Formula 13, the number of consistent sensor readings is divided by the total number of sensor readings and multiplied by 100 to generate the reliability percentage.

$$RY = \frac{number\ of\ consistent\ sensor\ readings}{total\ number\ of\ sensor\ readings} x100$$

Formula 13. Reliability Sensor Formula.

The developers assessed the reliability of the HydroSense system by evaluating the consistency of sensor readings under varying conditions. The reliability score was 100.00%, as provided in Appendix N in IoT system trustworthiness characteristics, indicating that all sensors consistently produced reliable data. This result signifies that HydroSense hardware components operated consistently over time without performance degradation.

5.3.5 Resilience

It measures the system ability to recover from disruptions or failures, such as network or power issues. It compares the number of successful recoveries to the total number of disruptions. This criterion was applied to ensure the recovery capability of HydroSense in situations where pH, TDS, turbidity, or temperature sensors face temporary failures. As indicated in Formula 14, the number of successful recoveries from system failures is divided by the total number of failures, then multiplied by 100 to convert it into a percentage. A high recovery rate demonstrates the systems resilience and ability to maintain reliable operation under adverse conditions.

$$RE = \frac{number\ of\ successful\ recoveries\ from\ system\ failures}{total\ number\ of\ failures} x100$$

Formula 14. Resilience Formula.

HydroSense resilience was evaluated by measuring its ability to recover from network outages or power failures. The resilience criterion received a score of 100.00%, as exhibited in Appendix N in IoT system trustworthiness characteristics. This indicates the system successfully recovered from all disruptions without losing data or functionality. HydroSense is highly resilient, ensuring continuous operations even in adverse conditions.

5.3.6 Safety

The safety criterion refers to the secure and reliable operation of the hardware under safe conditions. It compares the number of safe operational instances to the total operational instances. This criterion is important to ensure that all sensors operate safely without causing any hazards. As stated in Formula 15, the number of safe operational instances is divided by the total number of operational instances, then multiplied by 100 to generate the safety percentage.

$$S = \frac{number\ of\ safe\ operational\ instances}{total\ number\ of\ operational\ instances} x100$$

Formula 15. Safety Formula.

The developers evaluated the safety of HydroSense by ensuring that all sensors and devices operated within secure and safe conditions. The safety criterion received a score of 100.00%, as indicated in Appendix N in IoT system trustworthiness characteristics, meaning that all operational protocols were followed, and no safety issues were detected. This result signifies that HydroSense hardware is safe to operate in real-world environments without risk to users or equipment. This achievement highlights the system readiness for deployment in diverse environmental conditions.

5.3.7 Heterogeneity

It refers to the capability of the system to integrate and work with different types of sensors or devices. It compares the number of successfully integrated sensors to the total types of sensors in the system. This criterion evaluates the successful integration of pH, TDS, turbidity, and temperature sensors. This ensures the adaptability of the system to various sensors. As indicated in Formula 16, the number of successfully integrated sensor types is divided by the total number of sensor types and multiplied by 100 to obtain the percentage.

$$H = \frac{number\ of\ successfully\ integrated\ sensor\ types}{total\ number\ of\ sensor\ types} x100$$

Formula 16. Heterogeneity Formula.

Heterogeneity was assessed by evaluating HydroSense ability to integrate various types of sensors. The system received a score of 100.00%, as calculated in Appendix N in IoT system architecture characteristics, indicating that it successfully integrated all sensor types, including pH, TDS, turbidity, and temperature sensors. This result signifies that HydroSense architecture is flexible and supports various sensor types without compatibility issues.

5.3.8 Modularity

It measures the ease with which components of the system able be replaced or upgraded. It compares the number of modular components that manage to replace the total number of components. This criterion evaluates whether sensors are able to be replaced or added in a modular manner. As described in Formula 17, the number of replaceable modular components is divided by the total number of modular components and multiplied by 100 to calculate the modularity score. A high modularity score indicates a flexible and future-proof system design that simplifies maintenance and accommodates technological advancements.

$$M = \frac{number\ of\ replaceable\ modular\ compornents}{total\ number\ of\ modular\ components} x100$$

Formula 17. Modularity Formula.

The modularity of HydroSense was assessed by evaluating the ease with which its components potentially be replaced or upgraded. The modularity criterion received a score of 75.00%, as outlined in Appendix N in IoT system architecture characteristics, reflecting that while the system supports modular replacement, there is room for improvement. This result signifies that the system is somewhat modular, allowing for partial upgrades or replacements of sensors, but improvements in this area enhance the system flexibility.

5.3.9 Network Connectivity

It measures the stability and reliability of the sensor connections to the network. It compares the number of successful network connections to the total connection attempts. This criterion ensures the connectivity of pH, TDS, turbidity, and temperature sensors to the server. As shown in Formula 18, the number of successful network connections is divided by the total number of connection attempts and multiplied by 100 to compute the percentage.

$$NC = \frac{number\ of\ successful\ network\ connections}{total\ number\ of\ connection\ attempts} x100$$

Formula 18. Network Connectivity Formula.

The developers assessed HydroSense network connectivity by evaluating the stability and reliability of its connections to the network. The network connectivity criterion received a score of 80%, as referenced in Appendix N in IoT system architecture characteristics, indicating that most sensor connections were stable and reliable, though some areas require improvement. This score reflects partial compliance with connectivity standards, highlighting occasional issues that are able to affect seamless data transmission. Enhance network stability, improve the overall system performance, and ensure consistent communication between sensors and the system. Addressing these connectivity issues strengthen the system overall reliability and data accuracy in real-world applications.

5.3.10 ISO/IEC-30141 Compliance

It refers to the adherence of the hardware components to system performance standards. It compares the number of components that meet performance requirements to the total number of components in the system. This criterion ensures that all sensors perform within the required specifications. As stated in Formula 19, the number of compliances with performance and optimal requirements is divided by the total number of hardware elements, then multiplied by 100 to calculate the compliance score.

$$CE = \frac{n\ of\ compliances\ with\ performance\ and\ optimal\ requirements}{total\ number\ of\ hardware\ elements} x100$$

Formula 19. ISO/IEC-30141 Compliance Formula.

Compliance was evaluated by assessing whether HydroSense hardware components met the required system performance standards. The compliance criterion received a score of 100.00%, as presented in Appendix N in IoT system functional characteristics, meaning that all components operated within the specified performance requirements. This result signifies that HydroSense hardware meets all the necessary functional standards, ensuring reliable performance.

5.3.11 Data Characteristics

It relates to the ability of the system to handle different data types and ensure accuracy. It compares the number of correctly processed data types to the total required data types. This criterion ensures that pH, TDS, turbidity, and temperature data are handled accurately. As shown in Formula 20, the number of data types processed correctly is divided by the total required data types and multiplied by 100 to get the percentage.

$$\boxed{DC = \frac{number\ of\ data\ types\ processed\ correctly}{total\ required\ data\ types} x100}$$

Formula 20. Data Characteristics Formula.

Data characteristics were assessed by evaluating HydroSense ability to process different types of data accurately. The data characteristics criterion received a score of 100.00% referenced in Appendix N in IoT system functional characteristics, reflecting that all sensor data types were correctly handled and processed. This result shows that HydroSense accurately collects and processes data, ensuring its integrity. It demonstrates robustness and reliability, making it a dependable tool for water quality management.

5.3.12 Real-Time Capability

It measures how well the system delivers real-time updates for sensor data. This criterion is essential for pH, TDS, turbidity, and temperature sensors, ensuring they provide real-time data without delays. As indicated in Formula 21, the number of real-time updates provided is divided by the total number of required updates and multiplied by 100 to obtain the percentage.

$$RC = \frac{number\ of\ real - time\ updates\ provided}{total\ number\ of\ required\ updates} x100$$

Formula 21. Real-Time Capability Formula.

Real-time capability was evaluated based on HydroSense ability to provide real-time updates from its sensors. The real-time capability criterion received a score of 85.71% as presented in Appendix N in IoT system functional characteristics. This indicates that the system usually delivers real-time data, though some delays are possible. This score reflects partial compliance with real-time standards, suggesting the need for optimization to ensure consistent, immediate updates. Removing these delays enhances HydroSense suitability for time-sensitive applications.

5.4 Safety and Security Requirements

HydroSense is a water quality monitoring system designed for use in various environments and settings such as in a residential setting. The system ensures the safety and security of data by utilizing encryption for all sensor data transmissions, safeguarding sensitive information such as pH, TDS, turbidity, and temperature readings from unauthorized access. The hardware components of HydroSense are designed to operate safely under various conditions, adhering to strict safety standards to prevent electrical malfunctions or data corruption. Additionally, the system built-in security measures ensure that sensor readings remain accurate and intact throughout data collection and transmission. Users are provided with clear guidelines on operating the system safely, and all data is processed in real time while maintaining high levels of integrity and confidentiality. This comprehensive approach ensures that HydroSense remains a reliable and secure tool for monitoring water quality. It allows users to make informed decisions based on trustworthy data and enhances the system value in diverse applications.

5.5 Testing Requirements

Testing is vital in HydroSense development to ensure all components function as intended and meet operational standards. Through testing, developers identified issues, refined functionalities, and optimized the system overall performance. Testing phases included unit testing of individual sensors, integration testing to ensure seamless operation among components, and system testing to evaluate the system real-world performance. These steps helped improve the reliability and functionality of HydroSense, ensuring it delivered accurate data. The following sections detail the specific testing methodologies used.

5.5.1 Unit Testing

Unit testing for HydroSense evaluating individual components of the system to ensure they functioned correctly in isolation. Each module, including the

TDS, pH, turbidity, temperature sensors, and web application data visualization and logging features, was tested independently. The team developed test cases for specific functionalities, such as accurate data readings from sensors, responsiveness of the OLED display, and proper storage of data in CSV format. Any bugs or anomalies identified during these tests were resolved before the integration phase. The unit testing process helped the team verify that each component met its design specifications and contributed effectively to the overall system.

5.5.2 Integration Testing

The integration testing process focused on verifying the compatibility between the Arduino-based hardware, including sensors, and the web application for real-time data transmission and visualization. To assess data accuracy and system resilience, the developers employed test cases that simulated real-world scenarios, such as fluctuating water quality parameters and network interruptions. Any detected inconsistencies between the modules were documented and resolved to ensure a robust and reliable system. The team emphasized collaboration during this phase, involving hardware and software specialists to troubleshoot and refine the integration process. Overall, this approach validated all components effective interaction, ensuring HydroSense performed as designed.

5.5.3 System Validation

It is focused on verifying HydroSense overall functionality and performance in a real-world environment. Developers assessed the system resilience to network interruptions and power failures while ensuring continuous sensor operation. Testing assessed the systems accuracy and speed in delivering real-time water quality data. It was deployed under various conditions to verify reliability and data integrity, with stress tests ensuring robust performance under peak loads. Additionally, feedback from test users was incorporated to identify and address usability challenges, further refining the system. This final testing phase ensured that HydroSense met the required performance standards for water quality monitoring. The thorough testing process guarantees HydroSense operates effectively in diverse conditions and meets user expectations for reliability and performance.

5.5.4 Acceptance Testing

During this phase, the application approached completion, with the defects mentioned in the survey resolved. A total of thirty individuals participated in testing the application. The six IT students, twenty-one non-IT students, and one faculty member are from UNO-Recoletos and two other school visitors. Users interacted or watched the application demo before completing surveys, providing feedback to guide enhancements. Confidentiality of personal information was strictly maintained. The application was tested face-to-face, with participants completing a detailed questionnaire via Google Forms. The survey also gathered qualitative feedback to capture participants specific suggestions for improvements. This feedback was instrumental in refining the user interface and addressing minor issues before deployment. Furthermore, participants unanimously highlighted the systems intuitive design and ease of use, contributing to its high overall satisfaction ratings. This evaluation measured accuracy, simplicity, security, and overall user satisfaction using a scale of one to five, with five being the highest. The mean score was computed, and its description was identified using Table 20.

Mean Score	Interpretation
4.21 – 5.00	Very Good
3.41 – 4.20	Good
2.61 – 3.40	Average
1.81 – 2.60	Poor
1.00 – 1.80	Very Poor

Table 20. Survey Result Interpretation.

Table 21 summarizes the evaluation of the application based on various criteria, mean scores, and their interpretations, with 30 participants providing ratings. The criteria listed have a mean score ranging from 4.30 to 4.67. The developers then identified the top three mean scores and the lowest three scores. This analysis provided valuable insights into the applications strengths and areas for potential enhancement, ensuring a balanced approach to future updates. These findings guide the development of targeted improvements in upcoming versions. Participants highlighted specific features that exceeded expectations, such as the user-friendly interface and accurate data visualization. Conversely, suggestions were made to refine areas like response time and advanced customization options for enhanced usability. This feedback is instrumental in aligning the application with user expectations and industry benchmarks. It also fosters continuous improvement, ensuring the system remains reliable and user focused.

Criteria	Mean Score	Interpretation
Accuracy	4.60	Very Good
Auditability	4.60	Very Good
Communication Commonality	4.67	Very Good
Completeness	4.60	Very Good
Conciseness	4.43	Very Good
Consistency and Understandability	4.51	Very Good
Controllability	4.49	Very Good
Data Commonality	4.63	Very Good
Decomposability	4.43	Very Good
Error Tolerance	4.40	Very Good
Execution Efficiency	4.53	Very Good
Expandability	4.53	Very Good
Generality	4.46	Very Good
Hardware Independence	4.37	Very Good
Instrumentation	4.53	Very Good
Modularity	4.33	Very Good
Observability	4.34	Very Good
Operability	4.42	Very Good
Security	4.63	Very Good
Self-Documentation	4.30	Very Good
Functional Simplicity	4.50	Very Good
Structural Simplicity	4.40	Very Good
Code Simplicity	4.50	Very Good
Software System Independence	4.50	Very Good
Traceability	4.50	Very Good
Training	4.60	Very Good

Table 21. Summary of Survey Results.

The top highest criteria for HydroSense are communication commonality (4.67), execution efficiency (4.53), and expandability (4.53). Communication commonality reflects standard interfaces and protocols, ensuring seamless communication between components and a user-friendly interface. Execution efficiency highlights the system runtime performance, showing that HydroSense processes data swiftly and reliably during real-time water quality monitoring.

Expandability demonstrates the system ability to extend its architectural, data, or procedural design, allowing for future enhancements, such as additional sensors or features. These high scores underscore HydroSense robust design and adaptability to meet diverse user needs. This solid performance in key areas reinforces HydroSense as an effective and scalable solution for water quality management. It positions the system to easily accommodate future technological advancements and evolving user requirements.

Conversely, the criteria with relatively lower scores are self-documentation (4.30), modularity (4.33), and observability (4.34). self-documentation pertains to the degree to which the source code provides meaningful comments and explanations, which improves for easier maintenance and development. Modularity reflects the independence of program components, where some modules are likely to have dependencies that are optimized. Observability refers to the ability to monitor system states and outputs, where improvements help users better trace and identify issues during operation. Despite these areas for enhancement, all criteria received ratings categorized as very good, ranging from 4.30 to 4.67, showcasing HydroSense overall high quality and effectiveness in delivering its intended functionality.

The project performance requirements for HydroSense have been thoroughly outlined in this chapter. Key quality attributes for both hardware and software were defined, with metrics provided to evaluate their performance. Testing methodologies, including unit, integration, system, and acceptance testing, were detailed, ensuring that

HydroSense met operational and safety standards. Results from the evaluations, which scored all criteria as "Very Good," highlight the system reliability, usability, and efficiency, while identifying areas like self-documentation and modularity for potential improvement. The positive results from the testing phase validate the system ability to perform accurately and consistently in real-world scenarios. Feedback collected from testing was used to refine the user interface, making it more intuitive and accessible. The modular design was recognized as a strength, offering flexibility for future upgrades. Areas for improvement, such as enhancing the self-documentation feature, were noted for further development. Overall, the comprehensive testing process ensures HydroSense is a reliable and high-performing tool for water quality monitoring.

CHAPTER VI

PROJECT MANAGEMENT

The chapter discussed the factors and resources needed to implement the system functionalities seamlessly. The team identified the web application that met the expectations of the targeted users and their impressions when using it. The section discussed the development strategies, methods of production, and effective management of these activities.

6.1 User Classes and Characteristics

In this section, developers outlined the different user classes and their characteristics. The developers described each stakeholder and clarified the advantages of using the device and the application to tackle issues defined in the study. The team identified the following groups expected to benefit from the project.

6.1.1 Public and Private Organizations

The project assisted private and public organizations in obtaining information such as pH level, alkalinity, and acidity of tested water. Given the information and data, organizations determined the quality of water. Furthermore, this capability enhanced their ability to improve public health and environmental sustainability. This data also enabled organizations to identify potential risks to water sources and implement targeted interventions. As a result, they were able to ensure safer, cleaner water for communities while contributing to broader environmental conservation goals.

6.1.2 Consumers

Consumers were considered end-users who directly benefited from the application functionalities. Many consumers relied on the system for accurate water quality assessments, ensuring the safety of the water they consumed. This system provided a user-friendly interface to accommodate individuals with varying levels of technical expertise, thereby promoting widespread use and trust in its capabilities.

6.2 Product Feasibility Assessments

To reach intended users and maximize project impact regarding the deployment of the project, the team generated strategies to publicize the application, highlight its advantages, and promote the project and its benefits. Prior sections discussed the aspects of the project technical feasibility, specifying the hardware and software requirements for the project implementation. The section discussed the multiple aspects of the feasibility study necessary to accomplish the project purpose, including promotion, management, and economics.

6.2.1 Marketing

The HydroSense project adopted a targeted marketing approach tailored to its locally accessible design. The device, which operates exclusively within a localized network, allows users to interact with its functionalities directly through a connected browser on the device itself. This localized approach ensured that users in remote or resource-constrained areas benefit from the system without relying on external internet connectivity.

Affordability was a key focus, achieved using cost-efficient hardware components without compromising quality. At an early stage in the market, the team capitalized on the opportunity to leave a lasting impression by offering an innovative and user-friendly solution for water quality management. Promotional efforts included informative video advertisements showcasing the product functionalities and benefits.

Social media plays a significant role in advertising, enabling a broad reach and facilitating user recommendations based on positive experiences. The marketing materials effectively enhanced the project visibility and credibility by integrating visually appealing product and team logos. The promotional campaign also emphasized HydroSense consumer-friendly design, ensuring users of all technical backgrounds access clean and safe water through accurate data provided by the device.

6.2.1.1 HydroSense Logo

The product logo is present in Appendix H. This application logo was used for product packaging and other materials and platforms to promote the project. The logo symbolized the letter "S" for sense and represented a droplet with radio waves, signifying a water sensor. Additionally, the developers discussed the application droplet shape structure and the sensor illustration, which resembled its purpose.

