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Flood Disaster Preparedness and Response Using a Web-Based Integrated Flood Management System (IFMS)

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Abstract - Floods are one of the most frequent and damaging natural hazards in Malaysia, especially in low-lying places, such as Batu Pahat and Johor. National flood monitoring systems, such as InfoBanjir and Malaysian Meteorological Department (MET) Malaysia, have disjointed data pools, late updates, and inadequate public access. In this paper, we present an IFMS, which is a contemporary web platform developed to integrate national flood management systems through data collection, automatic processing, dynamic visualization tools, and others. The system architecture consists of three main layers: IoT-enabled flood sensors, centralized web server, and responsive user interfaces. Backend processing is performed using Laravel, and front-end design uses Bootstrap and Chart.js for live data visualization. The IFMS algorithm classifies severity using a predefined standard for water levels and rainfall, modelled by a pseudocode for reproducibility and scalability. The real-time data are centralized in various APIs, such as data.gov.my and Google Maps, to ensure real-time updates occur throughout the time, and interactive monitoring by map. According to the experimental assessment, the IFMS achieves a less than one minute data refresh speed which outstrips the 15–30 min delay compared with the one observed by InfoBanjir. After user acceptance testing (UAT) (194 respondents) user satisfaction rate 94.9% for the system and technical stability 89.7% were achieved so that the new solution to be acceptable and operational. The first solution is evidenced by an evaluation comparison with other systems implemented globally, such as the Iowa Flood Information System (IFIS), Tokyo Metropolitan Flood Control System, and European Flood Awareness System (EFAS) which showed innovation in adopting real-time API integration, hydrograph and hyetograph visualization, and mobile responsiveness. Consequently, the IFMS represents an important advancement in the flood management landscape in Malaysia, harmonizing global standards with local deployment to contribute to greater situational awareness, decision-making, and community resilience.

Keywords—Flood Management System, Real-time Data Processing, Internet of Things Integration, Big Data Analytics, Web-based Monitoring Platform, API-driven Architecture, Disaster Preparedness and Resilience

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1. INTRODUCTION

Floods are among Malaysia's recurrent and devastating natural threats, and low-lying areas such as Batu Pahat in Johor are highly affected, highlighting the need for improved disaster preparedness and real-time response facilities [1]. The existing flood management infrastructure of the country is very fragmented, poorly available, and partially public-oriented [2]. To fill this gap, this study proposes a Web-Based IFMS as an infrastructural solution, which is a data-rich and functional tool consisting of three modules: an initial flood monitoring and alert, an evacuation centre support, and a central web interface. Developed using contemporary technologies—Laravel for backend processing, Bootstrap for responsive interface design, and Chart.js for interactive data visualization— IFMS presents a web-based, intelligent solution [3]. Through the concurrent use of data and the Google Maps JavaScript API that retrieves, processes, and presents valuable environmental data including rainfall, water levels, and predictions [4]. Additional real-time river and rainfall data were also incorporated from Malaysia's official flood information portal, InfoBanjir [5]. Unlike international approaches that are mostly focused on macro-prediction or passive data distribution, IFMS provides real-time data processing, community-driven visualizations, and decision support, all within a modular and scalable system design [6]. By leveraging big data analytics, open APIs, and adaptive system architecture, the IFMS brings measurable enhancements both nationally and internationally compared to legacy systems and thus contributes towards improving disaster preparedness and monitoring of emergency situations in flood-prone areas by improving community resiliency [7].

Flooding is among the most common and destructive natural disasters globally, and has considerable socio-economic burden, especially in flood-prone areas such as Batu Pahat, Johor, and Malaysia [8]. These regions, along with many others around the world, continue to face rising flood threats driven by climate change and rapid urbanization. At the global level, recent studies have demonstrated rapid advancements in remote sensing, machine learning, and deep learning techniques for flood detection and mapping, particularly through optical and SAR satellite imagery, although challenges in generalization, feature extraction, and real-time automation remain significant [9]. Recent outbreaks of disasters in Malaysia, such as the March 2023 disaster and the Johor flood, which also affected residents in Batu Pahat, Muar, and Tangkak, have added to our understanding of the need for better and more effective flood control structures. Despite the recorded flood events, available flood-response systems in Malaysia are fragmented and have not yet developed a platform for real-time data provisions and the analytical tools necessary to make decisions in real time or communicate effectively to the populace.

These gaps undermine the ability to respond quickly and conduct meaningful outreach to the public in the case of floods. The most recent news on floods in Johor, which evacuated 27,774 in Batu Pahat, 4,080 in Muar, and 2,536 in Tangkak, highlights the necessity of assuring good preparedness and response capacity to disasters. Current platforms such as InfoBanjir and MET Malaysia provide rainfall and river-level information but face persistent challenges with fragmented data feeds, update intervals of 15–30 min, and limited integration with decision-support systems [5].

On the international front, there are a few high-tech platforms that have already shown a lot of development. The IFIS in the US and the Metropolitan Flood Control Integrated Information System in Tokyo provide real hydrology, interactive dashboards, and geospatial mapping [10]. Other systems include the EFAS and Copernicus Emergency Management Service (EMS), which offer flood forecasting, risk mapping, and early warning services on a continental scale within Europe, and the USGS National Water Information System (NWIS), which consolidates river-specific data and groundwater measurements into a national database. However, along with their advantages, these systems also have significant limitations, such as local data consolidation, insufficient hydrometeorological visualization (e.g., hydrographs and hyetographs), and mobile optimization gaps, which limit their application in real-time and community-level decision-making.

This study suggests an innovative response to these challenges in the form of a Web-Based IFMS. The IFMS combines live datasets of multisource sources, such as IoT sensors, open Application Programming Interfaces (APIs), and government-derived datasets in a centralized platform that is accessible through interactive dashboards.

Unlike current Malaysian platforms, IFMS offers near real-time data updates, integrates rainfall and river-level information into unified dashboards, and achieves a 94.9% user satisfaction rate during testing. On the other hand, unlike international flood management systems, IFMS incorporates hydrographs and hyetographs and is also fully mobile and optimized for field use, which makes it possible to provide authorities and first responders with direct information access in an emergency, when smartphones or tablet computers can become the main communication systems.

Unlike international systems, such as the IFIS, USA and the EFAS, Europe, which emphasize macro-scale forecasts and data aggregation, the IFMS system is designed for micro-regional deployment and community-centric interaction. Its real-time refresh rate of less than one minute is faster than the 15–30-minute delay common in Malaysia's InfoBanjir application. Furthermore, with hydrographs, hyetographs, and fully mobile-optimized dashboards, actionable insights for both the authorities and the people on the ground are provided—a combination absent in their global counterparts. Results (94.9% positive usability) user acceptance point to the ability to effectively respond 80–90% faster than current national platforms.

IFMS is a solution that covers the most important requirements of a state-of-the-art flood control system in Malaysia through an end-to-end real-time platform. The system improves situational awareness and supports flood decision-making using big data analytics, IoT connectivity, and interactive visualizations [11]. IFMS has significantly improved updated frequency, usability, and data integration compared to existing Malaysian and international platforms, and surpassed international systems in hydrographs, hyetographs, and complete mobile optimization. These developments make IFMS an excellent extension of flood management technology, as it adds novelties and practical results in disaster preparedness and response.

2. LITERATURE REVIEW

Recently, the frequency and severity of floods have increased, forcing governments and researchers to examine technological approaches to disaster preparedness and emergency rescue [12]. A range of flood monitoring systems have been developed over the past several years, including basic flood alert mechanisms based on sensors through dashboards integrated with cloud-based systems [13]. Despite this advancement, most of the systems that exist today are fractured and provide limited availability and capabilities in a real-time environment. In addition, these platforms are often not open to the outside world, thus hindering their usefulness in emergencies in which prompt and correct information is essential.

In Malaysia, the dissemination of flood-related records is prominent through authorized websites such as the Department of Irrigation and Drainage (DID) and the MET [14]. These portals provide very important information on meteorology and water levels; however, the static and fragmented interface of these portals reflects little interactivity and hinders real-time decision-making. Moreover, there are no visualization elements (i.e., interactive maps, search filters, and classification indicators) that allow one to quickly comprehend and act promptly.