6.2.1.2 Stealthy Kitten Logo

It included the members, their roles, the platforms they worked on, and the technical consultant. The group name was Stealthy Kitten, and the group logo was seen in Appendix I. The team logo was a collaborative effort involving all members and was mutually agreed upon. The logo symbolizes the teams unity and dedication.

6.2.1.3 Product Advertisement

The device was advertised through social media platforms, and a great consumer experience enabled users to recommend it to interested others. HydroSense was promoted through video advertisements that showcased its purpose, capabilities, features and uses. Moreover, it provided an overview of the device functionalities and the web application.

6.2.1.4 Product Packaging

The product packaging incorporated elements representing the application itself. It included the team logo, the device name, the manual, features, and a device description. This packaging emphasized both functionality and brand identity. The design and details of the product packaging are shown in Appendix K.

6.2.2 Management

The project was an application and device owned by Stealthy Cat. The application was developed by its members. The project team was accountable for maintaining and producing the application and device. Appendix C depicts the activities and scheduling concerns of the project.

The application was enhanced, and there was room for improvement. In this project focus area, team members considered private and public organizations and consumers with digital and technological literacy. The target user did not require a complex skill set, as a manual was provided in the product packaging. The users' responsibilities included testing the water, reviewing data results generated by the software, considering the margin of error, and accounting for any other external factors that affected the data-gathering process.

As mentioned previously, the project was an Arduino and web-optimized for desktop or laptop computers. It was important to note that the device only covered liquids, which meant user error still occurred. Finally, to fully appreciate the application, data and result generation were presented through statistics intended for users to gather information and results accurately.

6.2.3 Production

The project was a device and web-based, and the finished product used web hosting services. Before implementing the hosting and creating the device, it was necessary to conduct testing activities to ensure that the project criteria were accurate and on time. The Program Evaluation and Review Technique (PERT) indicated the development activities from planning to production (see Appendix C). By following the diagram, the project was approved for its initial release. The consultants and advisers performed inspections and quality control to help assess the system further.

6.3 Time Management

Effective time management was required to ensure the project progress and completion. It allowed the team to allocate resources by setting clear timelines and deadlines. Team members prioritize tasks and allocate their time appropriately to meet project milestones. By breaking down the project into tasks and allocating time for each, the team created a structured and optimized workflow, reducing the risk of bottlenecks and delays. Team members were likely to be more productive. Clear timelines and task priorities enabled team members to focus on their assigned tasks, reducing distractions and increasing overall productivity. Appendix C depicts the entire endeavor, which took 36 weeks of development to complete the application.

6.4 Communications, Coordination, and Team Composition

This section highlighted the team initiatives and collaborative efforts. Communication platforms such as Facebook Messenger and Microsoft Teams were used to share updates, discuss challenges, and exchange ideas. Developers were assigned specific tasks to streamline the project workflow and ensure timely completion. The use of tools like Google Drive facilitated document sharing and version control, promoting transparency and efficiency. This coordinated approach fostered a productive environment and contributed to the overall success of the project.

6.4.1 Communications

To achieve success in any project hinged on the cornerstone of effective communication, serving as the linchpin that propelled the team towards their goals. Team members' remote activities were conducted through Facebook Messenger and Microsoft Teams. These communication platforms actively shared ideas, suggestions, and opinions, creating a collaborative environment that fueled the project progress. Furthermore, the team harnessed the power of Google Drive and Google Docs to streamline document management processes. The meeting minutes ensured team members had suggestions, opinions, and recommendations to improve the final output quality.

6.4.2 Coordination

The three team members collaborated, shared, and communicated to ensure project continuity. The requirements created by the team were uniquely broken down, so they shared the allotted tasks within the time constraints set by the company. The team considered using time management tools to update progress and address any errors encountered during development. The teams writer communicated concisely with the lead developer about the effective functionality of the system program, with the help of the front-end developer for the application of the system user interface.

6.4.3 Team Composition

The team was composed of a hardware developer, a software developer, and a writer, each assigned distinct and essential tasks. Roles were clearly defined, enabling members to take responsibility for specific areas such as hardware implementation, software development, and documentation. By dividing responsibilities effectively, team members collaborated to seamlessly integrate their efforts. This structured approach ensured the project was completed efficiently and successfully, meeting its objectives.

6.4.3.1 Hardware Developer

The hardware developer played a crucial role in the team, focusing on designing, implementing, and testing the device physical components. They possessed expertise in circuitry, sensor integration, and microcontroller programming, ensuring the seamless operation of the device. To collaborate closely with software developers, the hardware developer contributed to the overall system architecture, ensuring compatibility and reliability. Additionally, they conducted rigorous testing to validate the functionality and performance of the hardware components. Their attention to detail and problem-solving skills were instrumental in overcoming technical challenges and delivering a high-quality, functional device for water quality assessment.

6.4.3.2 Software Developer

The software developer held a pivotal role within the team, spearheading the development of the digital components of the project. Their expertise lies in coding, debugging, and optimizing software functionalities to ensure seamless operation and user interaction. To collaborate closely with the hardware developer, they ensured the integration of software and hardware components, maintaining compatibility and functionality. They also contributed to designing and implementing the web application interface, leveraging programming languages such as HTML, CSS, and JavaScript. Through rigorous testing and debugging processes, the software developer guaranteed the reliability and efficiency of the system, enhancing its overall performance and user experience.

6.4.3.3 Writer

The writer was pivotal in the team and was responsible for meticulous documentation of every phase, update, and action throughout the project development. To collaborate closely with the lead and front-end developers, the writer facilitated discussions on challenges and resource-related issues. This role ensured comprehensive and accurate documentation, providing valuable support for the project progress and serving as a critical reference for future stages.

This chapter provides a comprehensive overview of the project management strategies for the HydroSense system. It identified key user groups, including public organizations and consumers, and detailed the benefits they gained from using the application. The feasibility assessment highlighted marketing efforts, cost-effective production, and technical considerations for successful deployment. Time management was crucial in meeting milestones and ensuring efficient task allocation. Communication and coordination tools, such as Microsoft Teams and Google Drive, enhanced team collaboration. Clear role definitions for hardware, software, and documentation contributors ensured seamless integration and quality assurance. Overall, strategic planning and execution enabled the successful development of a reliable water quality assessment solution. The project was completed within the defined timeline, adhering to the budget and quality standards. This success reflects the teams effective coordination and commitment to delivering a high-quality product.

CHAPTER VII

SUMMARY AND RECOMMENDATION

This chapter reviews HydroSense, focusing on its purpose, performance, and potential improvements. It highlights the role of the system in providing accurate water quality monitoring and user-friendly features for real-time and historical data analysis. Based on feedback from testing and evaluation, areas for enhancement have been identified to optimize its usability and scalability further. The recommendations aim to refine HydroSense design and expand its capabilities for broader applications.

7.1 Summary

HydroSense integrates hardware and software to provide a comprehensive water quality monitoring solution. The system offers real-time monitoring, data visualization, and actionable water treatment recommendations by leveraging sensors to measure TDS, pH, turbidity, and temperature. The accompanying web application enhances the user experience by providing historical data storage, interactive visualizations, and educational resources about water management. Testing results and user feedback underscore the effectiveness of the system in providing reliable and accurate data while maintaining ease of use. Overall, HydroSense addresses the global challenge of ensuring access to clean water, aligning with Sustainable Development Goal 6, and empowers users to make informed decisions about water safety and sustainability. The system also supports remote monitoring, allowing users to track water quality anywhere, providing convenience and flexibility. By offering personalized recommendations and alerts, HydroSense ensures that users are able to take timely actions to maintain water safety and quality.

7.1.1 Planning and Analysis

The planning phase of HydroSense focused on designing a comprehensive solution that integrates sensors with a user-friendly web application for real-time water quality monitoring. A detailed analysis of existing systems revealed the value of combining hardware and software to deliver actionable insights through recommendations and data visualization. The developers prioritized creating a system that addressed user needs effectively while remaining adaptable. Feedback from evaluators played a crucial role in refining the project functionality and improving the hardware and software components. This iterative approach ensured HydroSense met its objectives while addressing potential challenges early in development.

7.1.2 Design and Development

The design and development phase involved using Arduino and ESP32 microcontrollers to create a scalable, efficient, and robust hardware solution for HydroSense. The web application was meticulously designed to provide seamless connectivity and intuitive interfaces, making it accessible across various devices. Challenges such as sensor calibration and dependency on stable internet connections were identified and addressed to enhance the reliability and performance of the system. The developers emphasized building a modular, user-friendly solution for real-time data processing. These design principles allowed

HydroSense to effectively deliver accurate water quality measurements and meaningful insights.

7.1.3 Implementation and Testing

HydroSense underwent extensive testing involving IT professionals, end-users, and other evaluators to validate its functionality and reliability. The system demonstrated high accuracy and efficiency, meeting user expectations for water quality monitoring. Feedback from testers highlighted the need for improved modularity and more comprehensive documentation to facilitate ease of maintenance. The testing phase also revealed HydroSense potential for real-world applications, particularly in areas with limited resources, where access to clean water is critical. This rigorous evaluation process ensured that HydroSense was ready for deployment while identifying areas for future improvement.

7.2 Recommendations

HydroSense is a water quality monitoring system that provides users with real-time data, actionable recommendations, and historical analysis. While the system has demonstrated high performance and reliability, developers, evaluators, and testers have identified areas for improvement to enhance its functionality and scalability. The following recommendations focus on modular design, expanded observability, cloud data storage, and additional sensor integration to ensure HydroSense remains a versatile and comprehensive solution for water quality monitoring. By addressing these areas, HydroSense continue to evolve and meet the growing demands of users and the water quality monitoring industry.

7.2.1 Modular Design Refinement

HydroSense benefited from further modularizing its system components to enhance maintainability and testability. By isolating individual modules, updates and troubleshooting potentially be performed with minimal impact on other parts of the system. This approach reduces interdependencies between hardware and software components, making the system more adaptable to future upgrades. Additionally, modularity is likely to allow for more efficient debugging and testing, enabling developers to focus on specific functionalities without disrupting the overall system. Improved modular design ensures HydroSense remains scalable and reliable in diverse operational contexts.

7.2.2 Expanded Observability Features

By adding detailed error reporting and system logs significantly enhance HydroSense observability and user troubleshooting capabilities. These features enable users to identify and trace issues more effectively, ensuring a better understanding of system behavior. Real-time error detection and logging also contribute to continuous monitoring, even in cases of hardware or software anomalies. These enhancements improve system reliability and user confidence by providing clear and actionable diagnostic information. Observability features also aid developers in optimizing system performance and addressing potential issues proactively. Furthermore, these improvements enable faster issue resolution, minimizing downtime and ensuring seamless system operation. Ultimately, these enhancements contribute to a more robust and user-friendly experience, fostering greater trust in HydroSense performance and reliability.

7.2.3 Data Storing of Historical Data in the Cloud

Currently, HydroSense stores historical data locally, which limits accessibility and scalability. Transitioning to cloud storage for historical data allow users to access their records from any device, enhancing convenience and data security. Cloud storage also provides opportunities for advanced analytics, enabling users to track long-term water quality trends and make data-driven decisions. This feature further enhances HydroSense utility by preserving valuable historical data, regardless of device or location. Moreover, cloud integration facilitates sharing and collaboration among users, expanding HydroSense applications beyond individual use.

7.2.4 Additional Sensors for Enhanced Water Quality Detection

To expand HydroSense capabilities, integrating additional sensors, such as dissolved oxygen (DO) and chlorine sensors, is recommended. Dissolved oxygen is essential for assessing aquatic ecosystem health and determining water's suitability for fish and other organisms. Chlorine sensors are critical for monitoring disinfection levels and ensuring water safety by detecting harmful pathogens. By including these sensors, it is expected to provide a more comprehensive water quality analysis, making HydroSense applicable in a wider range of scenarios, such as industrial water treatment, aquaculture, and environmental monitoring. Incorporating these sensors further strengthens HydroSense role in sustainable water management. These enhancements are likely to significantly broaden HydroSense impact and relevance.

GLOSSARY

A. ACIDITY

The concentration of hydrogen ions in a solution, measured on the pH scale, indicates how acidic or basic the solution is. Higher acidity corresponds to a lower pH value.

B. ACCESS POINT

A device that provides wireless devices with access to a wired network, often using Wi-Fi, and acts as a bridge to enable communication between the two. It extends the range and capacity of the network.

C. AERATION

The process of introducing air into a substance to increase oxygen content, commonly used in water treatment to enhance oxygen levels or in soil to improve its quality. This helps in processes such as biological treatment and soil conditioning.

D. ALKALINE

It refers to substances with a pH greater than 7, indicating a basic solution that c neutralizes acids. Alkaline solutions are typically used to counteract acidic conditions and in various chemical processes.

E. DATA VISUALIZATION

The graphical representation of data to help users understand and interpret complex information easily. It includes charts, graphs, and maps that make patterns and trends in water quality data more accessible.

F. ELECTRICAL CONDUCTIVITY (EC)

The measure of a water ability to conduct electricity, which reflects its ion concentration. Higher EC values indicate greater levels of dissolved salts and minerals.

G. FILTRATION

The process of removing solids from liquids or gases by passing the mixture through a porous material that captures the particles. It is commonly used to purify water or air by trapping impurities.

H. HYDROLOGY

The scientific study of the movement, distribution, and properties of water on Earth, including its cycle through the atmosphere, surface, and groundwater. Hydrology informs water management and environmental protection efforts.

I. HYDROSENSE

An integrated system designed to monitor, analyze, and provide recommendations for improving water quality based on various data inputs. It combines hardware and software to offer actionable insights and guidance.

J. MICROCONTROLLER

A small, self-contained computer on a single integrated circuit designed to perform specific tasks or control operations in embedded systems. It processes inputs from sensors and executes programmed instructions.

K. pH LEVEL

A measure of how acidic or alkaline a solution is, determined on a scale from 0 to 14. A pH level below 7 indicates acidity, while a pH level above 7 indicates alkalinity.

L. RECOMMENDATION SYSTEM

A feature that suggests actions or solutions based on the analysis of water quality data. It helps users make informed decisions to improve or maintain water quality.

M. SALINITY

The measure of dissolved salt concentration in water, which affects its quality and suitability for various uses. High salinity levels impact aquatic life and water treatment processes.

N. SEDIMENTATION

The process where solid particles settle out of a fluid due to gravity or centrifugal force, forming sediment at the bottom. It is used in water treatment to remove suspended particles.

O. SPECIFIC GRAVITY (SG)

The ratio of a substance density compared to the density of water. It is used to identify and characterize substances based on their density relative to water.

P. SERVICE SET IDENTIFIER (SSID)

It is the unique name assigned to a wireless network to identify it to users and devices. It allows devices to distinguish between different Wi-Fi networks within range.

Q. TOTAL DISSOLVED SOLIDS (TDS)

It refers to the measure of all dissolved substances in water, including minerals, salts, and organic matter. High TDS levels negatively affect the taste of water and its overall quality. Elevated TDS may also indicate the presence of harmful substances, making water unsafe for consumption.

R. TURBIDITY

The cloudiness or haziness of a liquid caused by large numbers of suspended particles. It affects water clarity and indicate the presence of contaminants or sediments.

S. WATER CONTAMINATION

The presence of harmful or undesirable substances in water, which affect its safety and quality. Contamination come from various sources, including pollutants and pathogens.

T. WATER DISTILLATION

A purification method that involves heating water to create vapor and then condensing it back into liquid form. It effectively removes impurities and contaminants by separating them from the purified water.

LIST OF SCREENSHOTS

USERS' MANUAL

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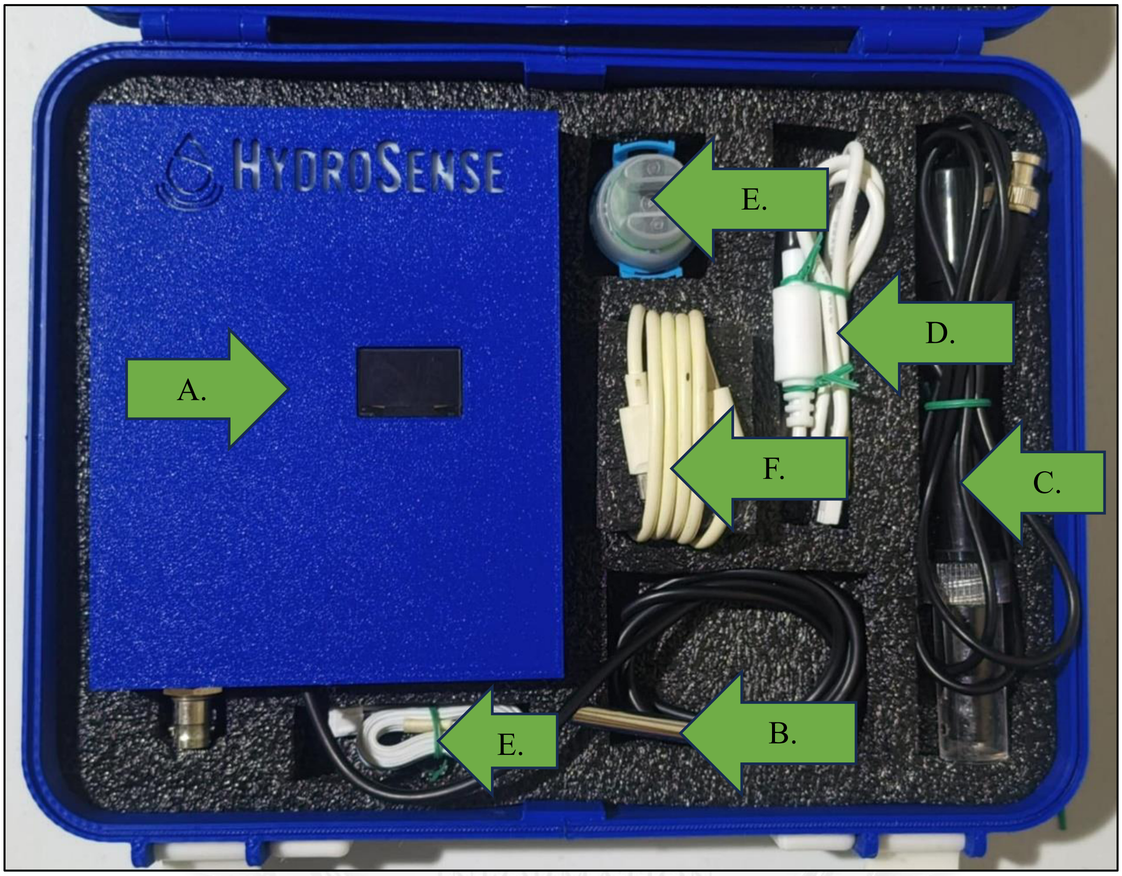
USERS' MANUAL

This user manual is a comprehensive guide to setting up and utilizing HydroSense. It enables real-time monitoring of water quality by interfacing with various sensors included in the package. This manual provides step-by-step instructions for connecting the TDS, pH, turbidity, and temperature sensors, as well as powering the device using a power bank or USB charger. It also learns how to access the web application hosted by the device and navigate through the Home, Live Data, Historical Data, Hydrology Resources, and About interfaces. Detailed diagrams and examples are included to simplify the setup and operation process. By following this guide, it effectively uses HydroSense to make informed decisions about water safety and management. All data processing and hosting are handled locally by the device, ensuring secure and direct access without the need for an external internet connection.

1. Inside the Package

Upon opening the package, users discover the HydroSense device, which comes with the temperature sensor pre-connected for ease of setup. Additionally, the package includes a pH sensor, TDS sensor, turbidity sensor, and a USB Type-C cable, all neatly arranged for convenience. Screenshot 1 in the manual provides a visual guide to the contents as they appear when unboxed, ensuring users identify each component effortlessly. Each sensor is designed to be easily connected to the HydroSense device for quick installation. This thoughtful packaging ensures users to start monitoring water quality with minimal effort.



Screenshot 1. Inside the Packaging.

A. HydroSense Device – It is the main device where every sensor be connected to.

B. Water Temperature Sensor – This sensor measures the water temperature.

C. pH Sensor – This sensor measures the pH of the water.

D. TDS Sensor – This sensor measures the total dissolved solids of the water.

E. Turbidity Sensor – This sensor measures how clear the water.

F. USB Type-C Cable – This cable is used to supply power to the HydroSense.

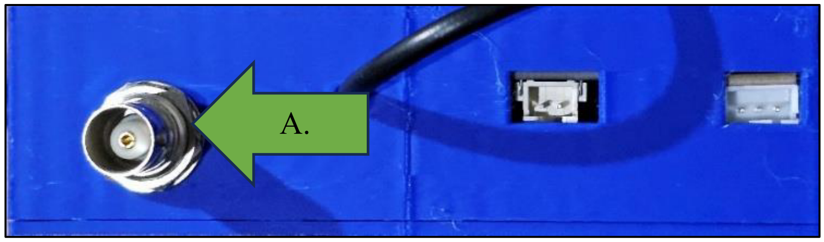
2. Connect the pH Sensor

To connect the pH sensor to HydroSense, align its BNC (Bayonet Neill–Concelman) connector with the corresponding port on the device. Ensure the connector is properly oriented to fit securely into the port located on the top of the HydroSense device. Screenshot 2 in the manual provides a visual reference for the appearance of the pH sensor BNC connector.

Screenshot 2. pH Sensor BNC Connector.

2.1 Identify the pH Sensor Port

The user must insert the pH sensor BNC connector into the HydroSense BNC port, ensuring a secure fit. The port is conveniently located at the top of the device making it easy to access. Refer to Screenshot 3 in the manual for a visual guide on where to insert the connector. This connection ensures the pH sensor is properly integrated with HydroSense for accurate readings.

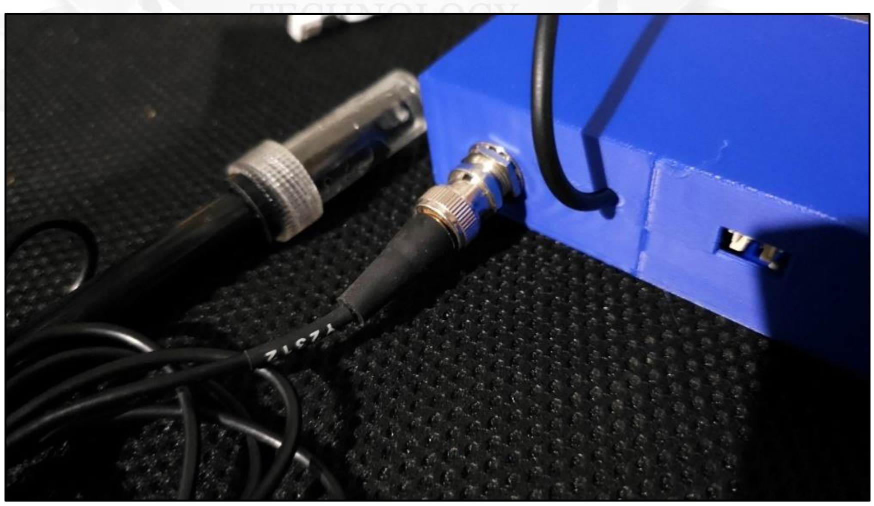


Screenshot 3. HydroSense BNC Port.

A. HydroSense BNC Connector – It is where the pH sensor BNC connector is to be attached to.

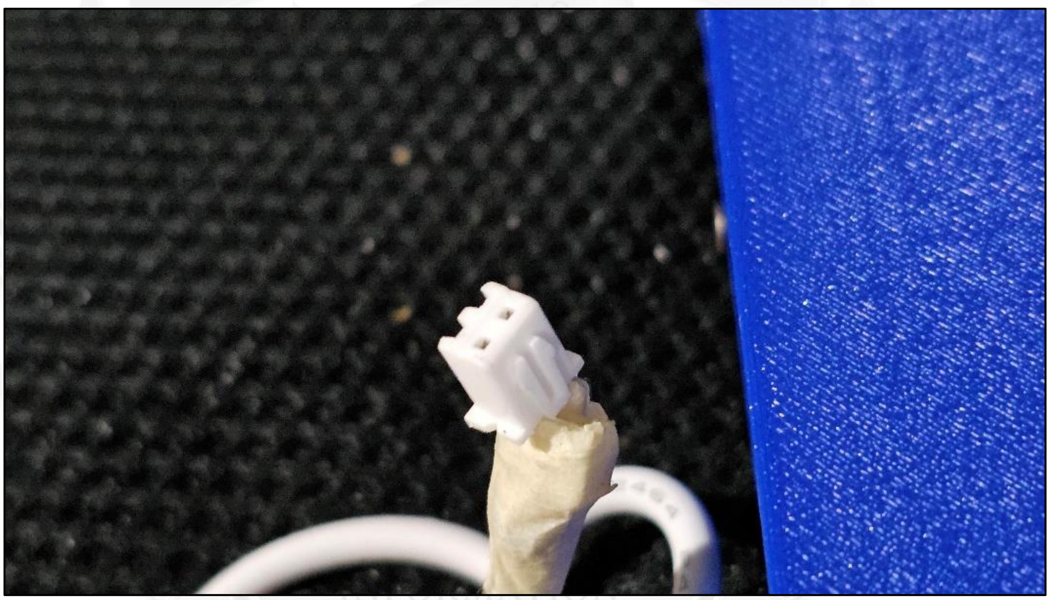
2.2 Insert the pH Sensor BNC Connector

The user must push the pH sensor BNC connector into the HydroSense BNC port and twist it securely until it locks in place. This ensures a firm and stable connection, preparing the sensor for accurate operation. Once connected, the pH sensor is ready to use. Screenshot 4 in the manual provides a visual example of the properly connected pH sensor.


Screenshot 4. Connected pH Sensor.

3. Connect the TDS Sensor

To connect the TDS sensor to HydroSense, align its 2-pin connector with the designated port on the device for a proper fit. Ensure the pins are correctly positioned to avoid any misalignment during connection. The manual includes Screenshot 5, which provides a visual reference for identifying the 2-pin connector. This step ensures the TDS sensor is ready for accurate water quality measurements.



Screenshot 5. TDS Sensor 2-pin Connector.

3.1 Identify the TDS Sensor Connector

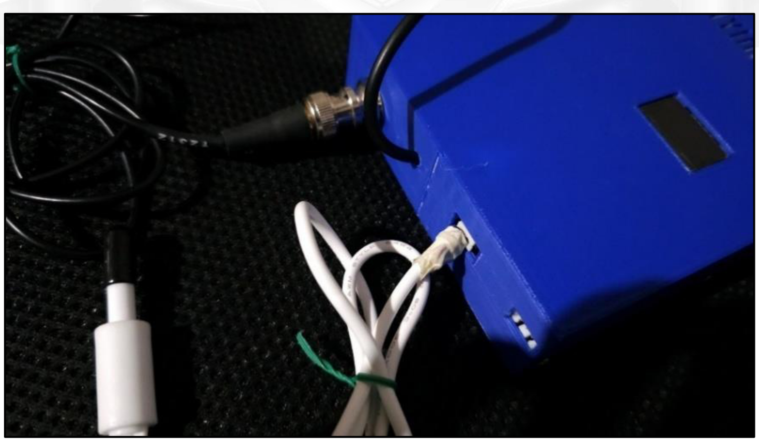
The user must insert the TDS sensor 2-pin connector into the HydroSense 2-pin port, ensuring it fits securely. The port is conveniently located at the top of the device, just above the logo, for easy access. Refer to Screenshot 6 in the manual for a clear visual guide on where to insert the connector. Properly connecting the sensor ensures it is ready for accurate water quality monitoring.

Screenshot 6. HydroSense 2-pin Port.

A. HydroSense 2-pin Connector – It is where the TDS sensor 2-pin connector is to be attached to.

3.2 Insert the TDS Sensor 2-pin Connector

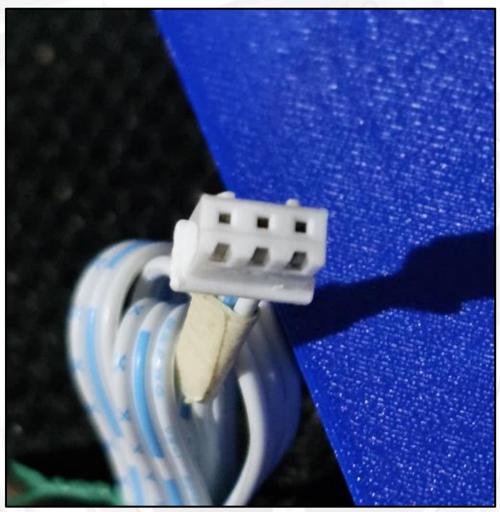
The user must push the TDS sensor 2-pin connector firmly into the HydroSense port until it locks securely in place. This ensures a stable connection for accurate functionality. Once the connector is properly attached, the TDS sensor is ready for use. Screenshot 7 in the manual provides a visual example of the connected TDS sensor for reference.



Screenshot 7. Connected TDS Sensor.

4. Connect the Turbidity Sensor

To connect the turbidity sensor to HydroSense, align its 3-pin connector with the designated port on the device. Ensure the pins are properly oriented to fit securely into the port without forcing. Screenshot 8 in the manual provides a clear visual reference for identifying the 3-pin connector. This alignment step is crucial for accurate turbidity sensor functionality.



Screenshot 8. TDS Sensor 2-pin Connector.

4.1 Identify the Turbidity Sensor Connector

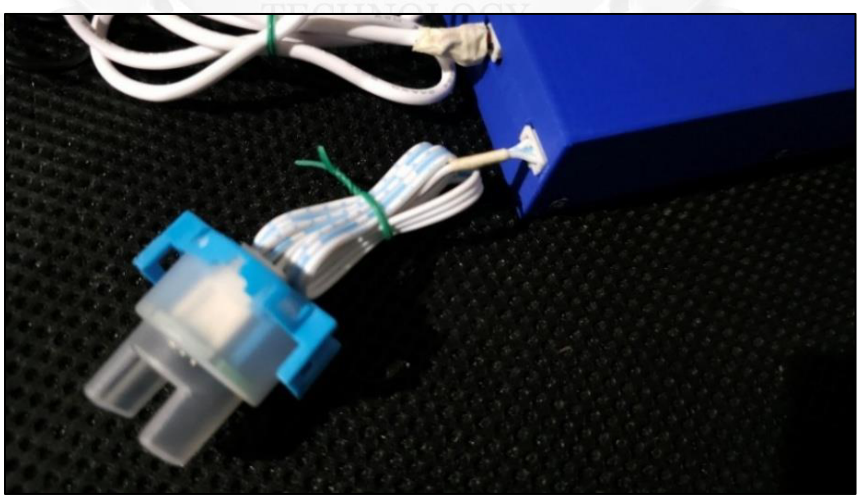
The user must insert the turbidity sensor 3-pin connector into the HydroSense 3-pin port, ensuring a secure and proper fit. The port is located at the top of the device, just above the logo, making it easy to locate. Screenshot 9 in the manual provides a visual guide to help identify the correct port for the connection. This step ensures the turbidity sensor is properly connected for reliable water quality readings.

Screenshot 9. HydroSense 3-pin Port.

A. HydroSense 3-pin Connector – It is where the Turbidity sensor 3-pin connector is to be attached to.

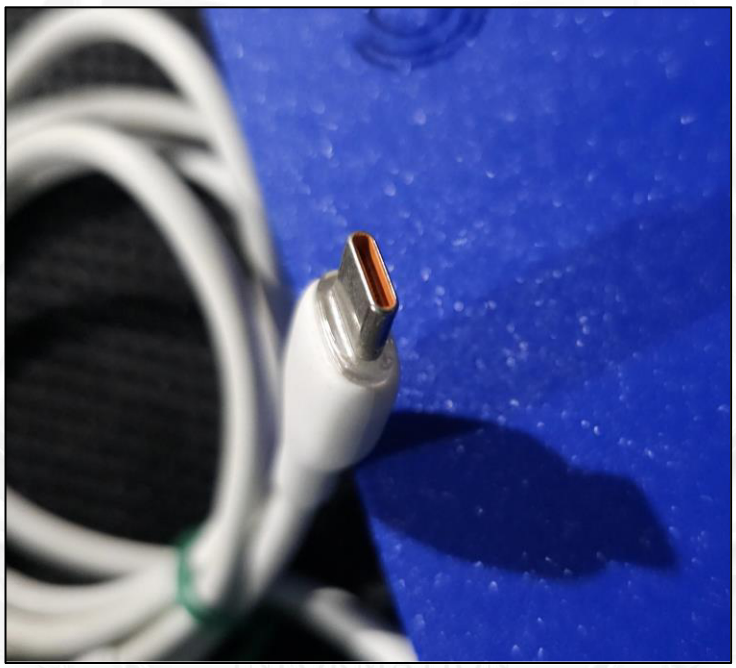
4.2 Insert the Turbidity Sensor 3-pin Connector

The user must push the turbidity sensor 3-pin connector firmly into the HydroSense port until it locks securely in place. This ensures a stable and reliable connection for accurate sensor functionality. Once connected, the turbidity sensor is ready to measure water clarity. Screenshot 10 in the manual illustrates the correctly connected turbidity sensor for reference.


Screenshot 10. Connected Turbidity Sensor.

5. Power the Device

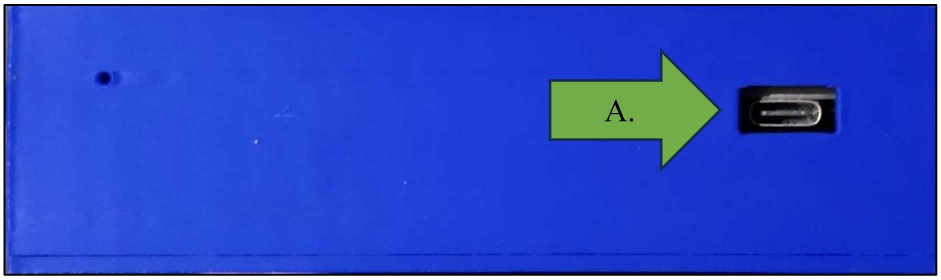
To power HydroSense, connect the USB Type-C cable to its corresponding port on the device. Ensure the cable is properly aligned for a secure fit. Screenshot 11 in the manual provides a visual reference for identifying the USB Type-C cable. This step prepares the device for operation by supplying it with the necessary power.



Screenshot 11. USB Type-C Cable.

5.1 Identify the USB Type-C Port

Insert the USB Type-C cable into the HydroSense USB Type-C port, ensuring a snug and secure connection. The port is conveniently located on the bottom side of the device for easy access. Screenshot 12 in the manual provides a clear visual guide to help identify the correct port for the cable. This step is essential for powering the device and enabling its functionality.

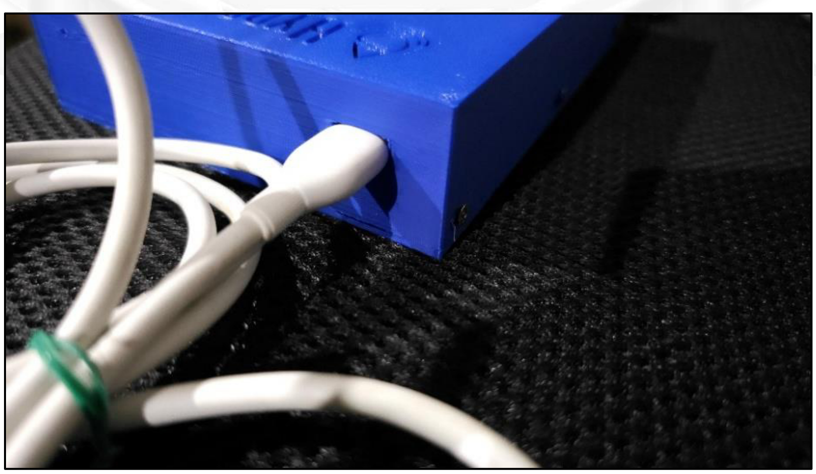


Screenshot 12. HydroSense USB Type-C Port.

A. HydroSense USB Type-C Port – It is where the USB Type-C cable is to be attached to.

5.2 Insert the USB Type-C cable

Push the USB Type-C cable firmly into the HydroSense port until it locks securely in place, ensuring a stable connection. This step is crucial to providing a reliable power supply to the device. Once connected, HydroSense is ready to be powered and used. Screenshot 13 in the manual illustrates the properly connected USB Type-C cable for reference.


Screenshot 13. Connected USB Type-C Cable.

5.3 Power HydroSense using a Power Bank

Users power HydroSense using a power bank that supplies five volts and 2.1 amps for optimal performance. Simply connect the other end of the USB Type-C cable to the power bank output port. This portable power option allows HydroSense to function without being tethered to a fixed power source. Screenshot 14 in the manual shows an example of the device connected to a power bank for reference.

Screenshot 14. HydroSense Connected to a Power Bank.