At the international level, progressive countries have implemented innovative flood monitoring mechanisms that transcend the scope of conventional alert systems. The Tokyo Metropolitan Flood Control Integrated Information System provides real-time river stage and rainfall data in Japan, and an interactive map display dashboard can significantly enhance preparedness and situational awareness. Similarly, in the US, the IFIS features real-time hydrological data as well as powerful filtering and visualizing capabilities that aid the decision-making process in floods [15]. In Europe, the EFAS and Copernicus EMS provide continental-scale forecasting of flooding, flood risk, and impact-based maps to assist national and local authorities in the proactive management of flooding. The U.S. NWIS also incorporates real-time river, groundwater, and precipitation data into a single national system available to both government agencies and individuals. Together, these international standards show that real-time, coordinated, and user-centred platforms have the potential to enhance citizen awareness, improve decision making, and promote faster response to emergency situations when there is a flood.
Global progress in smart flood management accelerated between 2023 and 2025. For instance, Dang et al. (2025) introduced an AI-integrated hydroinformatics framework for predictive alerts, whereas Turner and Sun (2024) proposed an open-source responsive flood event platform using live sensor streams. Similarly, Veerappan (2024) demonstrated an edge-enabled smart drainage system that achieved millisecond-level responsiveness, and Peixoto et al. (2024) developed an open-data-based geospatial prediction model. These advances informed the IFMS's emphasis on API modularity, open data standards, and real-time web visualization, bringing global best practices into Malaysia's flood-resilience context.

In contrast, most of the applicable systems in Malaysia are limited in functionality and fail to integrate, as in the case of InfoBanjir. Solving these weaknesses requires the development of a more effective real-time flood-monitoring mechanism that can provide governments and people with an accessible, actionable dataset. Therefore, innovation in the Web-Based IFMS is promoted in this study. In fact, such a platform facilitates the integration of diverse data sources, that is, IoT sensors, open APIs, and government data, into a single, web-accessible ecosystem. Compared to systems focusing on hardware only or mobile alerts, the IFMS combines big data analytics and uses an interactive dashboard to deliver flood-related information. Owing to the implementation of such technologies, the IFMS provides decision-makers and citizens with real-time situational awareness and actable insight, a factor that cannot be ignored in the effective response to floods and ensuring organizational and community safety.

2.1 Technological Paradigms in Flood Monitoring and Disaster Response

Flood disasters continue to have severe social and economic effects worldwide. This requires the inclusion of technology in early warning systems and disaster-response plans. The process of flood monitoring has changed dramatically over the past two decades, in which a system of manual measurements and broadcast warnings is being transformed into fully automated and sensor-based infrastructures and platforms that are linked with clouds. Some of the most prominent advantages of such technological improvements include decreased response time, improved situational awareness, and better cohesion among the various entities involved.

The use of IoT devices is the first among new innovations. Probes, such as water-level sensors, rain gauges, and other environmental monitors, are now routinely deployed in flood-prone areas to deliver near real-time information on rainfall intensity, as well as on irregularities in river and moisture levels. These devices utilize Wi-Fi, GSM, and LPWAN protocols to send observations to central servers for data processing and interpretation. A case in point is offered by the IFIS in the United States, which utilizes IoT devices that supply real-time and up-to-date information to governing authorities and users, enabling proper decision-making processes in the event of flooding. Such systems form a powerful tool for predictive analysis and automated alerting, if the necessary infrastructure exists.

In addition, remote sensing modes and Geographic Information Systems (GIS) have proliferated in the mapping of flood hazards and definition of hazard characteristics [16]. Using satellite-derived imagery in combination with topographical and hydrological models, we can draw the boundaries of the flood-eliminated areas, recreate the previous extent of the floods, and simulate future ones. However, GIS-based solutions are more at the macro-regional risk level; their granularity and real-time performance are often sub-par at the community level. The architecture of flood control in Tokyo provides an educational contrast: smart cities combine real-time data in both GIS and IoT schemes and provide practical feedback to the local administration and residents working on an interactive digital platform.

Another important development is the rise of cloud-based data assimilation in model-based decision support systems (DSS). Such platforms aggregate the measurements of sensors with weather forecasts and flood models into interactive web-based media and provide real-time observation, advanced data visualization, and predictive flood modelling.

Flood predictions and warnings have also gradually increased in popularity, making use of mobile phone applications that provide real-time flood reports. Community engagement is enhanced on the positive side, but the scalability and reliability of such tools are limited, especially in low-connectivity areas. IFMS can make a significant difference by providing timely prediction of flood data in a manner available on mobile-friendly interfaces for accessibility [17].

For Malaysia, while the foundation for sensor systems comes from government sources, including the DID and MET Malaysia, the integration of data into a single, real-time, public-facing system remains lacking. Data are displayed in static formats and do not interact with platforms, such as InfoBanjir. The IFMS includes interactive dashboards and tools to build a centralized, scalable, and user-friendly solution that integrates with real-time APIs. We used actionable intelligence for flood authorities and the public to act on, which is one of the key elements for enhancing flood response and community safety.

Therefore, overall technologies, IoT appliances, GIS and remote sensing, cloud-based data assimilation, and more have revolutionized modern flood management. Such tools can shorten response time, deepen situational awareness, and improve the coordination of stakeholders. In addition, they provide power to both authorities and citizens to provide perceptive data, which contribute in time and based on data, during flood emergencies.

2.2 Public Flood Information Systems in Malaysia

Malaysia's disaster data-sharing approach has used centralized and administration-based systems in the past. The most popular is InfoBanjir, operated by the DID, which is the public's main portal for rainfall and river water levels.

Notwithstanding its national scale, the system has several design and operational limitations that limit its effectiveness during high-impact events.

However, the interface hosted at InfoBanjir was more static, displaying environmental records using primitive tables and drop-down lists. While it is possible to filter stations based on state and district on the website, advanced functionalities such as time-series graphs, geospatial mapping, or station-wise historical analysis are not available. These gaps preclude users from observing trends over time or appreciating the spatial heterogeneity of risk. In addition, probably owing to a lack of responsive design or mobile optimization, it is difficult to use on a mobile device, such as in emergencies with mobiles as the main source of information.

Data integration is lacking. InfoBanjir runs entirely independent of weather forecasting agencies, system statuses of evacuation centres, or sensor-based warning systems, which results in a disjointed view about the situation on site. Users need to click on several items, such as MET Malaysia's weather portal or PPS reports, to put the puzzle together. It is not only inefficient for the public, but also for local councils that need to make decisions.

Numerical indicators for water level conditions such as alerts, warnings, and dangers are available, but are not attributed to geospatial overlays and are not supported by user-driven visual analytics. The system also does not allow user personalization of alerts, as users need to feel included and be active and proactive by their community.

Parallel work done by institutions such as MET Malaysia leans more towards weather prediction and is also disconnected from hydrological data or user-based design. Although timely, their bulletins are not intended for flood-prone community use and are not issued at a level specific to their downstream community.

Indeed, public information systems in Malaysia generally suffer from usability, interactivity, and data centralization shortcomings. Although they are essential for collecting and informing the public about the data, they are not fully equipped to analyse the data or use real-time, actionable interfaces. These limitations reinforce the importance of more integrative and dynamic platforms such as web modules, which can accumulate environmental data streams and visualize them on up-to-date, friendly digital frameworks [18].

2.3 Study of Existing Web-Based Flood Monitoring Systems

Disaster preparedness relies on flood monitoring systems; however, most frameworks demonstrate gaps in real-time data delivery, interactivity, and user experience. In Malaysia, information sources and packages continue to be fragmented and inert on platforms such as InfoBanjir and the MET Malaysia Portal. Systems such as the IFIS, Tokyo, Metropolitan Flood Control, and European systems such as EFAS and Copernicus EMS have sophisticated dashboards and geospatial maps but continue to struggle with local integration, hydro-meteorological data visualization, and mobile preparedness. The proposed IFMS controls these flaws by integrating real-time data streams, adding hydrographs and hyetographs, and providing mobile-friendly dashboards adapted to Malaysia, offering quantifiable benefits over national and international standards.

The widely used country portal is InfoBanjir in Malaysia, which is run by the DID, as shown in Figure 1. It is still the most popular nationally used government-maintained flood-monitoring portal posting real-time river water level and rainfall data through a simple web-based interface that provides the filtering of stations through drop-down menus. However, InfoBanjir does not have alluring interactive capabilities and sophisticated data-visualization tools, such as effective search and filter features, thus limiting the capacity of users to question flood data with high efficiency. Moreover, the platform is not mobile-responsive, making mobile accessibility in the case of flooding more challenging, especially in scenarios where mobile devices are the key information channels. Finally, InfoBanjir does not have live alert messages or complex search or filter options, all of which are essential elements in making prompt decisions related to a flood emergency.