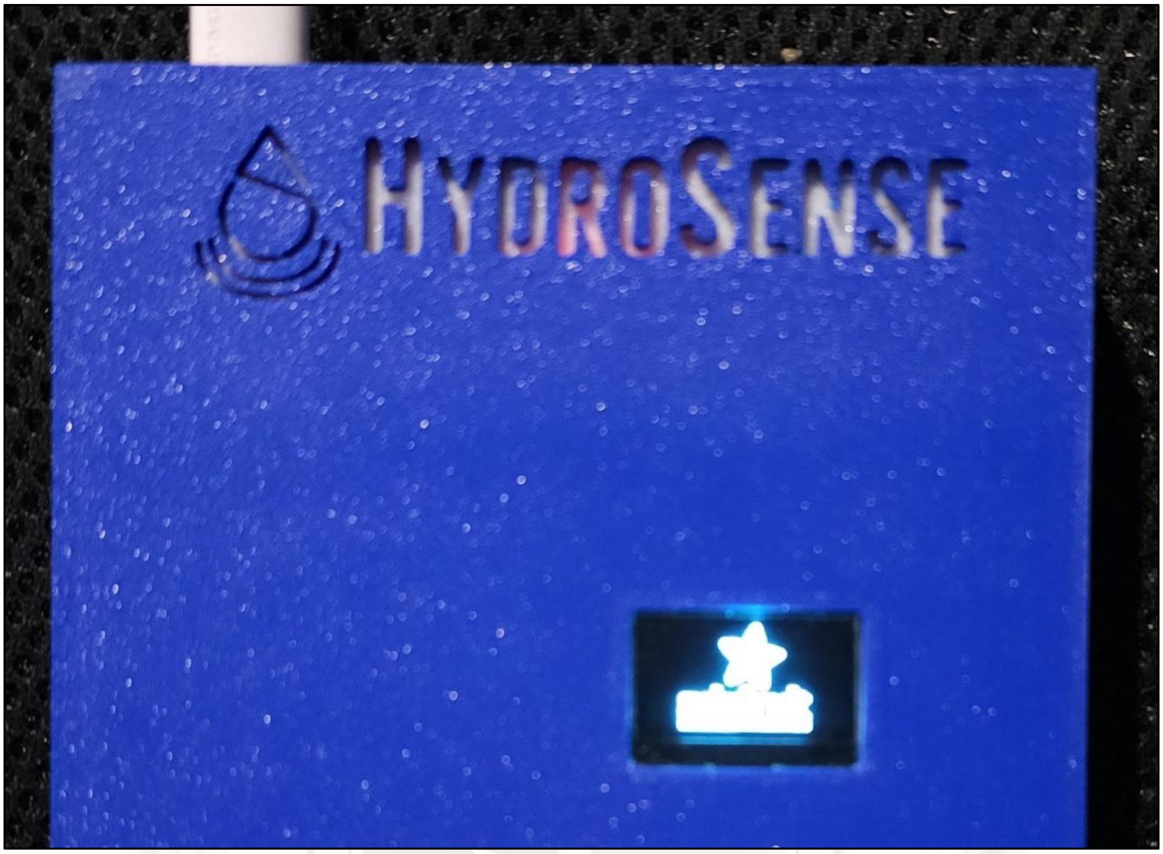
5.4 Power HydroSense using a Phone Charger

Users power HydroSense using a phone charger that provides 5 volts and 2.1 amps, ensuring the device receives adequate power. Connect the other end of the USB Type-C cable to the charger output port. This method offers a convenient way to power HydroSense using a standard phone charging adapter. Screenshot 15 in the manual illustrates the connection between HydroSense and a phone charger.

Screenshot 15. HydroSense Connected to a Phone Charger.

5.5 HydroSense Power On State

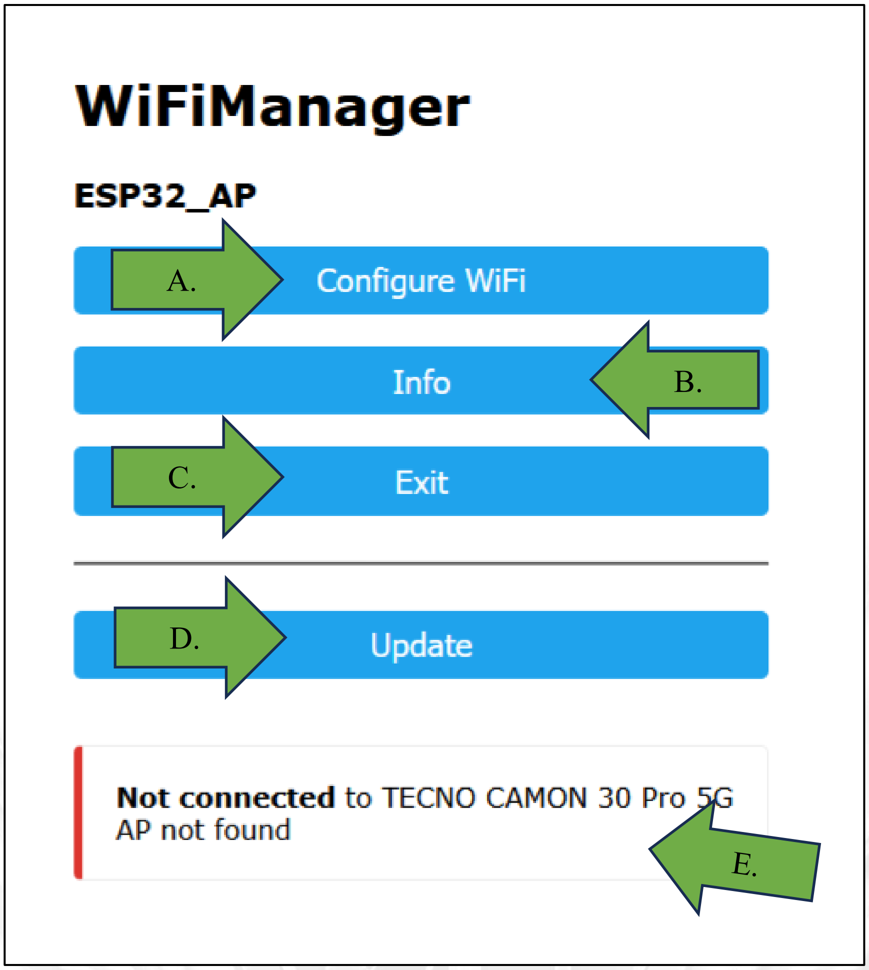
When HydroSense is powered by either a power bank or a phone charger, the device activates, and the OLED screen lights up. Additionally, a red LED illuminates the HydroSense logo, indicating that the device is operational. This visual confirmation helps users know the device is receiving power and is ready for use. The illuminated OLED screen also displays system status information, ensuring users monitor functionality at a glance. This combination of visual cues enhances user confidence during operation. Screenshot 16 in the manual shows HydroSense in its powered-on state.



Screenshot 16. HydroSense Power On State.

6. Interface to HydroSense

With HydroSense turned on, the user connects to the device Wi-Fi access point named "ESP32_AP" to access the WiFiManager. After connecting, they open a web browser and navigate to “192.168.4.1” to access the WiFiManager interface. This interface provides options for configuring the device Wi-Fi settings and other functionalities. Screenshot 17 in the manual illustrates the WiFiManager interface users encounter. Once connected, the user ensures the device is properly linked to their local network for seamless operation.



Screenshot 17. WiFiManager Interface.

A. Configure Wi-Fi Button – It opens a menu to see available Wi-Fi connections.

B. Info Button – It shows information regarding the internals of the device, used for debugging.

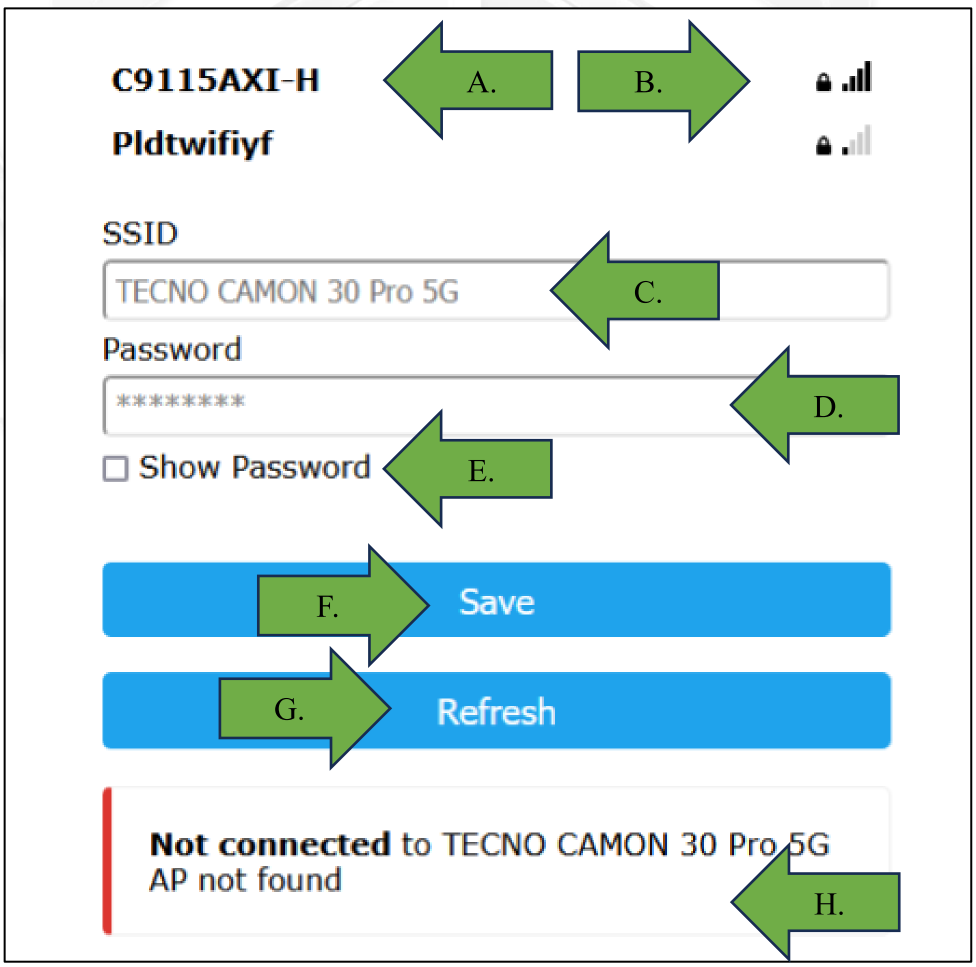
C. Exit Button – It exits the WiFIManager.

D. Update Button – A button that is used to update the firmware of HydroSense.

E. Wi-Fi Connection Feedback – It gives feedback if the previously connected Wi-Fi is not found.

6.1 Choose a Wi-Fi Connection

When the Configure Wi-Fi button is pressed in the WiFiManager, the user is directed to a screen displaying available Wi-Fi networks within range. This interface also shows the signal strength of each network, helping users choose the most reliable connection. Screenshot 18 in the manual provides a visual reference for this step, making it easy to navigate. Selecting a network and entering the credentials allows HydroSense to connect to the preferred Wi-Fi.



Screenshot 18. Choose a Wi-Fi Interface.

A. Available Wi-Fi Names – The user sees the available Wi-Fi and click it to copy the name to the SSID text field in C.

B. Wi-Fi Signal Indicator – Indicates the Wi-Fi signal strength.

C. SSID Text Field – The user types the name of the Wi-Fi they want to connect.

D. Password Text Field – The user puts the password of the Wi-Fi that corresponds to the SSID or Wi-Fi name.

E. Show Password Tick box – When ticked, the password typed is not obfuscated.

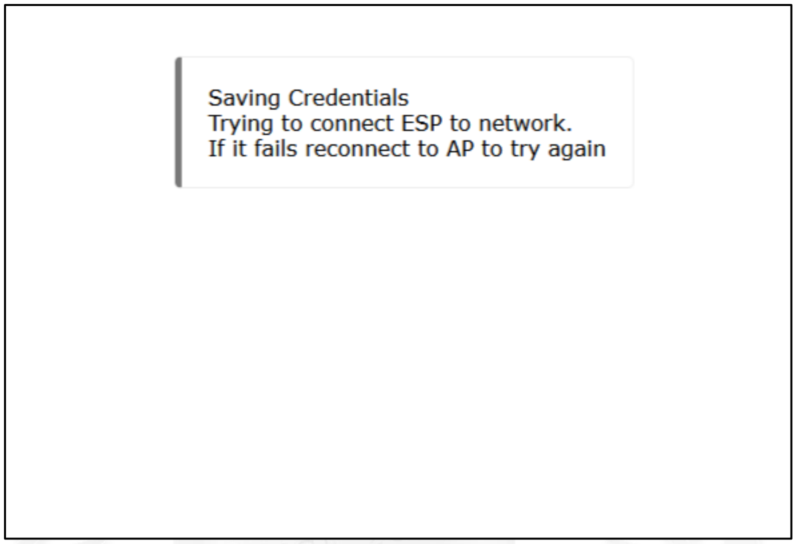
F. Save Button – When pressed, the Wi-Fi credentials are saved to HydroSense.

G. Refresh Button – Refreshed the Wi-Fi list in case new Wi-Fi connections is created.

H. Wi-Fi Connection Feedback – It gives feedback if the previously connected Wi-Fi is not found.

6.2 HydroSense Connecting to Wi-Fi Interface

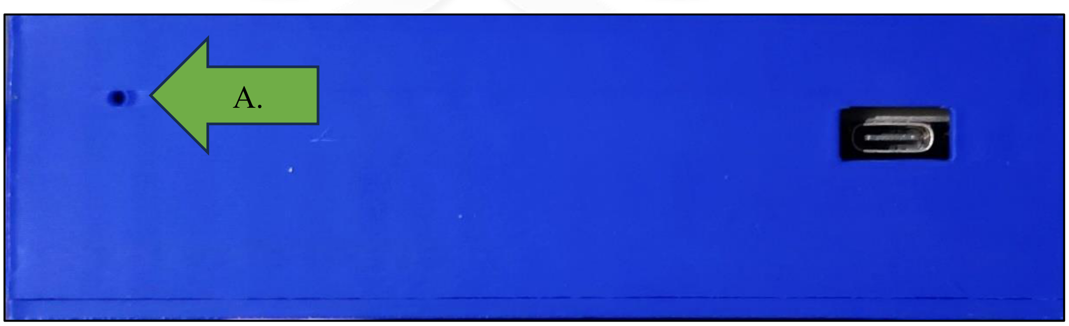
When the save button is clicked, HydroSense begins attempting to connect to the Wi-Fi network using the credentials provided in the "Choose a Wi-Fi Connection" step. The device initiates the connection process and provides feedback on the progress through the application interface. Screenshot 19 in the manual illustrates this stage, giving users a clear idea of what to expect. A successful connection ensures HydroSense is ready for full functionality. If the connection fails, users are prompted to verify their credentials and try again. For further troubleshooting, consult the "Wi-Fi Connection Issues" section in the manual.



Screenshot 19. HydroSense Attempts to Connect to Wi-Fi.

6.3 Locate the Reboot Pinhole

After HydroSense attempts to connect to Wi-Fi, the device needs to be reset to finalize the setup process. The reset button is located on the left side of the USB Type-C port and is accessible through a small pinhole. Users use a pin or similar tool to press the button and reset the device. Screenshot 20 in the manual highlights the exact location of the reset pinhole for easy identification.

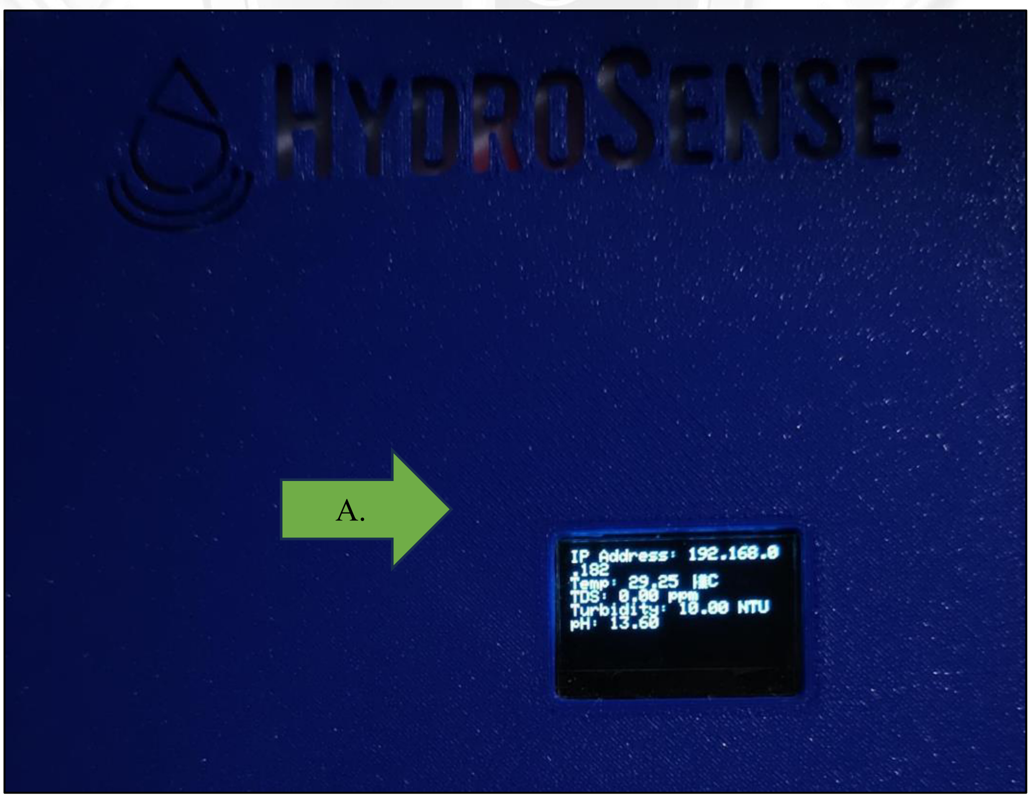


Screenshot 20. Reboot Pinhole Location.

A. Reset Pinhole – A hole where the user put a pin to press the reboot button to reboot HydroSense.

6.4 HydroSense Ready State

Pressing the reset button prompts HydroSense to reconnect to the Wi-Fi network using the saved credentials. Once connected, the device displays the application IP address along with real-time sensor data on the screen. This information allows users to access the HydroSense interface and monitor water quality data. Screenshot 21 in the manual provides a visual example of the displayed information.

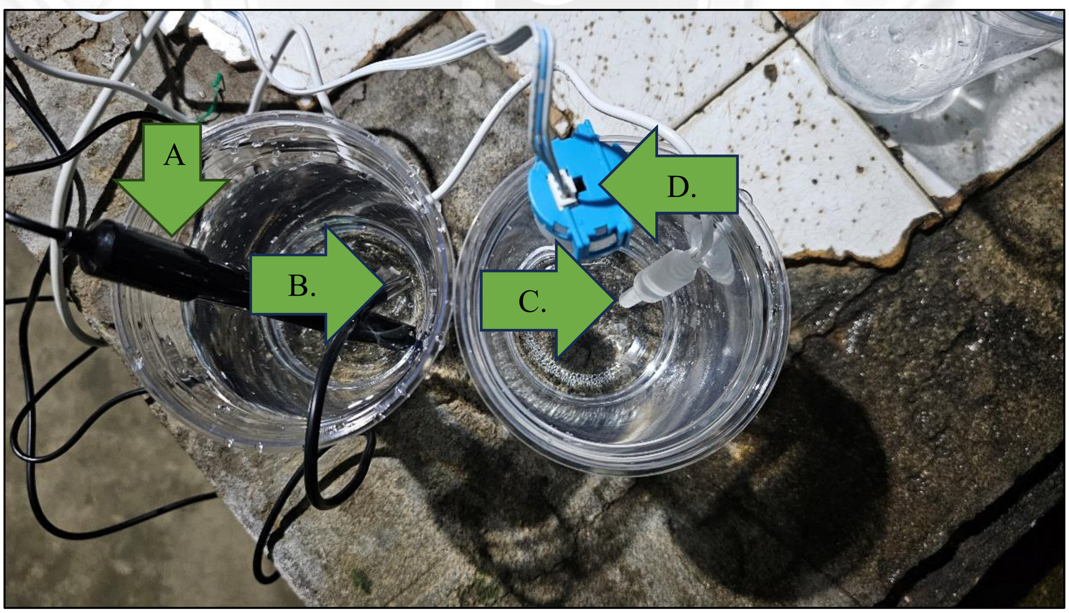


Screenshot 21. Data Displayed in HydroSense Screen.

A. HydroSense Screen – Shows the IP address as well as sensor data.

6.5 Subject the Sensor to Water

The user prepares 2 containers containing the water the user wants to measure. The user then subjects the four sensors to the water. The water temperature sensor and the pH sensor go on the first container while the TDS and turbidity sensor go on the other container while minding that the turbidity sensor is not waterproof from the above and therefore must only be subjected halfway in the water. Screenshot 22 shows how the sensors are separated.



Screenshot 22. Subject the Sensor to Water.

A. Water Temperature Sensor – This sensor measures the water temperature.

B. pH Sensor – This sensor measures the pH of the water.

C. TDS Sensor – This sensor measures the total dissolved solids of the water.

D. Turbidity Sensor – This sensor measures how clear the water.

6.6 Access the HydroSense Application

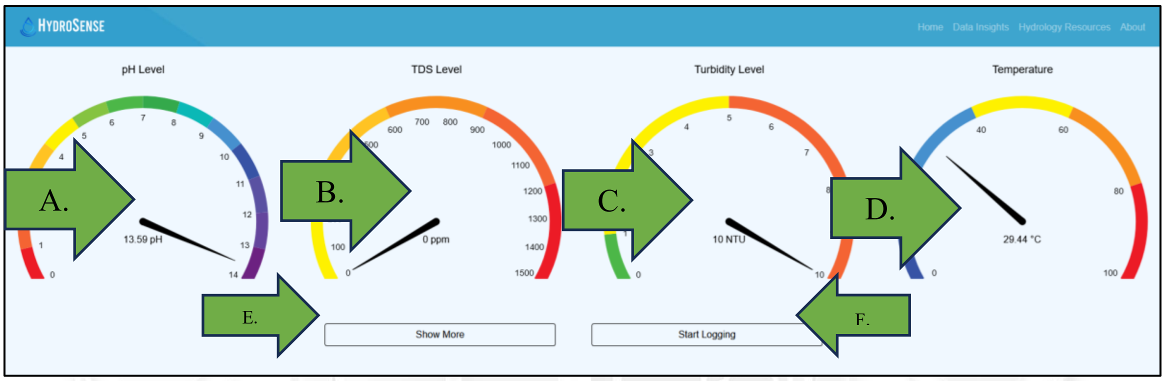
To access HydroSense, the user must connect their device to the same Wi-Fi network as HydroSense. They then copy the IP address displayed on the HydroSense screen into their browser. This action opens the HydroSense homepage, which provides an interface for monitoring water quality and navigating its features. Screenshot 23 in the manual illustrates the appearance of the homepage once accessed.

Screenshot 23. Accessed HydroSense Homepage.

7. Homepage Interface

The HydroSense homepage interface displays real-time measurements of water quality parameters using four gauges: pH Level, TDS Level, Turbidity Level, and

Temperature. These gauges provide a clear and immediate overview of water conditions. Below the gauges, users find the Show More button for additional details and recommendations, and the Start Logging button to initiate data logging. Screenshot 24 in the manual visually represents the layout of the homepage.



Screenshot 24. HydroSense Homepage.

A. pH Level Gauge – This gauge indicates the acidity or alkalinity of the water.

B. TDS Level Gauge – This gauge reflects the concentration of dissolved particles in the water

C. Turbidity Level Gauge – This gauge indicates the water clarity or cloudiness.

D. Water Temperature Gauge – This gauge shows the water current temperature.

E. Show More Button – When clicked, reveals additional recommendations and health risk.

F. Start Logging Button – When clicked, allows the user to initialize data logging.

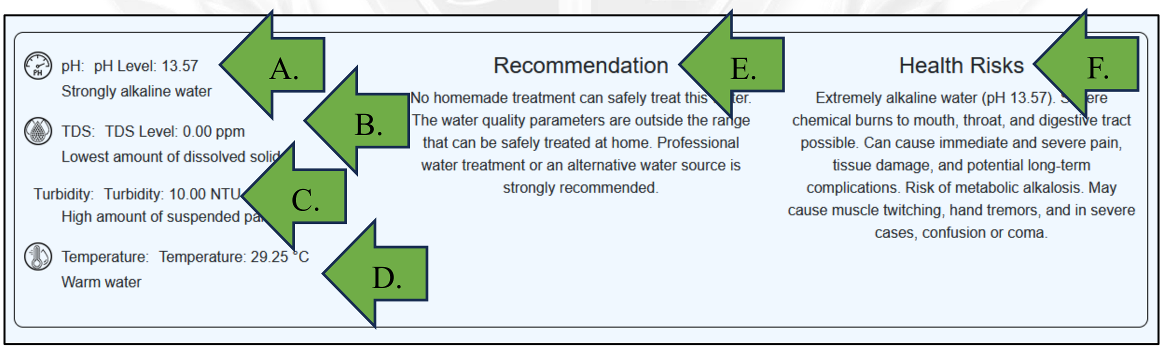
8. HydroSense Navigation Bar Interface

The Navigation Bar provides users with quick and convenient access to various sections of the HydroSense interface. It allows seamless traversal between the Home Page, Data Insights Page, Hydrology Resources Page, and About Page. Screenshot 25 in the manual illustrates the layout of the Navigation Bar for reference.

Screenshot 25. Navigation Bar Interface.

9. Recommendation and Health Risks Interface

Click the Show More button expands the interface to reveal detailed information about the water quality parameters. This includes recommendations for improving water safety and an assessment of associated health risks. The expanded view provides users with actionable insights and educational content based on the analyzed data. Screenshot 26 in the manual illustrates this detailed interface.



Screenshot 26. Health Risk Interface.

A. pH Level Summary – This part provides a brief summary of the pH Level.

B. TDS Level Summary – This part provides a brief summary of the TDS Level.

C. Turbidity Summary – This part provides a brief summary of the Turbidity.

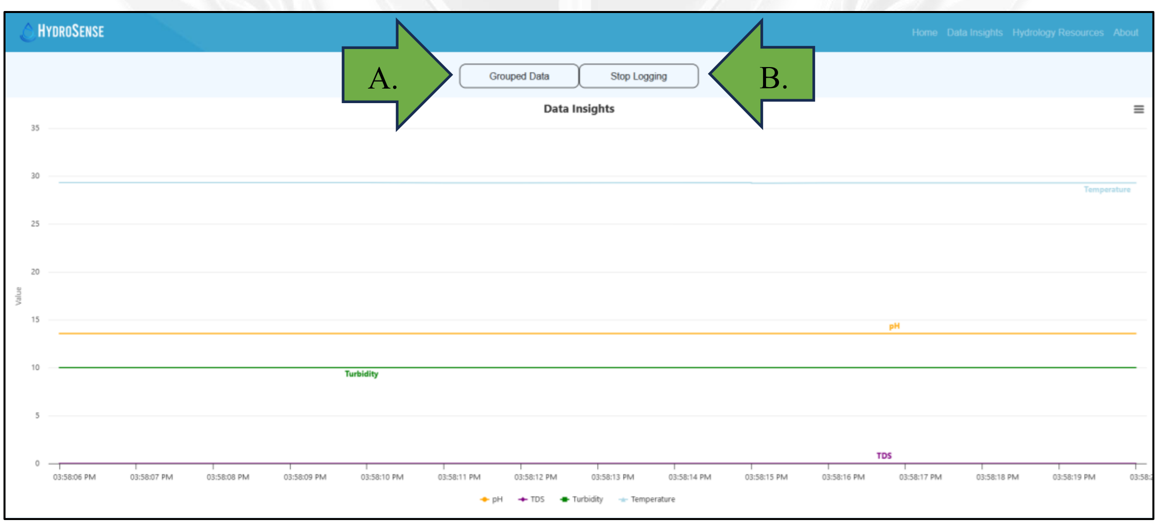
D. Water Temperature Summary – This part provides a brief summary of the Water Temperature.

E. Recommendation Assessment – This part provides users with actionable guidance based on the analyzed water quality parameters.

F. Health Risk Assessment – This part educates users about the potential dangers of consuming water with the current quality parameters.

10. Live Data Interface

When the Start Logging button is activated, the user is redirected to the Live Data Interface, where real-time sensor data is displayed. The data is plotted on graphs, updating every second to provide a live view of water quality metrics. Screenshot 27 in the manual illustrates the layout and functionality of the Live Data Interface.



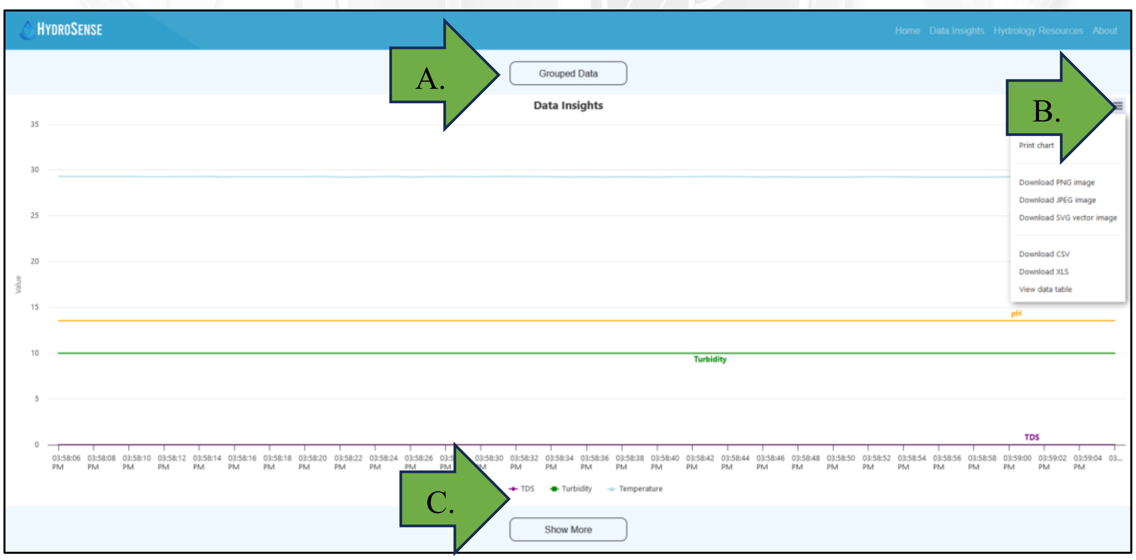
Screenshot 27. Live Data Interface.

A. Grouped Data Button – This button separates the four data streams into separate graphs.

B. Stop Logging Button – This button stops data logging and saves the data to memory.

11. Data Insights Interface

Press the Stop Logging button redirects the user to the Data Insights Interface, where all logged data is displayed. This interface allows users to review the recorded water quality measurements collected during the logging session. The organized presentation helps users analyze trends and patterns effectively. Screenshot 28 in the manual illustrates the appearance and functionality of the Data Insights Interface.



Screenshot 28. Data Insights Interface.

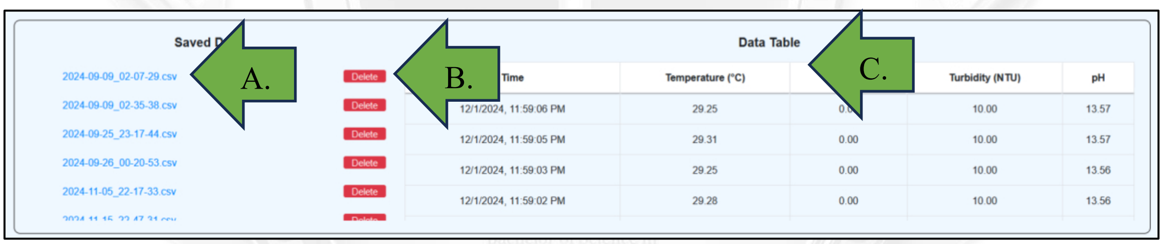
A. Grouped Data Button – This button separates the four sensor data into separate graphs.

B. Hamburger Menu Button – This button drops a menu that gives different options for saving the data to the users' own device.

C. Show More Button – This button reveals the previous saved data files as well as the showing each sensor data tick on a table of the currently opened save file.

12. Saved Data Interface

This interface displays the Saved Data and a corresponding Data Table for previously recorded water quality measurements. On the left, the Saved Data section lists filenames of CSV files containing logged data, allowing users to download these files for offline analysis. Each entry is accompanied by a Delete button, enabling users to remove unwanted records from the storage. On the right, the Data Table presents a detailed view of the logged water quality data including the timestamp. Screenshot 29 shows this.



Screenshot 29. Saved Data Interface.

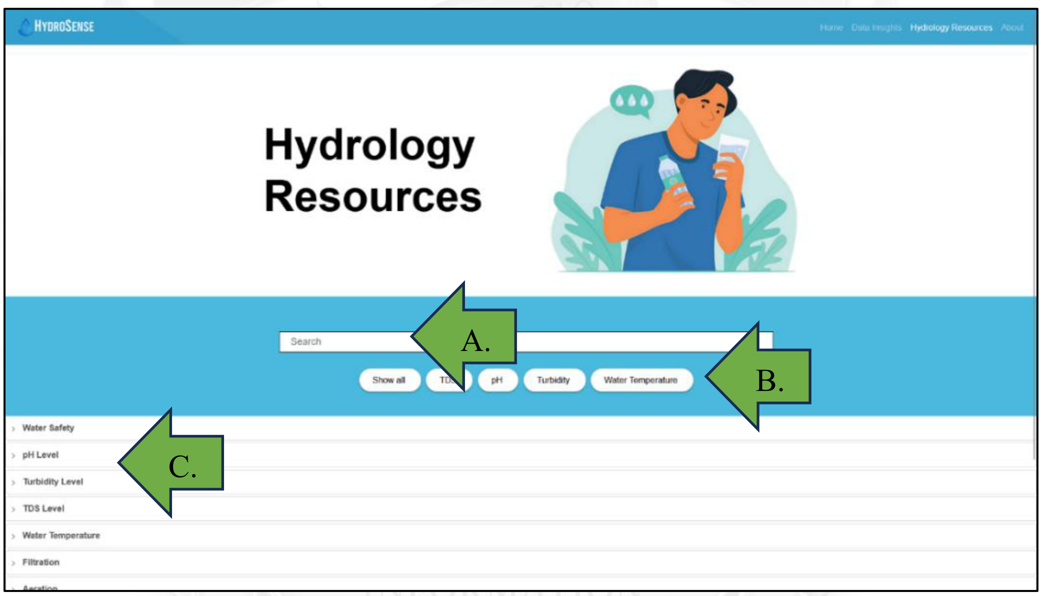
A. File Hyperlinks – When clicked directs the user to view that specific file to the Data Insights Interface.

B. Delete Button – This button deletes the file in line with the button.

C. Data Table – The table shows all the datapoints in the opened CSV file.

13. Hydrology Resources Interface

The Hydrology Resources Interface offers users educational and practical information on water quality and treatment. Topics are displayed in a list format, allowing users to click on each item to view detailed information in a popup window. This feature makes it easy to access relevant insights and guidance on maintaining and improving water quality. Screenshot 30 in the manual illustrates how the interface presents these resources.



Screenshot 30. Hydrology Resources Interface.

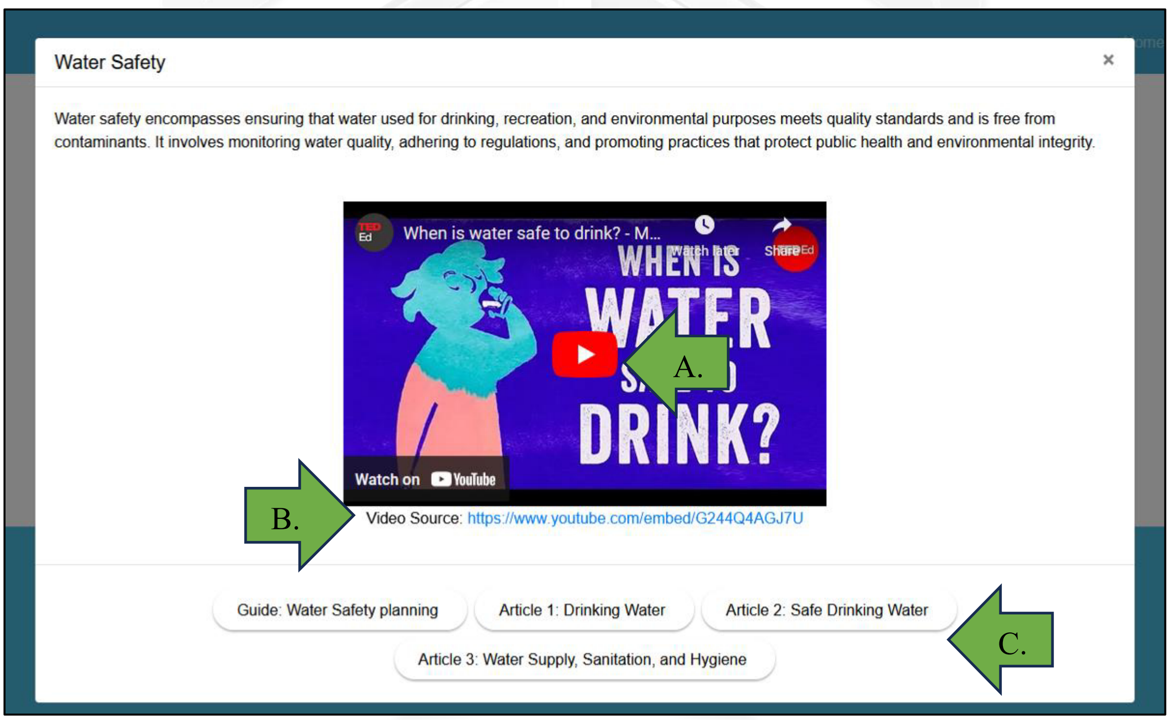
A. Search Bar – The user search words and phrases related to a topic and related topics show at the bottom and non-related topics disappear.