Similarly, as shown in Figure 2, the MET Malaysian Portal focuses on severe weather warnings and forecasts. The site provides real-time rainfall estimates but neither displays information about river water levels nor provides interactive dashboards. Although mobile friendly, it does not provide detailed information on floods and does not contain search and filtering and detailed information visualization. Thus, the MET Malaysia Portal falls short of creating dynamic, interactive flood risk management, especially in places where there is a high need to interpret data rapidly.

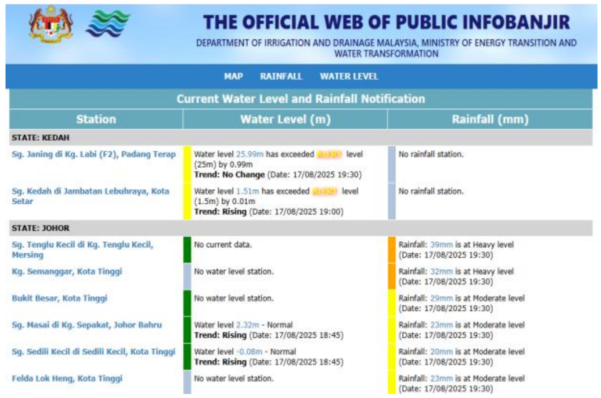


Figure 1. InfoBanjir Official Website

Figure 2. MET Malaysia Website

In contrast, the IFIS, shown in Figure 3, provides a significantly more advanced flood-monitoring system in the United States [19]. IFIS broadcasts real-time water-level measurements of rivers and rainfall data with interactive dashboards on map displays that enable users to monitor flood levels in a variety of geographic areas in near real time. The system is responsive to mobile users and has wide search-filter criteria, thereby enhancing usability. In addition, IFIS offers API services that allow real-time access to flood data to external developers and government agencies. Although the system rates well in sharing information and providing interactive capability, it still lacks major elements of analysis, including graphical hydrographs and hyetographs, which are necessary for a successful trend analysis and predictive analysis.

Similarly, Tokyo's Metropolitan Flood Control Integrated Information System in Figure 4 is an all-inclusive flood monitoring platform in which real-time data on river stages and rainfall are integrated. The platform provides an interactive map dashboard that shows flood conditions in a visually accessible manner. However, this system cannot provide graphical hydrographs and hyetographs that are essential for the detailed evaluation of flood trends. Moreover, although the platform has APIs, it still lacks the level of mobile optimization of other systems, depriving them of their use in emergencies when mobile devices are often utilized.

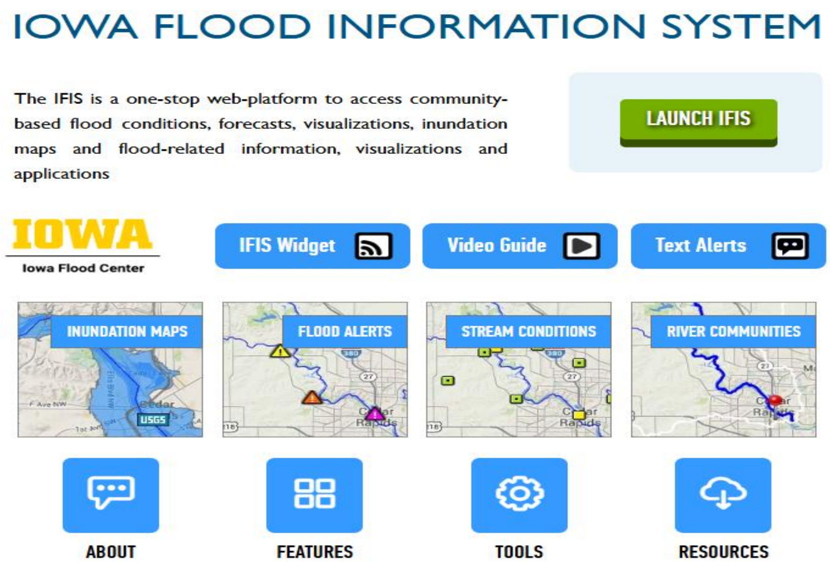


Figure 3. IFIS Website

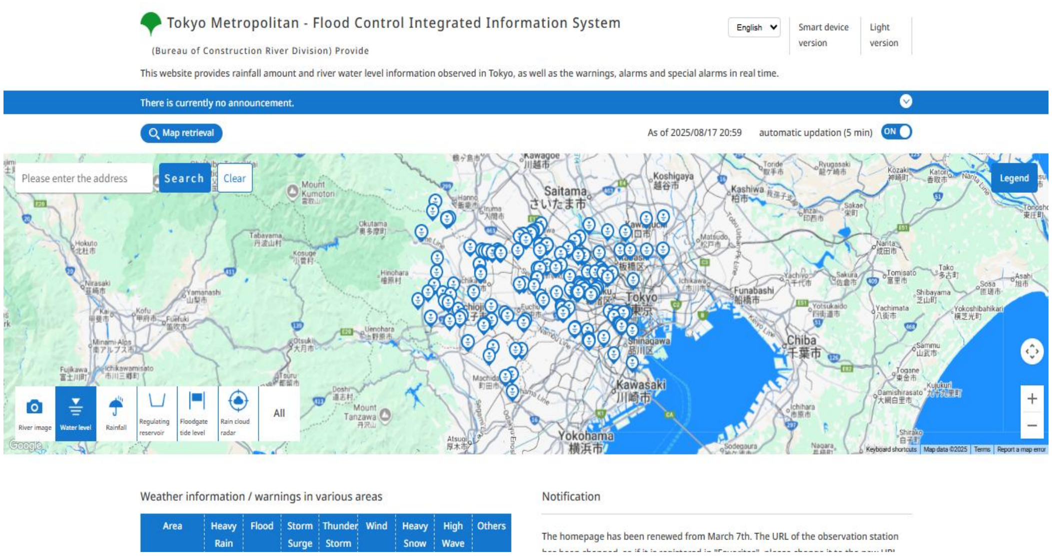


Figure 4. Tokyo Metropolitan Flood Control Integrated Information System Website

The EFAS is a branch of the Copernicus EMS that provides situational awareness and early flood prediction in Europe (Figure 5). It combines both hydrological and meteorological models to provide probabilistic forecasts up to 10 days ahead with an interactive online map viewer to track the state of floods. Nonetheless, EFAS does not provide detailed outputs to national authorities, and its public user interface does not have sophisticated real-time visualization (hydrographs), which restricts its practical application by communities in case of emergency situations.

In Figure 6, the USGS WaterWatch system is a website that reports real-time streamflow and flooding locations throughout the United States, combining hydrological data with historical averages to identify anomalies. The interactive maps on the site can help users to see the flood location in the regions; therefore, the site is a suitable interactive tool for hydrological monitoring. However, WaterWatch is still mostly data-based, with few interactive dashboards and predictive modelling applications, thus limiting its usefulness to non-technical users and decision makers who may need actionable and real-time information.

Figure 5. EFAS Website

Figure 6. USGS WaterWatch Website (United States)

A check for Flooding is a UK platform that provides people with location-specific flood warnings, predictions, and advice on planning, as shown in Figure 7. It enables the search by town or postcode and has clear and mobile-optimized warnings and response guidance, making it accessible during emergencies. However, the platform is not intended to be analytically deep and lacks interactive dashboards, hydrographs, and geospatial overlays; thus, it is not well suited for facilitating deep trend analysis and high-level flood management planning.

By comparing the features of these systems both locally and internationally, it is evident that while significant progress has been made in flood monitoring systems globally, there are significant failures in the practice of providing interactive facilities, mobile responsiveness, and comprehensive data integration, as shown in Table 1. These weaknesses limit the efficiency of flood monitoring frameworks and the quality of decision support during emergencies. The proposed IFMS addresses these limitations by integrating real-time river water-level data, real-time rainfall data, interactive map dashboards, and API integration. In addition, the Proposed IFMS improves upon existing systems by incorporating graphical hydrographs and hyetographs to enhance flood trend analysis, along with a mobile-responsive design that ensures accessibility during emergencies.

Figure 7. UK Government Flood Information Service Website

Table 1. Comparison of Existing Systems with the Proposed Web System

Features	InfoBanjir	MET Malaysia Portal	IFIS (USA)	Tokyo Flood Control System (Japan)	EFAS	USGS Water Watch (USA)	UK Flood Information Service	Proposed IFMS
Real-Time River Water Level Data	✓	✗	✓	✓	✓	✓	✓	✓
Real-Time Rainfall Data	✓	✓	✓	✓	✓	✓	✓	✓
Interactive Map Dashboard	✓	✗	✓	✓	✓	✗	✓	✓
Search and Filter	✗	✗	✓	✓	✓	✓	✗	✓
Mobile Responsive Design	✗	✓	✓	✗	✗	✗	✗	✓
Graphical Hydrograph and Hyetograph	✓	✗	✗	✗	✗	✗	✗	✓
API Integration	✓	✗	✓	✓	✓	✓	✓	✓

3. METHODOLOGY

The system is envisioned as a layered flood monitoring and response framework that combines environmental measurement, centralized computation, and web-based dissemination [20]. The system comprises three layers: flood sensors, a central web server, and end-user interfaces. Data collection is realized through IoT-based flooding sensors (nodes) around high-risk areas, including Arduino microcontrollers, GSM/Wi-Fi nodes, and solar cells, to power the unit and communicate the collected sensor data to the urban sensor Wi-Fi network, including the water gauge and rainfall intensity. These sensor readings are transmitted continuously to the central web server, which constitutes the central part of the system and the central subject of this study.

The data were aggregated and processed on the web server. It receives incoming sensor data and validates such data while storing them [21]. It runs classification algorithms to process incoming data and determine flood severity and manages the logic governing station dynamics. Through API integration, the server facilitates friction-gainless communication between data sources and user-facing modules, providing responsive interactions and the ability to scale the system modularly [22]. In addition, it enables the creation and display of interactive dashboards, supports filtering and query-driven mechanisms, and renders graphical visualizations such as hydrographs and hyetographs, which depict patterns of water level and rainfall over some specific background information.

User interaction with the system is achieved through a responsive web-based interface that makes data accessible and easy to understand for various stakeholders, from disaster response personnel to the public [23]. They can check the status of the station, evaluate alarm conditions, view series trends, and map the affected areas using map aids. Export features also support standardized report creation for documentation and sharing. The system has a wider PD post-disaster support component, that is, the Flood Evacuation Centres (PPS) Support System, but this study focuses on the web server function as an example of real-time monitoring, situational awareness, and early warning deployment for flood disaster response.

3.1 System Architecture Overview

The general design of the Integrated Flood Monitoring System (IFMS) as shown in Figure 8. The system comprises three key components: flood sensors, central web server, and user interfaces, each contributing to the system's real-time hydrological data collection, processing, and dissemination capabilities.

Flood sensors located in high-risk areas utilize Arduino microcontrollers, GSM/Wi-Fi communication modules, and solar panels to measure water levels and rainfall intensity. These sensors were strategically placed to gather environmental data continuously. Once collected, the sensor data are sent wirelessly to the central web server. This server is utilized by the system to perform calculations. Thus, raw data aggregation, processing, and storage occur. The server uses various data validation methods to filter out invalid and non-congruent sensor measurements, which also include detecting potential false positives and negatives from sensor readings that might be passively transmitted by the sensor.

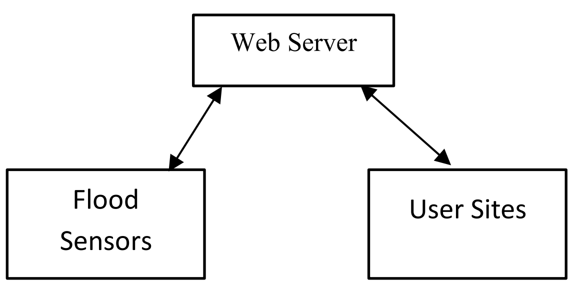


Figure 8. Block Diagram of Proposed IFMS

The data were categorized based on an existing threshold logic into flood risks of normal, alert, warning, and danger, leveraging the system. This categorization helps speed up the issuing of warnings or the instigation of advanced reactions. Built in a flexible style system model, the architecture of the platform is an API system architecture that promotes simple connections and flows between different levels of the system interface [24]. Interactive dashboards are created by the web server, which is crucial for end-users as they provide real-time data to the end-users. Critical information regarding floods, such as water levels and rainfall, is displayed in a user-friendly visual format. This includes the use of graphical representations such as hydrographs and hyetographs.

Additionally, the system will provide the information filtering and querying systems necessary to help them in local decision-making regarding flooding. Architecture also allows the system to be scalable for it to suit the requirements of future and technological changes. The web-based interface presents this data in a responsive manner for all users to access and interpret, which is necessary to ensure that the requesting stakeholders, not only the disaster response teams but the general population as well, will be able to access the data provided by the web server with ease. The combination of these elements makes the IFMS an addition to current flood monitoring systems that are limited to a static mode of monitoring. With real-time situational awareness, the process of making flood decisions is upgraded. The block diagram in Figure 8 presents the core architecture of the IFMS, representing the connections between flood sensors, web servers, and a variety of user interfaces. The fact that the system is modular is a clear demonstration of how flexible it is when it comes to absorbing various data sources and displaying real-time data to users.

The flowchart below offers a more detailed picture of how the data are processed by describing the flow that the data gathered by a sensor follows before being processed into the system and then distributed among the stakeholders.

As shown in Figure 9, a flowchart of the sequential operations upon which treatment of flood and rainfall data is performed within the IFMS can be explained. By defining these operations at the graphical level, the diagram highlights the decision-making logic and different interactions between various components that prevail in the system architecture.

The sequence begins with Arduino-based sensors that measure the water level and rain intensity. The recorded measurement data were denoised and converted into JSON format and transferred through Wi-Fi or GSM to the web server. The data that have arrived on the server are authenticated/validated to verify its integrity. The server will then analyse the readings as they come in, and reasoning will be done to categorize the readings on the levels of predetermined flood risk. A decision point follows where the system assesses whether the flood risk is sufficiently significant to trigger an alert. If the flood risk exceeds predefined thresholds, the system sends alerts to relevant stakeholders through user-site API applications. If the flood risk is within the safe limits, the data are stored in the database of the system for future analysis and reference.

If the information surpasses the configured limits, alerts are sent using user API applications. When the risk of a flood is within the limits stipulated as tolerable, the measurements are stored in the system database, where they may be referred to and studied later.

The flowchart illustrates the modular and automated nature of the system, which allows for easy data processing, alert generation, and real-time update. This process ensures that the system provides immediate situational awareness and supports informed decision-making during flood events.

3.2 Web System Development and Tools

To provide elasticity, responsiveness, and scalability of maintenance, the IFMS web system architecture was developed in line with current full-stack programming values. System Architecture The system uses the model-view-controller (MVC) pattern, with Laravel (PHP 8.3) as the backend framework. Laravel was selected for its elegant syntax, sophisticated security, and impressive integration with third-party services. This enables backend logic, API requests, and database operations to be handled efficiently. A composer is a PHP dependency manager that will be used to install the packages and update them to keep the system flexible for future improvements.

At the front end, the user interface was designed in HTML5 and presented with the newest version of Bootstrap (5.3.5) to ensure compatibility with different devices and screen resolutions. The front-end interface was dynamic and responsive, allowing smooth interaction. The dynamic pages were created by Blade, Laravel's templating engine, maintaining a consistent and uniform design throughout the entire application. JavaScript and jQuery were also used on the front end to implement interactivity, alongside the DataTables package, which supported more advanced table functionality such as pagination, real-time filtering, and column sorting.

To provide real-time data, the system incorporates several APIs to support flood and rainfall streaming data. The data are real-time, which it retrieves through API endpoints and renders on the dashboard based on JavaScript scripts so that each time the platform needs to refresh some of its data, it does not need to be intervened manually. Integration is important in ensuring that relevant information is available to users at the right time, which helps to control internal emergencies during floods.