B. Filter Buttons – The user filter specific topics by clicking the button related to the topic chosen.

C. Topic Buttons – The user click the button related to the topic chosen and a popup appear to educate them about the topic.

14. Specific Hydrology Resource Topic Interface

The interface includes an informative description, outlining key aspects related to the topic that is chosen. If a user clicks on “Water Safety,” Screenshot 31 shows key aspects like ensuring water quality for drinking, recreation, and environmental purposes, while emphasizing adherence to standards and practices that safeguard public health and environmental integrity. Additionally, it provides actionable insights and resources to help users maintain and improve water safety.



Screenshot 31. Specific Hydrology Resource Topic Interface.

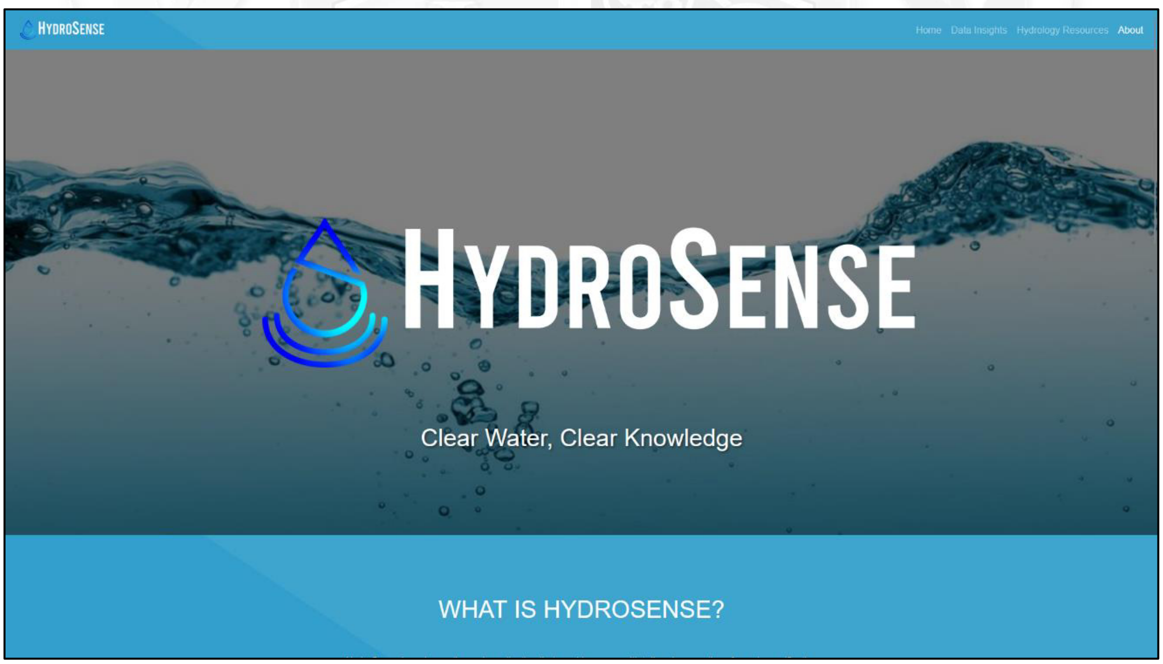
A. Play Button – The video plays if this button is pressed.

B. Video Source Hyperlink – The user click this button to open the source of the video.

C. Articles and Guides Buttons – When clicked, the user redirected to a site that has articles or guides about the topic chosen.

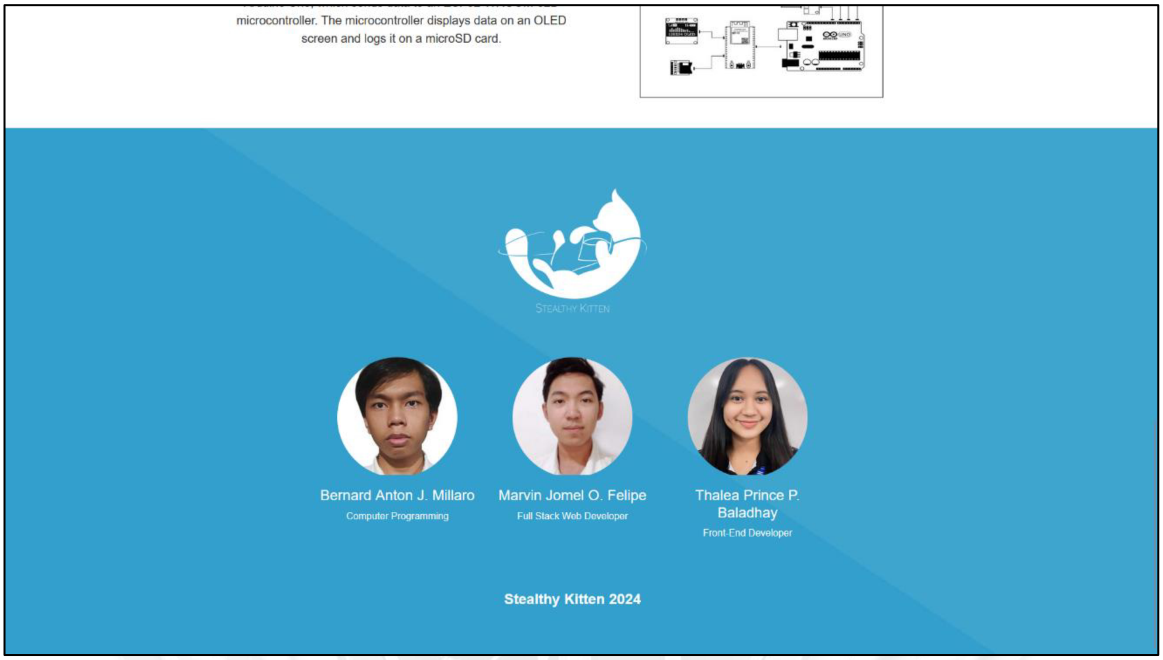
15. About Interface

The About Interface provides users with information about the HydroSense device, including details on its functionality and design. It also highlights insights about the developers and their role in creating the device. Screenshot 32 in the manual illustrates the layout of the About Interface.



Screenshot 32. About Interface.

Additionally, the page highlights the developers, "Stealthy Kitten," showcasing the developers with their respective roles. This section provides a comprehensive overview of HydroSense mission, technological framework, and the developers behind its creation. It reflects the team commitment to innovation and water quality management solutions. Users also gain insights into the inspiration and goals that guided the development of the device. Screenshot 33 shows this page and the developers.



Screenshot 33. Stealthy Kitten.

The HydroSense user manual provides a comprehensive guide for setting up and using the device to monitor water quality. It explains how to connect the sensors, power the device, and access its web application. The interface includes features such as real-time data visualization, historical data logging, and educational resources on water quality. The manual also highlights additional functionalities, such as health risk assessments and developer information, for a complete user experience.

APPENDIX A

Mutual Agreement Form for Co-Authorship

(Adopted from Philippine Association of Institutions for Research (PAIR), Inc.)

WE, the researcher, and research adviser/consultant, have worked together in a capstone project from January 2024 to August 2024.

WE have used various forms of contact during the thesis work such as Microsoft Teams and Facebook.

WE agree that

- the academic partnership leads to publication of the manuscript with the research consultant as the author and the researcher, the primary author.
- the paper be presented in public forum by the researcher if available at such an opportunity or by the research adviser/consultant if the researcher is no longer around.
- only the name of the oral presenter shall be submitted to the Conference organizer.

WE agree to dress formally and prepare adequately for the formal oral presentation in both the oral defense panel and the public presentations.

Signed this 27th of July in the year of our Lord 2024 in Bacolod City, Philippines.

THALEA PRINCE P. BALADHAY
Researcher

ELMER T. HARO, Ph.D.
Adviser

MARVIN JOMEL O. FELIPE
Researcher

REINHARDT D. FIRMEZA, MIT Candidate
Witness

BERNARD ANTON J. MILLARO
Researcher

APPENDIX B

HydroSense Concept Paper.

Project Concept Title	HydroSense		Technical Consultant
Main Proponent	Millaro, Bernard Anton J.		Elmer T. Haro, Ph.D.
Collaborators	Felipe, Marvin Jomel O.	Team name	Consultant's Appointment Status
	Baladhay, Thalea Prince P.	Stealthy Kitten	☒In Agreement ☐To be Approached

Rationale of the Concept Paper

Clean water is essential to life, as hydration is the most basic function of water, necessary to keep the body of a living organism hydrated. It is important to preserve and sustain the availability of water for our bodies that rely on water for digestion, metabolism, transportation of nutrients, and temperature regulation [PM2024]. One of the Sustainable Development Goals (SDGs) is the SDG 6, clean water and sanitation adopted by the United Nations (UN). SDG 6 clean water and sanitation goal is to ensure availability and sustainable management of water sanitation for all and achieve universal and equitable access to safe and affordable drinking water for all. [OD2021]

HydroSense is not just a technological advancement. It is a solution for communities grappling with waterborne diseases due to not having access to clean water. It goes beyond mere detection. It acts as a driving force for data-driven decision-making. It provides legitimate articles and guides about hydrology based on credible sources, offering guidance on how to manage water. These resources serve as references for understanding water and ways to manage it, including purification methods. Through seamless integration, our software – hardware integration application empowers communities to proactively monitor and manage their water resources, mitigating risks and safeguarding public health.

Features and Functions

HydroSense, powered by Arduino and essential sensors, offers real-time water quality monitoring with TDS, turbidity, temperature, and pH data. Its user-friendly web app provides actionable insights, purification recommendations, and hydrology resources for effective water management.

1. Contaminant Detection
   HydroSense's sensors for TDS, turbidity, temperature, and pH provide real-time water quality data, enabling accurate assessment of harmful substances. This empowers users with tailored purification recommendations, ensuring clean water access and proactive quality management.

2. Data Visualization
   HydroSense visualizes water quality through real-time graphs and historical trends for TDS, turbidity, temperature, and pH. Users can view current values, track changes over time, and download data in CSV format for analysis or sharing, enhancing water quality monitoring and management.

3. Water Quality Recommendation HydroSense's recommendation system analyzes sensor data to provide tailored water purification advice, helping users address contaminants effectively and maintain access to clean water. 4. Hydrology Resources HydroSense offers resources on water quality, safety, and purification, featuring guides on monitoring, health impacts of contaminants, and best practices. Content from trusted sources like WHO and CDC ensures accuracy and relevance.
Technical Requirements
Arduino TDS sensor pH sensor Turbidity sensor Water temperature sensor Bluetooth or Wi-Fi for wireless data transfer Database for storing data of the sensors Real-time graphing of data framework
Project Usability / Justification of Benefits
Enable users to monitor TDS in water in real-time for early detection of pollution or contaminants. A tool for users to ensure safety in their water supply or sources
Anticipated Challenges
Calibrating TDS Data transmission security between devices
References
https://www.aquasana.com/info/tds-meter-what-is-it-and-do-you-need-it-pd.html

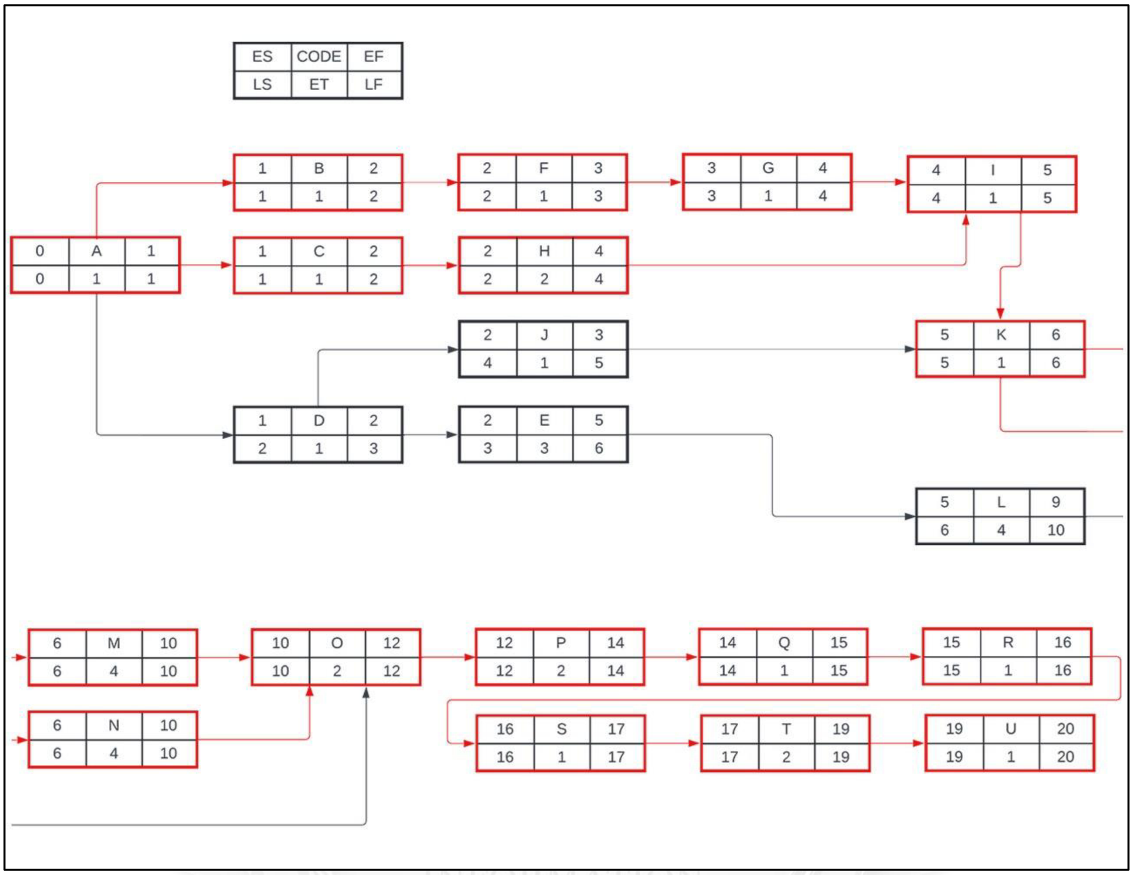
APPENDIX C

PERT Table.

CODE	ACTIVITIES	PREDECESSOR	DURATION (in week/s)
A	Identify the project requirements	-	1
B	Identify projects scope	A	1
C	Identify projects target users	A	1
D	Identify projects hardware and software specification	A	1
E	Procure hardware components	D	3
F	Search for related apps	B	1
G	Analysis of existing similar apps	F	1
H	Conduct an interview	C	2
I	Analyze gathered data	G, H	1
J	Make a draft of the web pages	D	1
K	Evaluate the functionalities and design	J, I	1
L	Develop hardware prototype	E	4
M	Website front-end coding	K	4
N	Website backend coding	K	4
O	Finalize hardware project	L, M, N	2
P	Integration of Web and Hardware	O	2
Q	Recognize and fix errors	P	1
R	Test execution	Q	1
S	User acceptance testing	R	1
T	Recognize and fix errors	S	2
U	General Release	T	1

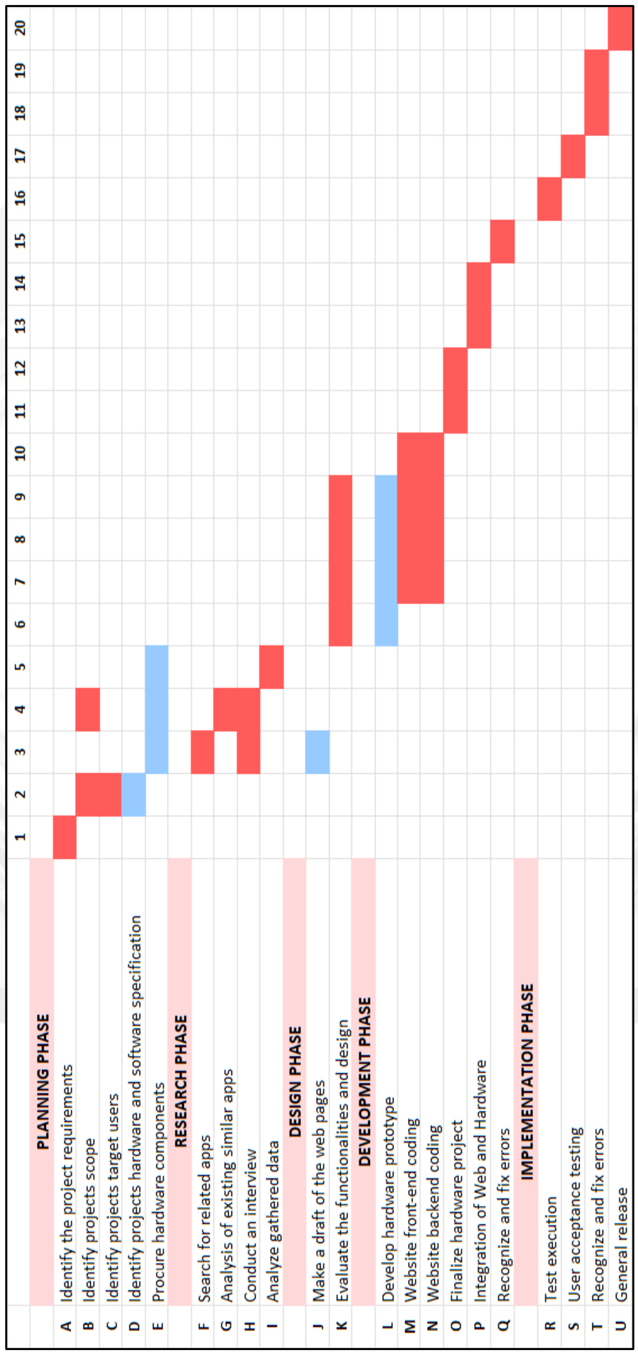
APPENDIX D

PERT Diagram.



APPENDIX E

Gantt Chart.



APPENDIX F

Project Cost.

Project Cost		
Hardware Cost	Product	Price
	Arduino ESP32-WROOM-32D	₱ 179.00
	OLED Screen 0.96in	₱ 78.00
	Temp Sensor 1SET	₱ 91.00
	Turbidity Sensor	₱ 314.00
	pH 0-14 module	₱ 459.00
	ESP32 Adapter 38P	₱ 90.00
	Micro SD Card storage module	₱ 23.00
	Dupont Jumper Wire	₱ 116.00
	TDS Sensor	₱ 226.00
Total Hardware Cost:		₱ 1,576.00
Operation Cost	Product	Price
	3D Printer	₱ 2,100.00
	Filaments	₱ 2,800.00
Total Operation Cost:		₱ 4,900.00
Total Project Cost:		₱ 6,476.00

APPENDIX G

Minutes of the Capstone Project Proposal Defense.