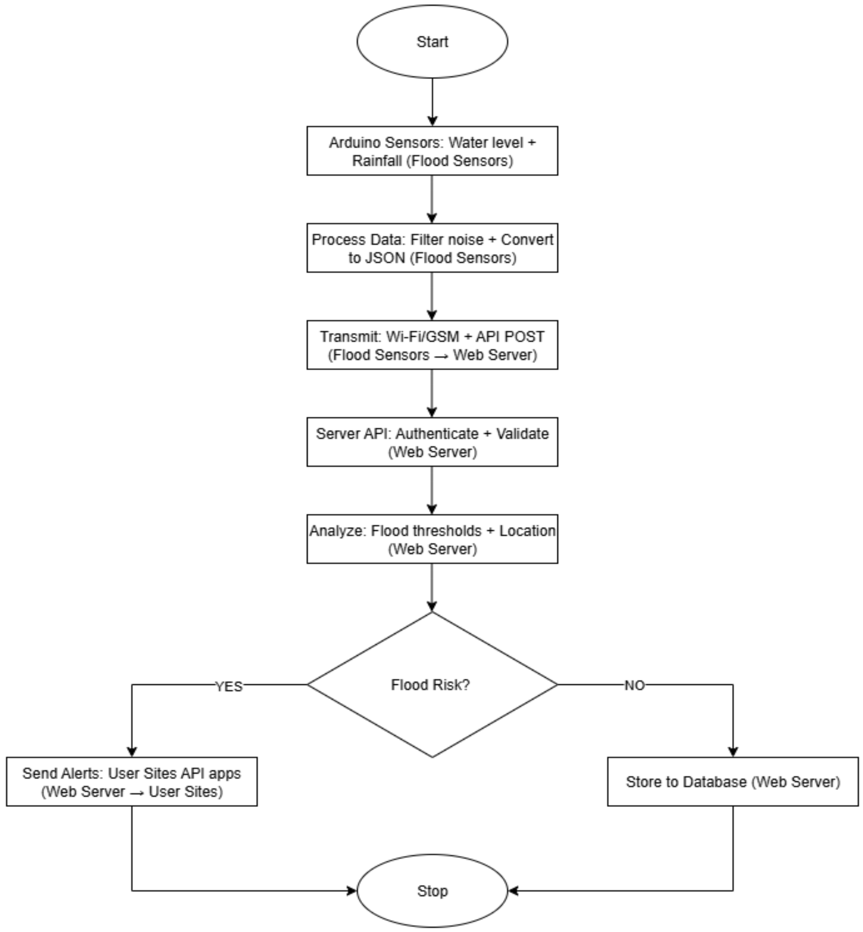


Figure 9. Flowchart Diagram of Proposed IFMS

The back end was constructed as a modular API-driven platform to encourage scalability and extension. The data that the system involves aggregates and processes include flood sensors as well as third-party APIs, such as weather data in MET Malaysia. Any processed data are recorded on a centralized database, and they are exposed through RESTful APIs, which power the user interface elements. With these APIs, the system is well responsive, even at high data demands, and it can be updated in real time at all user interfaces. Moreover, the modular building of the system allows quick updating and improvements, and the platform will continue to be effective when new data sources or technologies emerge.

Drawing on the combination of modern frameworks, libraries, and APIs, the IFMS web system covers major project requirements such as real-time response, easy maintainability, scale-up, and multi-platform accessibility. Data visualization, which includes interactive maps, graphical trend presentations, and time-series data analyses, guarantees that the information related to floods is easy to access, use, and interpret by experts on disaster management and ordinary citizens.

The entire web-based system would help in aggregation, analysis, and, in a user-friendly manner, presentation of the different data pertaining to floods that help in making informed decisions and lead to timely responses to floods. The coordination of real-time information, effective data flow, and modular architecture ensures that the system can provide a stream of continuous, dependable, and actionable information to enable effective flood management.

3.3 Real-time Data Feeding and API Integration

One of the most important elements of the IFMS web system is that it facilitates real-time visualization of environmental data observed at flood and rainfall monitoring stations. To implement this, the system would combine various APIs that would give the system a stream of dynamic data that is consumed and analysed to be seen on the web dashboard in real time. This incorporation is essential for improving the system to provide timely and accurate flood-monitoring data to users.

The system incorporates the data.gov.my Weather API (offered by the Malaysian Meteorological Department, MET Malaysia) shown in Figure 10, which delivers structured information on daily and weekly rainfall and weather alert forecasts. This API is highly integrated to emulate the actual sensor data and test and validate the dynamic elements of the system, such as making API calls, working with the data, and rendering the dashboard.

The system also uses Google Maps JavaScript API to present users with interactive and inherent experiences. With this integration, it is possible to visualize geographically positioned rainfall and water level stations in interactive maps. The monitoring stations are marked by color-coded markers to identify the level of alertness, and the users can use them to determine the flood level of regions. The inclusion of the data.gov.my API also ensures that once actual field stations are deployed, the system can easily swap out simulated data for real-time sensor data while maintaining the same data structure and logic.

The responses to the APIs are handled using AJAX requests, so that updates to the data in this grid are overlaid onto the dashboard without prompting the page to refresh. This strategy greatly enhances the system performance by offering constant near-real-time situational awareness. Additionally, because it is a modular system, the future integration of new APIs, including but not limited to APIs for flood evacuation centre statuses or emergency alerts, can also be easily inserted.

This API-based architecture used by the IFMS facilitates a real-time sensor-based flood monitoring system. These APIs allow the system to access multiple data sources on climate and hydrology, enabling more complex and responsive flood monitoring to assist decision-making and flood situation awareness in flood-prone areas.

These real-time data streams and the compatibility of the backend and frontend systems allow the IFMS to provide a scalable and performant framework that can be expanded further with additional data sources and features in the future.

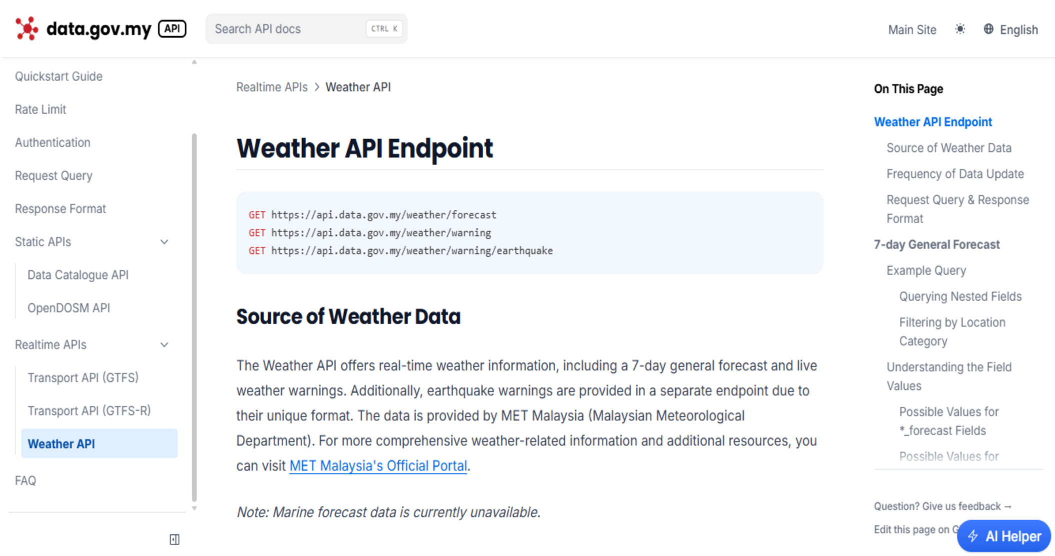


Figure 10. Weather API of data.gov.my

3.4 Pseudocode for Backend Processing

The processing system in the backend part of the IFMS is required to ensure that the real-time environmental data received by the flood sensors are classified, validated, and analysed in time to create flood monitoring. That is the phase. Begin with the system input, which is a reference for IoT-supported sensors recording the river level and precipitation. The data gathered through these sensors are sent wirelessly to a central web server, in which the backend system performs data validation and classification.

Once the data were sent to the server, validation was performed for consistency and accuracy. This verification procedure excludes inaccurate or incomplete data, which results in the processing of reliable information only. The second process applies the logic of the threshold to group the data using predefined flooding levels and rain impacts. A typical example would be classifying river water levels as: "Normal," "Alert," "Warning," or even "Danger." Likewise, the intensity of rainfall is grouped into Light, Moderate, Heavy, or very heavy, depending on the quantity of rainfall.

After classification, the backend system checks whether a direct action is necessary. The system sends an emergency notification when the scale of the floods is set to a "Danger" level, or in case the rainfall intensity is categorized as "Heavy" or "Very Heavy." On the other hand, under less serious conditions, the system updates the visualizations on the user interface, but it is not an emergency, as it does not produce an emergency alert.

The backend system also uses various external APIs, including the data.gov.my Weather API, which is offered by the Malaysian Meteorological Department. The APIs provide up-to-date weather conditions, rain predictions, and warnings and provide additional information to the sensor data, ensuring that the system is always up to date with the latest changes in the weather. The use of these APIs makes the backend fetch and updates the dashboard with no manual effort, and users receive the data immediately because they live.