May 31, 2024 | 6:30 pm – 8:00 pm
College of Information Technology
University of Negros Occidental – Recoletos

Project Proposal Title	HydroSense
Group Members	Thalea Prince Baladhay Marvin Jomel Felipe Bernard Anton Millaro
Panel Members	Reinhardt D. Firmeza Elmer T. Haro, Ph.D. Reymund L. Sabay
Interpellators	Kristian Franco Christian Javier Alfie Mondia

1. The conference started with a prayer led by Marvin Felipe.
2. The group members were introduced by Marvin Felipe.
3. The oral presentation was delivered by Thalea Prince Baladhay, Marvin Jomel Felipe and Bernard Anton Millaro.
4. After the presentation, the following are the suggestions, recommendations of the interpellators and the panel members:

Chapter/Section	Recommendations/ Suggestion	Proponent	Action Taken	Reference / Proof
System Features and Functionalities	Issues in storage limitation	Reinhardt D. Firmeza	Added to recommendations	Hardware
Product Prototype/Interface	Overly loaded System	Reinhardt D. Firmeza	Revised the interface for the overly loaded system.	Page 63
	Methods and legends on reports	Elmer T. Haro	Added to the interface in data insights	Page 64

	Issues on the layout of the interface	Alfie Mondia	Change the layout of the interface	Page 63 to Page 70
References	Consult experts on water quality	Reymund L. Sabay	Added to recommendations	
	Availability of the websites for user		Added to the hydrological resources	Page 67

5. After the deliberation of the interpellators and panel members, the proposal is considered accepted with revisions in the documentation and in the prototype.

6. The conference ended 8:10 PM.

Transcribed by : Thalea Prince P. Baladhay

Noted by : Elmer T. Haro, Ph.D.

APPENDIX H

Product Logo.

The proponents choose the colors and elements, which have an interpretation that reflects the application purpose. Each color symbolizes the application values and interests, as well as to draw attention of users and be more recognizable. Blue gradient emphasizes the water and cleanliness, as blue recognizes security and creativity since it produces a slow physiological response. However, interpretations of blue can be paradoxical, as it's also associated with calmness and serenity due to its connection with bodies of water.

The logo of the application incorporates various elements and illustrations, each symbolizing a key aspect of the project's purpose. The water droplet shape is designed to resemble the letter "S," emphasizing the "sense" in HydroSense product. Additionally, the two radio waves at the bottom interpret the product's connectivity and communication capabilities, illustrating its seamless data gathering and transmission functionalities.

APPENDIX I

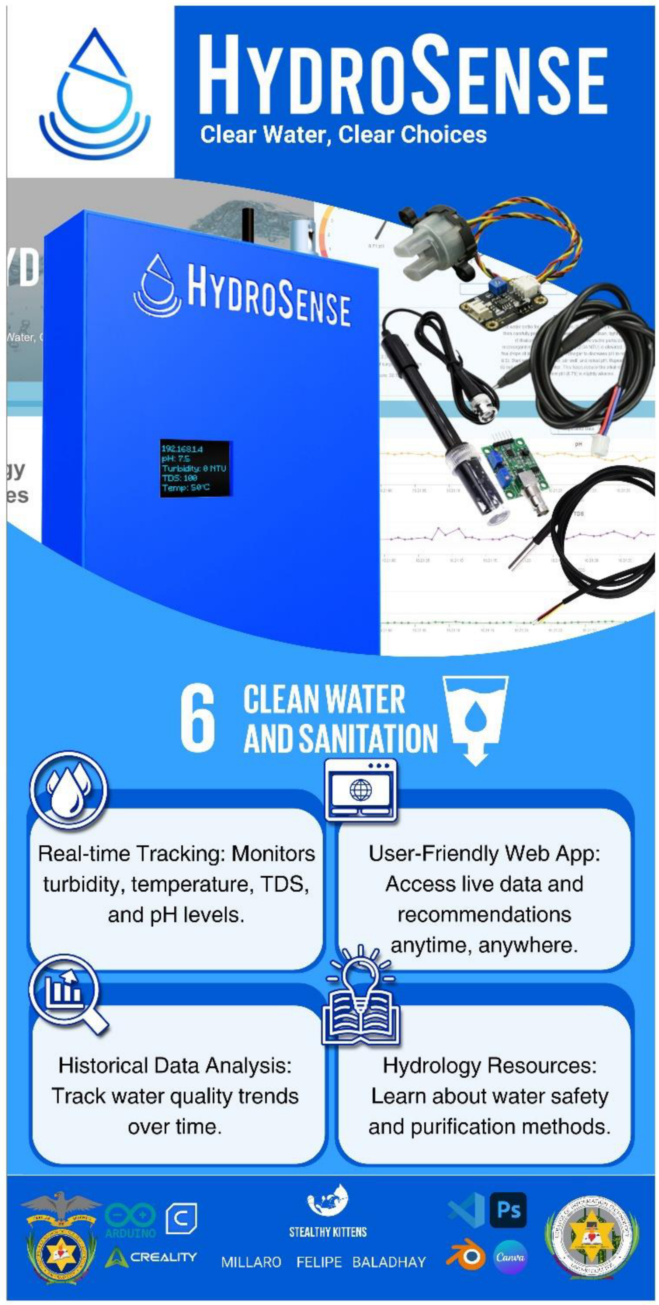
Group Logo.

STEALTHY KITTEN

The colors and elements that comprise the team's logo indicate their characteristics and expertise. The grey gradient symbolized formality and sophistication with elegance and simplicity. The team's mascot, a kitten, represents playfulness and the importance of learning through play to develop adult skills.

APPENDIX J

Product Poster.

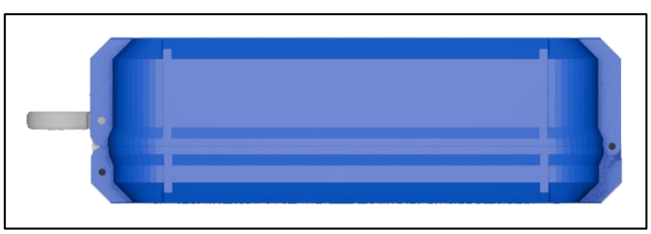


APPENDIX K

Product Packaging.

Front

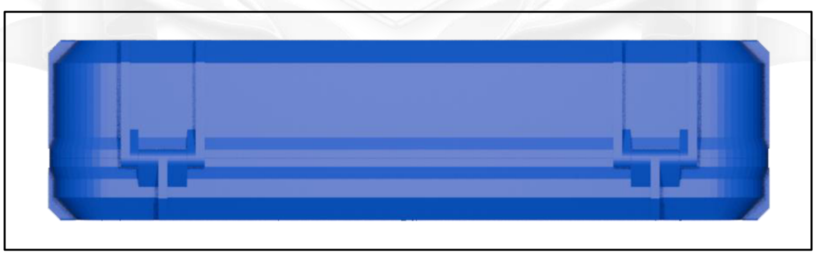
Side (right and left)



Back

Top Side

Bottom



APPENDIX L

Minutes of the Capstone Project Final Defense.

August 8, 2024 | 4:30 pm – 6:30 pm
College of Information Technology
University of Negros Occidental – Recoletos

Project Proposal Title	HydroSense
Group Members	Thalea Prince Baladhay Marvin Jomel Felipe Bernard Anton Millaro
Panel Members	Reinhardt D. Firmeza Elmer T. Haro, Ph.D. Reymund L. Sabay
Interpellators	Alexander Nicole Bravo Christian Javier Alijah Mckale Rodis

1. The conference started with a prayer led by Marvin Felipe.
2. The group members were introduced by Marvin Felipe.
3. The oral presentation was delivered by Thalea Prince Baladhay, Marvin Jomel Felipe and Bernard Anton Millaro.
4. After the presentation, the following are the suggestions, recommendations of the interpellators and the panel members:

Chapter/Section	Recommendations/ Suggestion	Proponent	Action Taken	Reference / Proof
Title and Front Matters				
Introduction and System Decomposition	Technical details of the hardware in simplified version	Alijah Mckale V. Rodis	Simplified technical details of the hardware ensure easy understanding and accessibility for users.	Page 20
Product Prototype/Interface	Improve the case of sensors	Christian Javier	The sensor casing was improved for enhanced durability and protection.	Hardware
	Adjust the size and design of the hardware	Alexander Nicole Bravo	The hardware was resized and redesigned for	Hardware

			improved usability and portability.	
	Hydrology Resources properly cited	Reinhardt D. Firmeza	Properly cited hydrology resources ensure credibility and accuracy of the provided information.	Page 67
	Reports and recommendations	Reymund L. Sabay	Reports and recommendations provide users with clear insights and actionable steps for improving water quality.	Page 63
	Presentations of graphs	Alijah Mckale V. Rodis	Graphs are presented in an intuitive format, enabling easy interpretation of water quality data.	Page 64, Page 65
Appendices	Improve the promotional video and product packaging	Elmer T. Haro, Ph.D.	Enhancements were made to the promotional video and product packaging to better showcase features and attract users.	Page 172, Page 173
References	Ensure that the citation is properly specified in the references section	Reinhardt D. Firmeza	Rephrased the sentence for clarity and grammatical correctness.	Page 203

5. After the deliberation of the interpellators and panel members, the proposal is considered accepted with revisions in the documentation and in the prototype.

6. The conference ended 6:00 PM.

Transcribed by : Thalea Prince P. Baladhay

Noted by : Elmer T. Haro, Ph.D.

APPENDIX M

Internal Quality Measurement Results in Software.

Hydrology Resources	
Understandability	
X = A / B A = Number of UI functions whose purpose is understood by user. B = Total number of interface functions.	
Functions	Status
View Hydrology Resources Topics	Understood
View Hydrology Resources Articles	Understood
View Hydrology Resources Guides	Understood
View Hydrology Resources Video	Understood
Search Bar	Understood
Topic Sorting	Understood
Start Logging button	Not Understood
Computations (6 / 7) * 100 = 85.71%	
TOTAL	85.71%
Learnability	
X = 1 - A / B A = Number of incomplete help topics. B = Total number of help topics.	
Functions	Status
View Hydrology Resources Articles	Help Topics Available
View Hydrology Resources Guides	Help Topics Available
View Hydrology Resources Videos	Help Topics Available
Computations (3 / 3) * 100 = 100.00%	
TOTAL	100.00%
Operability	
X = A / B A = Number of customizable functions. B = Total number of functions requiring customization.	
Functions	Status
Customizable Search Filters	Completed

Computations (1 / 1) * 100 = 100.00%	
TOTAL	100.00%
Attractiveness	
X = A / B A = Number of customized interface elements. B = Total number of interface elements.	
Functions	Status
Responsive Web Interface	Implemented
Cohesive Color Scheme	Implemented
Custom Icons and Graphics	Implemented
Computations (3 / 3) * 100 = 100.00%	
TOTAL	100.00%
ISO/IEC-9126 Compliance	
X = A / B A = Number of correctly implemented compliance items. B = Total number of compliance items.	
Functions	Status
Compliance with WHO Content Standards	Implemented Correctly
Compliance with FDA Content Standards	Implemented Correctly
Compliance with CDC Content Standards	Implemented Correctly
Regularly Updated Content	Delayed
Computations (3 / 4) * 100 = 75.00%	
TOTAL	75.00%

Contaminant Detection	
Accuracy	
X = 1 - A / B A = Number of data items with incorrect precision. B = Total number of data items requiring precision.	
Functions	Status
Water pH Level Detection	Accurate
Water TDS Level Detection	Accurate
Water Turbidity Level Detection	Accurate
Water Temperature Level Detection	Accurate
Computations	

(4 / 4) * 100 = 100.00%	
TOTAL	100.00%
Interoperability	
X = A / B A = Number of correctly implemented data formats. B = Total number of required data formats.	
Functions	Status
JSON Data Format Compatibility	Implemented
HTTP Communication	Implemented
CSV format in saving data	
Computations (3 / 3) * 100 = 100.00%	
TOTAL	100.00%
ISO/IEC-9126 Compliance	
X = A / B A = Number of correctly implemented compliance items. B = Total number of compliance items.	
Functions	Status
Intuitive User Interface	Implemented Correctly
Error Handling	Implemented Correctly
Icons for each level	Not Implemented Correctly
pH level gauge	Implemented Correctly
TDS level gauge	Implemented Correctly
Turbidity level gauge	Implemented Correctly
Water temperature gauge	Implemented Correctly
Computations (6 / 7) * 100 = 85.71%	
TOTAL	85.71%

Data Visualization	
Resource Utilization	
X = A / B A = Number of I/O error messages. B = Number of lines of code related to system calls.	
Functions	Status
I/O Error Handling	No Errors
System Calls for Data Loading	No Errors

Memory overflow when refreshed	Error
Data Export Operations	No Errors
Computations (3 / 4) * 100 = 75.00%	
TOTAL	75.00%
Time Behavior	
X = A / B A = Number of time delays. B = Total number of data streams.	
Functions	Status
Real-time Data Stream 1 (pH Sensor)	No Delays
Real-time Data Stream 2 (TDS Sensor)	No Delays
Real-time Data Stream 3 (Turbidity Sensor)	No Delays
Real-time Data Stream 4 (Temperature Sensor)	No Delays
Group/Ungroup Toggle for Line Chart	No Delays
Computations (5 / 5) * 100 = 100.00%	
TOTAL	100.00%
ISO/IEC-9126 Compliance	
X = A / B A = Number of correctly implemented compliance items. B = Total number of compliance items.	
Functions	Status
Compliance with data visualization performance standards	Implemented Correctly
Compliance with real-time data monitoring requirements	Implemented Correctly
CSV export functionality compliance (Data Integrity)	Implemented Correctly
Computations (3 / 3) * 100 = 100.00%	
TOTAL	100.00%
Data Handling and Visualization	
X = A / B A = Number of data types processed and visualized correctly B = Total number of data types	

Functions	Status
pH sensor data visualization	Correct
TDS sensor data visualization	Correct
Turbidity sensor data visualization	Correct
Temperature sensor data visualization	Correct
CSV export for historical data analysis	Correct
Computations (6 / 6) * 100 = 100.00%	
TOTAL	100.00%
User Interaction and Customization	
X = A / B A = Number of customizable or interactive features implemented B = Total required customizable features	
Functions	Status
Customizable chart views (grouping/ungrouping sensors)	Correct
Historical data download in CSV format	Correct
Turbidity sensor data visualization	Correct
Ability to zoom and filter data for specific timeframes	Correct
Computations (4 / 4) * 100 = 100.00%	
TOTAL	100.00%
Real-time Capability	
X = A / B A = Number of real-time updates provided B = Total number of required updates	
Functions	Status
Real-time updates for pH sensor data	Real-time
Real-time updates for TDS sensor data	Real-time
Real-time updates for turbidity sensor data	Real-time
Real-time updates for temperature sensor data	Real-time
Computations (4 / 4) * 100 = 100.00%	
TOTAL	100.00%

Water Quality Recommendation
Understandability

X = A / B A = Number of UI functions whose purpose is understood by user. B = Total number of interface functions.	
Functions	Status
pH level display	Understood by User
Turbidity level display	Understood by User
TDS level display	Understood by User
Water temperature display	Understood by User
Water Quality Recommendation Based on Sensor Data	Understood by User
Computations (6 / 6) * 100 = 100.00%	
TOTAL	100.00%
Learnability	
X = 1 - A / B A = Number of incomplete help topics. B = Total number of help topics.	
Functions	Status
Explanation of TDS levels and health impacts	Comprehensive
Explanation of pH levels and health impacts	Comprehensive
Explanation of turbidity and its health risks	Comprehensive
Explanation of water temperature and its significance	Comprehensive
Health Impact of Unsafe Water	Comprehensive
Water purification method recommendations	Comprehensive
Computations (6 / 6) * 100 = 100.00%	
TOTAL	100.00%
Operability	
X = A / B A = Number of customizable functions. B = Total number of functions requiring customization.	
Functions	Status
Customizable sensors update time	Not Completed
Customizable water quality thresholds (safe TDS range)	Implemented

Customizable water quality thresholds (safe pH range)	Implemented
Customizable water quality thresholds (safe Turbidity range)	Implemented
Customizable water quality thresholds (Temperature range)	Implemented
Computations (4 / 5) * 100 = 100.00%	
TOTAL	100.00%
ISO/IEC-9126 Compliance	
X = A / B A = Number of correctly implemented compliance items. B = Total number of compliance items.	
Functions	Status
Compliance with real-time monitoring requirements	Complaint
Compliance with water safety standards (WHO)	Complaint
Computations (2 / 2) * 100 = 100.00%	
TOTAL	100.00%

APPENDIX N

Internal Quality Measurement Results in Hardware.

IoT system trustworthiness characteristics	
Availability	
X = A / B A = Number of unplanned hardware downtimes. B = Total number of operational instances.	
Functions	Status
pH sensor	Operational
pH sensor interface board	Operational
TDS sensor	Operational
TDs sensor interface board	Operational
Turbidity sensor	Operational
Turbidity sensor interface board	Operational
Temperature sensor	Operational
Arduino Uno	Operational
ESP32	Operational
Computations (1 – 0 / 9) * 100 = 100.00%	
TOTAL	100.00%
Confidentiality	
X = A / B A = Number of secure transmissions. B = Total number of data transmissions.	
Functions	Status
Wi-Fi data encryption	Secure
pH sensor data encryption	Secure
TDS sensor data encryption	Secure
Turbidity sensor data encryption	Secure
Temperature sensor data encryption	Secure
Single user can login per device	Not Secure
Computations (5 / 6) * 100 = 83.33%	
TOTAL	83.33%
Integrity	

X = A / B A = Number of correctly transmitted data packets. B = Total number of transmitted packets.	
Functions	Status
pH sensor data integrity	Correct
TDS sensor data integrity	Correct
Turbidity sensor data integrity	Correct
Temperature sensor data integrity	Correct
Saved data integrity	Correct
Computations (4 / 4) * 100 = 100.00%	
TOTAL	100.00%
Reliability	
X = A / B A = Number of consistent sensor readings. B = Total number of sensor readings.	
Functions	Status
pH sensor consistency	Consistent
TDS sensor consistency	Consistent
Turbidity sensor consistency	Consistent
Temperature sensor consistency	Consistent
Computations (4 / 4) * 100 = 100.00%	
TOTAL	100.00%
Resilience	
X = A / B A = Number of successful recoveries from system failures. B = Total number of system failures.	
Functions	Status
Recovery from network disruption	Successful
Recovery from power failure	Successful
Recovery from sensor malfunction	Successful
Computations (3 / 3) * 100 = 100.00%	
TOTAL	100.00%
Safety	
X = A / B A = Number of safe operational instances.	

B = Total number of operational instances.	
Functions	Status
Safe sensor operation during data handling	Safe
Electrical safety for hardware components	Safe
Computations (2 / 2) * 100 = 100.00%	
TOTAL	100.00%

IoT system architecture characteristics	
Heterogeneity	
X = A / B A = Number of successfully integrated sensor types. B = Total number of sensor types.	
Functions	Status
pH Sensor Integration	Successful
TDS Sensor Integration	Successful
Turbidity Sensor Integration	Successful
Temperature Sensor Integration	Successful
Computations (4 / 4) * 100 = 100.00%	
TOTAL	100.00%
Modularity	
X = A / B A = Number of replaceable modular components. B = Total number of modular components.	
Functions	Status
pH Sensor	Replaceable
TDS Sensor	Replaceable
Turbidity Sensor	Replaceable
Temperature Sensor	Non-Replaceable
Computations (3 / 4) * 100 = 75.00%	
TOTAL	75.00%
Network Connectivity	
X = A / B A = Number of successful network connections.	

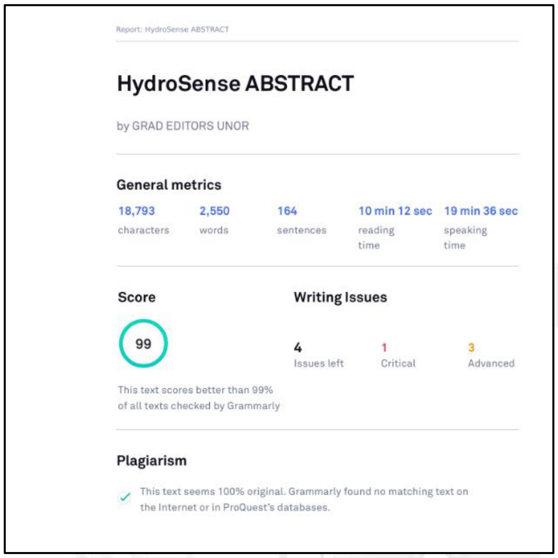
B = Total number of connection attempts.	
Functions	Status
Android Phone #1	Successful
Android Phone #2	Successful
Android Phone #3	Successful
Laptop #1	Successful
Laptop #2 20 meters away	Unsuccessful
Computations (4 / 5) * 100 = 80.00%	
TOTAL	80.00%

IoT system functional characteristics	
Compliance	
X = A / B A = Number of compliances with performance and operational requirements. B = Total number of hardware elements.	
Functions	Status
Sensor data compliance with system performance standards	Compliant
Sensor operation compliance with specified response times	Compliant
Sensor compliance with data accuracy thresholds	Compliant
Sensor compliance with real-time monitoring standards	Compliant
Computations (4 / 4) * 100 = 100.00%	
TOTAL	100.00%
Data Characteristics	
X = A / B A = Number of data types processed correctly. B = Total required data types.	
Functions	Status
pH sensor data processing	Correct
TDS sensor data processing	Correct
Turbidity sensor data processing	Correct
Temperature sensor data processing	Correct
Water recommendation data processing	Correct
Health risk data processing	Correct
Computations	

(6 / 6) * 100 = 100.00%	
TOTAL	100.00%
Real-time Capability	
X = A / B A = Number of real-time updates provided. B = Total number of required updates.	
Functions	Status
pH sensor updates	Real-time
TDS sensor updates	Real-time
Turbidity sensor updates	Real-time
Temperature sensor updates	Real-time
Water recommendation updates	Real-time
Health risk updates	Real-time
Hydrology resources updates	Delayed
Computations (6 / 7) * 100 = 85.71%	
TOTAL	85.71%

APPENDIX O

Grammarly Results.



Report: HydroSense ABSTRACT

HydroSense ABSTRACT

by GRAD EDITORS UNOR

General metrics

18,793	2,550	164	10 min 12 sec	19 min 36 sec
characters	words	sentences	reading time	speaking time

Score

99

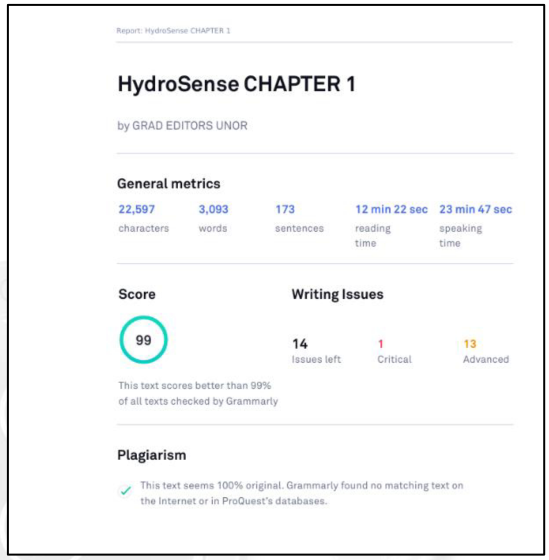
This text scores better than 99% of all texts checked by Grammarly

Writing Issues

4	1	3
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.



Report: HydroSense CHAPTER 1

HydroSense CHAPTER 1

by GRAD EDITORS UNOR

General metrics

22,597	3,093	173	12 min 22 sec	23 min 47 sec
characters	words	sentences	reading time	speaking time

Score

99

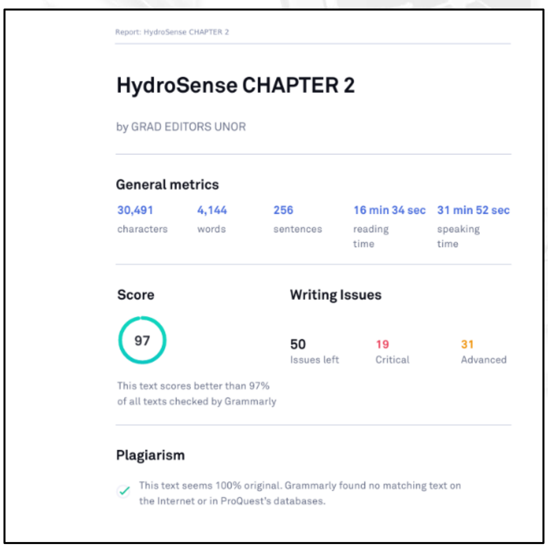
This text scores better than 99% of all texts checked by Grammarly

Writing Issues

14	1	13
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.



Report: HydroSense CHAPTER 2

HydroSense CHAPTER 2

by GRAD EDITORS UNOR

General metrics

30,491	4,144	256	16 min 34 sec	31 min 52 sec
characters	words	sentences	reading time	speaking time

Score

97

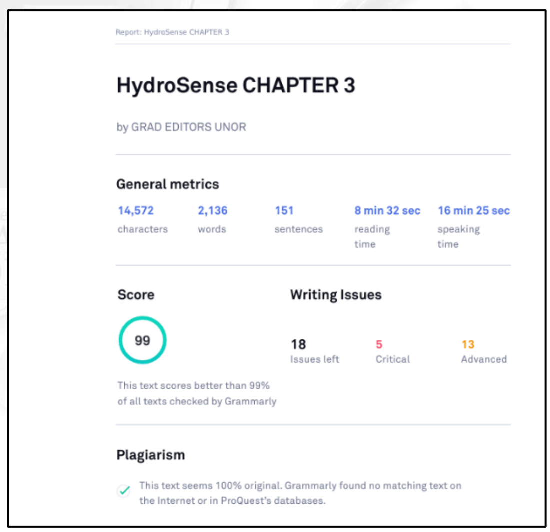
This text scores better than 97% of all texts checked by Grammarly

Writing Issues

50	19	31
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.



Report: HydroSense CHAPTER 3

HydroSense CHAPTER 3

by GRAD EDITORS UNOR

General metrics

14,572	2,136	151	8 min 32 sec	16 min 25 sec
characters	words	sentences	reading time	speaking time

Score

99

This text scores better than 99% of all texts checked by Grammarly

Writing Issues

18	5	13
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.

Report: HydroSense CHAPTER 4

HydroSense CHAPTER 4

by GRAD EDITORS UNOR

General metrics

16,456	2,356	124	9 min 25 sec	18 min 7 sec
characters	words	sentences	reading time	speaking time

Score

98

This text scores better than 98% of all texts checked by Grammarly

Writing Issues

21	8	13
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.

Report: HydroSense CHAPTER 5

HydroSense CHAPTER 5

by GRAD EDITORS UNOR

General metrics

43,684	6,048	339	24 min 11 sec	46 min 31 sec
characters	words	sentences	reading time	speaking time

Score

96

This text scores better than 96% of all texts checked by Grammarly

Writing Issues

53	14	39
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.

Report: HydroSense CHAPTER 6

HydroSense CHAPTER 6

by GRAD EDITORS UNOR

General metrics

13,376	1,840	127	7 min 21 sec	14 min 9 sec
characters	words	sentences	reading time	speaking time

Score

98

This text scores better than 98% of all texts checked by Grammarly

Writing Issues

19	10	9
Issues left	Critical	Advanced

Plagiarism

This text seems 100% original. Grammarly found no matching text on the Internet or in ProQuest's databases.

Report: HydroSense CHAPTER 7

HydroSense CHAPTER 7

by GRAD EDITORS UNOR

General metrics

7,867	1,019	65	4 min 4 sec	7 min 50 sec
characters	words	sentences	reading time	speaking time

Score

96

This text scores better than 96% of all texts checked by Grammarly

Writing Issues

13	8	5
Issues left	Critical	Advanced

Plagiarism

1 %

0 source

1% of your text matches 0 sources on the web or in archives of academic publications

APPENDIX P

Turnitin Results.

HydroSense

ORIGINALITY REPORT

6%	4%	3%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

APPENDIX Q

Water Safety Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	When is water safe to drink?	https://www.youtube.com/watch?v=G244Q4AGJ7U
World Health Organization (WHO)	Guide	Guidelines for drinking-water quality	https://www.who.int/publications/i/item/9789240045064
World Health Organization (WHO)	Article	Drinking-water	https://www.who.int/news-room/fact-sheets/detail/drinking-water
IntechOpen	Book	Safe Drinking Water: Concepts, Benefits, Principles and Standards	https://www.intechopen.com/chapters/57345
National Library of Medicine	Book	Water Supply, Sanitation, and Hygiene	https://www.ncbi.nlm.nih.gov/books/NBK525207/

APPENDIX R

pH Level Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	Acid and Base | Acids, Bases & pH	https://www.youtube.com/watch?v=V5MqcL9Bck
DataStream	Guide	Physical & Chemical Characteristics (pH)	https://datastream.org/en-ca/guidebook/ph
MedicalNews Today	Article	The pH of water: What to know	https://www.medicalnewstoday.com/articles/327185
Wastewater Digest	Article	What is pH?	https://www.wwdmag.com/what-is-articles/article/10940015/what-is-ph
ScienceNews Explores	Article	Scientists Say: pH	https://www.snexplores.org/article/scientists-say-ph

APPENDIX S

Turbidity Level Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	What Is Turbidity In Water? 6 Things You Should Know	https://www.youtube.com/watch?v=vuFweYh8VRI
HELCOM	Guide	Guidelines for monitoring of turbidity	https://helcom.fi/wp-content/uploads/2019/08/Guidelines-for-measuring-turbidity.pdf
Wastewater Digest	Article	What is Turbidity?	https://www.wwdmag.com/what-is-articles/article/10939754/what-is-turbidity
United States Geological Survey	Article	Turbidity and Water	https://www.usgs.gov/special-topics/water-science-school/science/turbidity-and-water
International Association of Dredging Companies	Articles	Turbidity	https://www.iadc-dredging.com/subject/environment/turbidity/

APPENDIX T

TDS Level Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	Best bottled water pH TDS test	https://www.youtube.com/watch?v=D5jvCN6FqOs
Kent Health Care Products	Guide	What are Total Dissolved Solids (TDS) & How to Reduce Them?	https://www.kent.co.in/blog/what-are-total-dissolved-solids-tds-how-to-reduce-them/
Safe Drinking Water Foundation	Article	TDS and pH	https://www.safewater.org/fact-sheets-1/2017/1/23/tds-and-ph
ResearchGate	Study	A Study on the Total Dissolved Solids and Hardness Level of Drinking Mineral Water in Bangladesh	https://www.researchgate.net/publication/313103314_A_Study_on_the_Total_Dissolved_Solids_and_Hardness_Level_of_Drinking_Mineral_Water_in_Bangladesh
Fresh Water Systems	Blog	What Is TDS in Water & Why Should You Measure It?	https://www.freshwatersystems.com/blogs/blog/what-is-tds-in-water-why-should-you-measure-it

APPENDIX U

Water Temperature Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	MEASURE THE TEMPERATURE OF WATER WHEN IT'S HEATED, BOILING AND COOLING	https://www.youtube.com/watch?v=lLSfLMZHVGw
Safe Drinking Water Foundation	Article	WATER TEMPERATURE FACT SHEET	https://www.safewater.org/fact-sheets-1/2018/8/15/water-temperature-fact-sheet
National Library of Medicine	Book	The effect of water temperature and voluntary drinking on the post rehydration sweating	https://pmc.ncbi.nlm.nih.gov/articles/PMC3762624/
United States Geological Survey	Article	Temperature and Water	https://www.usgs.gov/special-topics/water-science-school/science/temperature-and-water
Multidisciplinary Digital Publishing Institute	Article	Drinking Water Temperature around the Globe	https://www.mdpi.com/2073-4441/12/4/1049

APPENDIX V

Filtration Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	Determine Water Quality using Arduino and Turbidity Sensor	https://www.youtube.com/watch?v=MytUqOz5vbY
YouTube	Video	Filtration Testing & Piloting Guidelines	https://www.youtube.com/watch?v=h_aTYKtBSvw
ScienceDirect	Article	Water Filtration	https://www.sciencedirect.com/topics/chemical-engineering/water-filtration
ScienceDirect	Article	Filtration Process	https://www.sciencedirect.com/topics/engineering/filtration-process
National Library on Medicine	Book	Effectiveness of Membrane Filtration to Improve Drinking Water	https://pmc.ncbi.nlm.nih.gov/articles/PMC5094238/

APPENDIX W

Aeration Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	Water aeration principle	https://www.youtube.com/watch?v=uLOZblR1VyY
University of Massachusetts Amherst	Article	Aeration Treatment of Drinking Water Supplies	https://ag.umass.edu/cafe/fact-sheets/aeration-treatment-of-drinking-water-supplies#:~:text=Aeration%20treatment%20consists%20of%20passing,to%20volatilize%20into%20the%20air.
National Library on Medicine	Book	Field Research on Mixing Aeration in a Drinking Water Reservoir	https://pmc.ncbi.nlm.nih.gov/articles/PMC6862099/
Wastewater Digest	Article	What is Aeration for Wastewater Treatment?	https://www.wwdmag.com/what-is-articles/article/10939130/what-is-aeration-for-wastewater-treatment
Solitude Lake Management	Article	Oxygenate Your Waterbody with Aeration	https://www.solitudelakemanagement.com/top-3-aeration-articles/

APPENDIX X

Water Distillation Sources in Hydrology Resources.

Source	Type	Title	Link
How to Make Distilled Water	Video	How to Make Distilled Water	https://www.youtube.com/watch?v=VHZitT0-fCY
University of Nebraska–Lincoln	Book	Drinking Water Treatment: Distillation	https://extensionpubs.unl.edu/publication/g1493/2013/pdf/view/g1493-2013.pdf
MedicalNews Today	Article	Is distilled water safe to drink?	https://www.medicalnewstoday.com/articles/317698
Wastewater Digest	Article	What is Water Distillation?	https://www.wwdmag.com/what-is-articles/article/10940138/what-is-water-distillation
IWA Publishing	Article	Distillation Treatment and Removal of Contaminants from Drinking Water	https://web.archive.org/web/20240625080557/https://www.iwapublishing.com/news/distillation-treatment-and-removal-contaminants-drinking-water

APPENDIX Y

Sedimentation Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	Sedimentation	https://www.youtube.com/watch?v=YQ2kIXaRNWE
Etch2o	Guide	2023 Guide to Sedimentation in Water Treatment	https://www.etch2o.com/sedimentation-in-water-treatment/
IOPscience	Paper	Increasing the efficiency of sedimentation tanks for drinking water treatment	https://iopscience.iop.org/article/10.1088/1755-1315/1076/1/012049
Taylor & Francis	Paper	Reduction of sedimentation and water turbidity at intakes of drinking water treatment plants	https://www.tandfonline.com/doi/full/10.1080/23570008.2023.2210892
IWA Publishing	Article	Sedimentation Processes	https://web.archive.org/web/20240720121731/https://www.iwapublishing.com/news/sedimentation-processes

APPENDIX Z

Boiling Water Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	Boiling Water Bubbles, what makes them exactly? What are they made of?	https://www.youtube.com/watch?v=egwCLxxSfwI
CDC	Guide	Boil Water Advisory	https://web.archive.org/web/20240822023550/https://www.cdc.gov/healthywater/emergency/drinking/drinking-water-advisories/boil-water-advisory.html
CDC	Guide	Making Water Safe in an Emergency	https://web.archive.org/web/20240208041305/www.cdc.gov/healthywater/emergency/making-water-safe.html
MedicalNews Today	Article	What are the benefits of drinking hot water?	https://www.medicalnewstoday.com/articles/319673
YouTube	Video	Boiling Water Bubbles, what makes them exactly? What are they made of?	https://www.youtube.com/watch?v=egwCLxxSfwI

APPENDIX AA

Water Treatment Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	How Do Water Treatment Plants Work?	https://www.youtube.com/watch?v=0_ZcCqqpS2o
CDC	Guide	A Guide to Drinking Water Treatment and Sanitation for Backcountry and Travel Use	https://web.archive.org/web/20240807060639/https://www.cdc.gov/healthywater/drinking/travel/backcountry_water_treatment.html
ScienceDirect	Articles	Drinking Water Treatment	https://www.sciencedirect.com/topics/earth-and-planetary-sciences/drinking-water-treatment
SafetyCulture	Articles	A Guide to Understanding Water Treatment	https://safetyculture.com/topics/water-treatment/
ScienceDirect	Article	Water Management, Treatment and Environmental Impact	https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/water-treatment

APPENDIX AB

Alkaline Water Sources in Hydrology Resources.

Source	Type	Title	Link
YouTube	Video	How to make Alkaline Water	https://www.youtube.com/watch?v=s7KKost6a34
Distillata	Guide	A Complete Guide to Alkaline Water	https://distillata.com/blog/a-complete-guide-to-alkaline-water/
Healthline	Articles	What Is Alkaline Water, and What Are the Benefits?	https://www.healthline.com/health/food-nutrition/alkaline-water-benefits-risks
National Library of Medicine	Book	Alkaline Water and Longevity	https://pmc.ncbi.nlm.nih.gov/articles/PMC4906185/
MedicalNews Today	Article	Is alkaline water good for you?	https://www.medicalnewstoday.com/articles/313681

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