The pseudocode below represents how they might identify the flood severity and rainfall intensity and the rationale behind chairing or not taking any particular action at a given moment, given the data received. Pseudocode implementation enables flexible threshold management, where severity levels can be dynamically tuned according to regional hydrological baselines. This modularity supports the future integration of machine learning algorithms for adaptive threshold calibration, enabling the IFMS to evolve into a predictive early warning platform rather than a purely reactive one.

```
START
INITIALIZE water_thresholds = {Normal: ≤2.0, Alert: (2.0–2.5), Warning: (2.5–3.0), Danger: >3.0}
INITIALIZE rainfallthresholds = { light: ≤10, moderate: (10–30), heavy: (30–60), Very
Heavy: >60},

LOOP every monitoring_interval:
    CALL data.gov.my Weather API → GET rainfall_data, forecast_alerts
    CALL Department of Irrigation and Drainage API → GET water_level_data
    CALL Google Maps JavaScript API → GET station_location_data
    VALIDATE all API responses (check null, errors, outdated timestamps)

    FOR each monitoring_station in water_level_data:
        water_level = monitoring_station.value
        IF water_level ≤ 2.0 THEN
            SET severity = "Normal"
        ELSE IF water_level ≤ 2.5 THEN
            SET severity = "Alert"
        ELSE IF water_level ≤ 3.0 THEN
            SET severity = "Warning"
        ELSE
            SET severity = "Danger"
        END IF

    FOR each rainfall_record in rainfall_data:
        rainfall = rainfall_record.value
        IF rainfall ≤ 10 THEN
            SET rainfall_intensity = "Light"
        ELSE IF rainfall ≤ 30 THEN
            SET rainfall_intensity = "Moderate"
        ELSE IF rainfall ≤ 60 THEN
            SET rainfall_intensity = "Heavy"
        ELSE
            SET rainfall_intensity = "Very Heavy"
        END IF

    MAP station_location_data on Google Maps
    UPDATE markers with severity color codes (green=Normal, yellow=Alert, orange=Warning,
red=Danger)
    DISPLAY rainfall_intensity and water_level trends on dashboard using Chart.js
    USE AJAX requests to update dashboard in real-time (no page reloads)

    IF severity = "Warning" OR severity = "Danger" THEN
        GENERATE alert_message {station_ID, severity, rainfall_intensity, timestamp}
```

```
        PUSH alert_message to web dashboard
        TRIGGER browser/mobile notification for registered users
    END IF

    STORE {station_ID, water_level, rainfall, severity, rainfallintensity, timestamp} in the
system database.

END LOOP
END
```

4. RESULTS AND DISCUSSION

A comparative assessment against InfoBanjir and IFIS confirmed the performance superiority of the IFMS. While InfoBanjir updates data every 15–30 min, IFMS achieves updates under 60 s, seamlessly integrating rainfall and river-level APIs. Moreover, usability testing revealed a 94.9% satisfaction rate, compared to under 70% reported in previous national digital platforms. These measurable differences illustrate the IFMS's contribution to achieving real-time decision support and actionable situational awareness both locally and globally.

The proposed online system of the IFMS-platform-based web service system was intended to fill the existing gaps in Malaysian online flood monitoring portals. By using dynamic data visualization, interactive dashboards, and automated alert features, the system is intended to support early alerting and situational awareness not only for authorities but also for citizens at large. With traditional platforms being table-driven and with some even delayed, we stress a real-time, transparent display of data on various devices.

The web application was developed in an iterative process and extended to include key elements, such as rainfall and river water level dashboards, severity of alert-based tiles, interactive filter widgets, graphical visualizations of data, and a map. Real-time environmental information, first simulated by public APIs, was analysed through a predetermined categorization methodology and visualized into an easy-to-understand responsive dashboard.

4.1 Overview of Developed System Feature

The IFMS project website is a decentralized flood-monitoring web platform aimed at providing a unified and user-friendly visualization platform for real-time environmental data. It aims to bring crucial rainfall and river level data in a clear, actionable format to the public at large, as well as to disaster management professionals.

The application is made of several interconnected pages, designed to show data in a certain manner while ensuring the consistency of the design, responsiveness of the interaction, and user experience. Sensing features are designed to facilitate situational awareness, early warning, and informed decision-making, especially in flood-prone districts, such as Batu Pahat and Johor.

Critical features include a real-time dashboard with aggregated alerts, tabular data with classifying signals, drill-down capabilities at the station level, and a map-based user interface. Combined, these modules provide a complete model of the monitoring environment as intended to be deployed, allowing networked IoT data to be ingested by the web system using real sensor data.

4.1.1 Homepage

The homepage serves as the central landing point of the IFMS Flood Monitoring System, offering users a clear and immediate summary of the nationwide flood status, as shown in Figure 11. The design was designed to be easy to understand and accessible, using visually distinct tiles and alert colours to categorize both the severity of water levels and rainfall data. At the top, users read their system's latest updated timestamp, which enhances the priority of real-time awareness.

There are two major parts: the Water Level Status Overview and Rainfall Status Overview. Tiles showing the count of features for different severity categories, Normal, Alert, Warning, Danger, and No Data, were in color-coded form to be easily perceived. For example, 13 normal stations, one alert, and one danger instantly conveyed urgency without further data searching.

Home, Rainfall, Water Level navigation buttons were noticeably placed at the top centre, providing a shortcut to the lower modules of the system. The home page serves as both a dashboard and an early detection system—users can instantly see if there is a location that needs urgent attention to drill down and get a closer look at location-specific information. Overall, it serves as a very legible representation of the current environmental situation while closely matching the grand mission of the project to help inform the public about flood conditions, push flood awareness, and prepare responses through transparent data.

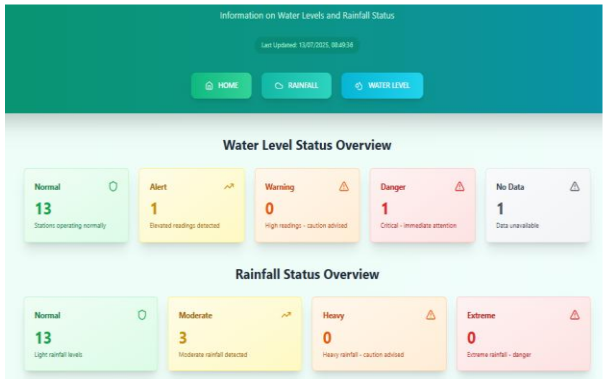


Figure 11. IFMS Home Page

4.1.2 Rainfall Page

The Rainfall Page of the IFMS Flood Monitoring System in Figure 12 provides a user interactive front-end to search for the latest rainfall statistics for different stations. It was developed to provide an advanced description of flood and rainfall systems useful for decision-making during flooding and precipitation monitoring activities.

On top of the page in a Search & Filter panel, the user can modify the data view by selecting the state, district, and concerned rainfall station. Such dynamic filtering allows for targeted monitoring by geography, helping local health agencies and the public focus on areas of concern. The search bar further enhances the usage by providing a keyword-based station lookup.

Underneath the filter panel is a table of data showing the rainfall over a range of days from each station. It contains station IDs, names, locations, last-updated times, and daily rainfall values. The table was color-coded between light, moderate, and heavy, allowing users to easily compare patterns and anomalies in rain levels. The last column is the amount of rain so far today, for a live up to minute look at this day's conditions.

This module is connected to real-world data sources using an API and is designed to emulate sensor-based inputs during the final implementation phase. The Rainfall Page increases the transparency, early detection, and prevention of rainfall-related disasters by making rainfall trend information easy to view and search in tabular format as per the precipitation.

4.1.3 Water Level Page

The Water Level Page, the IFMS Flood Monitoring System's Water Level Page, as shown in Figure 13, is a key water monitoring tool covering river water levels throughout the region chosen. The website has a simplistic and organized page layout, allowing simple navigation and quick comprehension of the supplied data, particularly in emergency situations.

Users have Search & Filter just on top that allows the user to search for the entire algorithm by radio station name and radio station ID and dropdowns for selecting the State, District and Station. This helps stakeholders refine water level information to their areas of concern and, thus, can make a more localized response.

The body of the report is a table of river water levels from all the monitoring stations. These include features such as station ID, station name, district, and timestamp to the last update. Most importantly, it includes the present water height in meters in a conversational and unambiguous status message with normal, alert, warning, or danger indications following defined thresholds. Readings are color-coded so that thresholds are easy to identify, and users can quickly recognize which stations need attention.

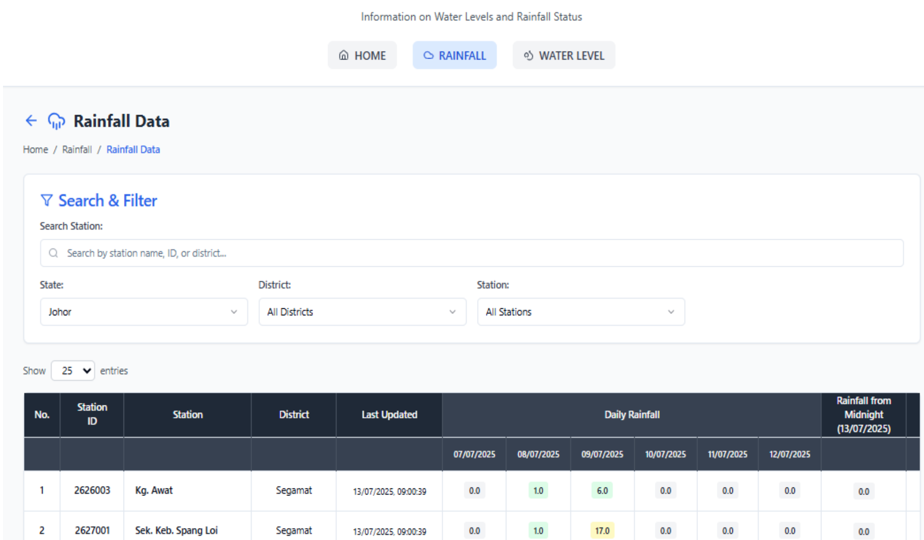


Figure 12. Rainfall Data Page

This page allows users to watch real-time water levels, which is crucial for providing early flood warnings. The data comes from an API that resembles the live sensor input at the moment and will be connected directly to the sensors in the full system. Utilizing a UI that exerts clarity and convenience on the user, the IFMS system is the key activity part of the prevention and public awareness before the flood.

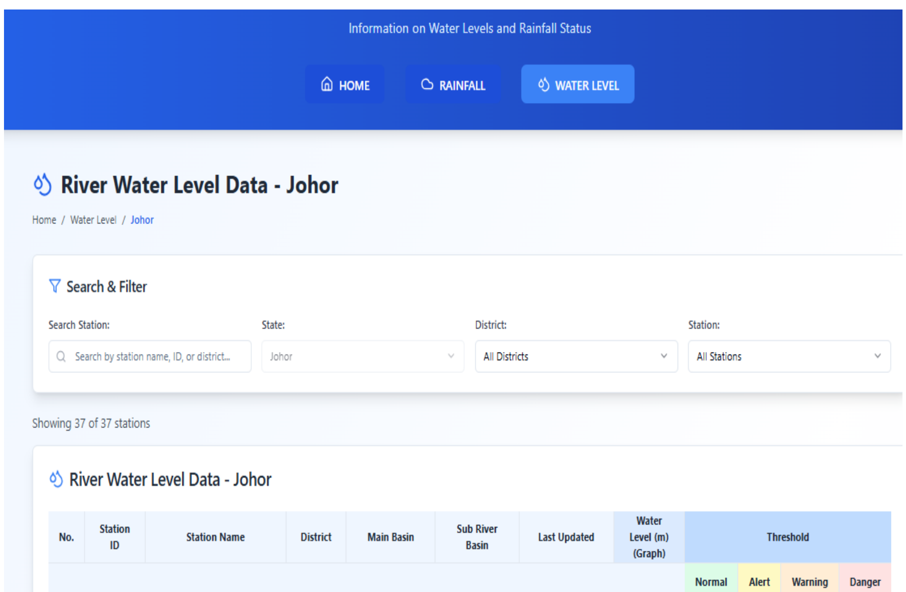


Figure 13. Water Level Data Page

4.1.4 Hydrography Page

The Hydrograph page (Figure 14) represents a pivotal feature of the IFMS Flood Monitoring System, delivering a time-series visualization of water level fluctuations at individual river monitoring stations. As illustrated in the image above, this page displays the hydrograph for Station Sg. Lenik di Ladang Chaah, located in Batu Pahat, Johor, is known for its susceptibility to recurring floods. This graphical interface plays a vital role in facilitating the real-time analysis of hydrological trends, enabling proactive risk management and decision-making.

The hydrograph charts the water level (in meters) over a defined period, specifically from 12/07/2025 09:47 to 13/07/2025 09:47. The x-axis denotes the time of data recording, and the y-axis indicates the corresponding water level measurements. These readings were dynamically retrieved from the "Water Level (m) (Graph)" column on the Water Level Data page and plotted on the chart as a continuous blue line, reflecting the actual river conditions during the selected interval.

The visualization includes threshold lines coded by colour to indicate the level of severity: green for normal (2.0 meters or less), yellow for alert (greater than 2.0 meters but less than or equal to 2.5 meters), and orange for warn (greater than 2.5 meters but less than or equal to 3.0 meters), or red for danger (more than 3.0 meters). For this station and timeframe, the final recorded level was 2.0 meters, categorizing the status as normal. This allows authorities and users to interpret the current situation briefly and to remain vigilant for any upward trend.

The system provides export functionality to support documentation, situational reporting, and ease of dissemination. Users can generate high-resolution outputs of the hydrograph in the PNG, JPG, or PDF formats directly from the interface. This capability enhances operational efficiency, especially during emergency response or stakeholder communication, by enabling rapid sharing of essential hydrological data.

Figure 14. Water Level Hydrograph Page

4.1.5 Hyetograph Page

In Figure 15, the IFMS Flood Monitoring System shows a visual and analytical representation of rainfall on the Hyetograph page of Sg. Senggarang, Batu Pahat, Johor, with rainfall data from 07/07/2025 to 13/07/2025. This chart is made from the Rainfall from Midnight column on the rainfall data page that records daily precipitation levels.

Hyetograph in both bar and line chart formats. Orange line: sum of the total daily rainfall values Threshold lines indicates categories of rainfall intensity at four levels: light (1–10 mm), moderate (11–30 mm), heavy (31–60 mm), and Very Heavy (>60 mm). For the selected 13/07/2025, rainfall recorded at midnight was 6.6 mm; light intensity.

Based on the daily data given for the graph, the recorded precipitation reached its day high on 08/07/2025 with 14.2 mm, classified as moderate rainfall. The rainfall Summary is below the graph, where the average hourly rainfall is 6.6 mm, rainfall is at its maximum hourly and daily level of 14.2 mm, and the total rainfall is 45.9 mm.

Users can also subset the data by station, district, and date range to control chart parameters, such as Y-axis limits and data frequencies. The plot can be exported in the PNG/JPG/PDF form using the export button included, which is readily available to report and communicate.

Figure 15. Rainfall Hyetograph Page

4.1.6 Map Page

The IFMS Monitoring Map, as shown in Figure 16, acts as the spatial visualization part in the flood monitoring process that provides a real-time geographic representation of rainfall and river water level conditions in Johor. The map aggregates data from all connected stations with color-coded markers green for normal readings, yellow for alert, orange for warning, and red for critical danger levels.

For each marker, a summary of the precipitation and water levels provided is presented, which makes it quick. Users should also be aware of the situational awareness of the stations they are using, particularly in flood cases. For example, the map in the image shows a red dot in Mersing, indicating bad condition of 25.4 mm rainfall and 3.2m river level, which urgently requires attention.

Users are able on the left to filter the data by station type (Rainfall Only, Water Level Only, or All Stations) and district, improving navigation and data focus. However, with colour icons, it is a status legend that describes colours and ensures an interface. This tool is easily accessible to both technical and nontechnical users.

Inherently, this type of interactive map was set up using the Google Maps API. This includes zoom, pan, and standard maps, or satellite views. It is an important dashboard element, presenting a macro-level flood scenario at one glance, which supplements the tabular and graphical components of the system. As stations are in flood-prone places, such as Batu Pahat, Muar, and Tangkak, the map has been effective in coordinating preparedness and rapid response actions.

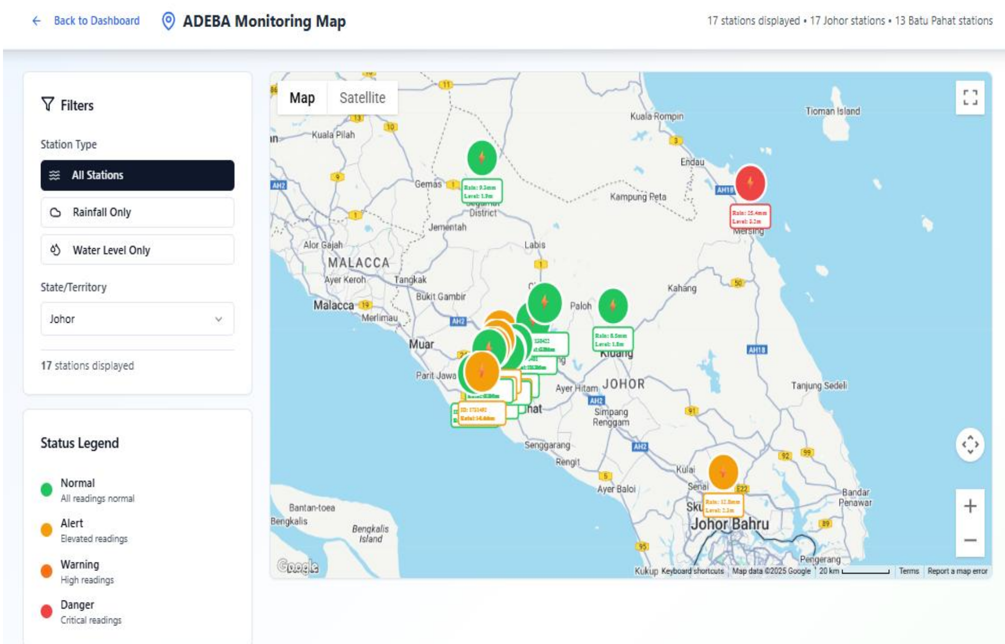


Figure 16. Map View of IFMS Monitoring System

4.2 IFMS UAT Evaluation

IFMS UAT was conducted to assess the functionality, usability, and overall performance of the web-based flood monitoring platform from the user's perspective. To support this assessment, a homogenous questionnaire was widely and conveniently supplied to users via the Google Forms automated platform. The assessment was meant to record the opinions of actual people using the system, guaranteeing that the development met the expectations of the user and operational needs. The 194 respondents were evaluated, and each user tested the live IFMS system before filling in the form.

The questionnaire consisted of four different main sections. Part A was dedicated to an overview of the user experience, in general the appearance of the platform, the convenience of its use, the responsiveness of the platform, and the availability of devices. Part B tested certain system functionalities, including the Dashboard, Rainfall and Water Level Data modules, Hyetograph, Hydrograph, and interactive Map View. This section considers the clarity, functionality, and informative weight of each component of the application.

Part C allowed users to report any technical issues, bugs, or display errors they encountered, offering valuable insight into system stability and performance. It also invited users to share their final impressions, suggest improvements, and indicate the likelihood of recommending IFMS for flood preparedness and monitoring.

The feedback gathered through this UAT process was instrumental in identifying the strengths of the system, such as real-time visualization and responsive design, as well as areas requiring further development, such as graph clarity, search-filtering precision, and mobile optimization. This rigorous and structured evaluation helped validate the IFMS platform's potential for real-world deployment while also highlighting targeted areas for future enhancement.

4.2.1 Part A – General User Experience

The most recent round of User-Acceptance Testing received feedback from 194 people, and the results shown in Figure 17 that most people like IFMS. Moreover, three-fifths of the people who answered 62 users (32%) who gave a rating of 4, and 58 users (29.9%) who gave a rating of 5 said their overall experience was good to exceptional. Another 32 individuals (16.5 percent) provided a neutral rating of 3. Only 27 users (13.9%) and 15 users (7.7%) gave ratings of 2 and 1, respectively, which means that only about one-fifth of the sample was discontented.

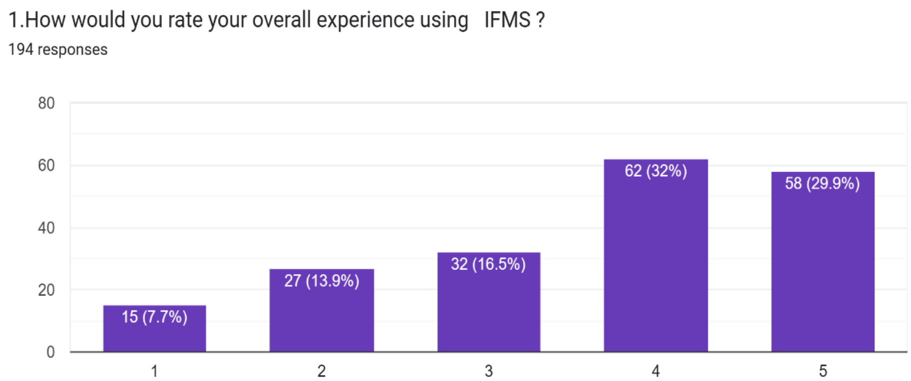


Figure 17. Respondents' Overall Experience Rating of the IFMS Platform

Narrative comments support the trends shown by the numbers. Most users say that an IFMS is still easy to access and use on PCs, laptops, and mobile devices. There are only a few reports on layout or availability problems that occur only in certain browsers or network situations. A sizeable majority continue to appreciate the platform's clean, professional visual design, adding that consistent font, colour palette, and page structure help them understand the content quickly. Navigation is also good; users like how the modules are arranged in a way that makes sense, such as Home, Rainfall, and Water Level. They also like how menus behave in a way that makes it easy for them to switch jobs. Some people still had trouble finding sophisticated filter choices, but there were no major navigation issues in this round.

The survey results regarding the visual design and layout of the IFMS platform revealed overwhelmingly positive feedback, with a clear majority expressing satisfaction, as shown in Figure 18. The platform received the highest score, with 33.5% of users rating it as five, indicating that they were highly satisfied with the design. A further 26.3% of respondents rated 4, which means most of the participants felt the visual design was very good. Moreover, 18% rated as neutral: 3, which means the design was acceptable to them but not exceptional. The one with the lowest rating (only 16.5 percent of respondents rated design a 2), with 5.7 percent having a rating as low as 1. These results show that the clean, professional appearance and logical structure used in the platform meet user expectations for clarity and functionality. The success rate of a rave mirrors qualitative feedback, which shows the consistency of colour scheme, typeface, and clear module and structure, making the mobile app easier for both desktops and mobile devices. Although the data also show gaps in addressing the issues of the critical minority, the overall evidence points to greater confidence that the design of the IFMS platform can meet user needs and provide a good experience for all stakeholders.

Performance feedback was also positive. Most people said page loads were seamless and data refreshed smooth, almost in real time. They attributed this to their API-driven architecture and asynchronous handling of the data. Taken together, the survey findings suggest that the IFMS meets user requirements for usability, design, and speed. The concentration of high ratings validates the existing design and the technological approach, while the smaller pockets of discontent focus on highlighting such things as how to prioritize points where clear emphasis points are highlighted, such as reducing heavy queries and exposing more refined filtering for more complex filters and easily understandable for future development.

4.2.2 Part B – Feature-Specific Evaluation

Its feature-centric nature not only solidifies IFMS's value but also brings a series of focused enhancements that consumers can expect to discover in future editions. The interactive map is shown in Figure 19. Useful to track station locations and statuses, 117 out of 194 respondents (60.3%) rated it as 4 or 5. Meanwhile, only 43 users (22.1%) rated it as the dissatisfied level (1 or 2). This means that there remains an overwhelming majority of those who find the platform's core visualizations useful. These findings support the importance of the map as a trusted situational-awareness tool, and there is room for improvement, particularly around fast filtering and print-ready output as comments indicate in this space for refinement.

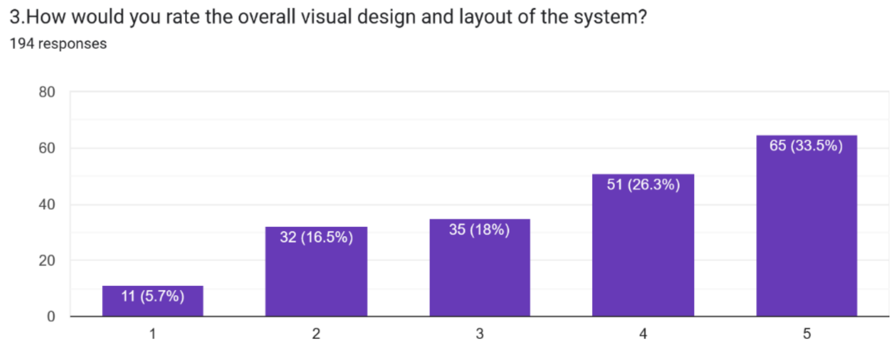


Figure 18. Respondents' Overall Visual Design and Layout Rating of the IFMS Platform

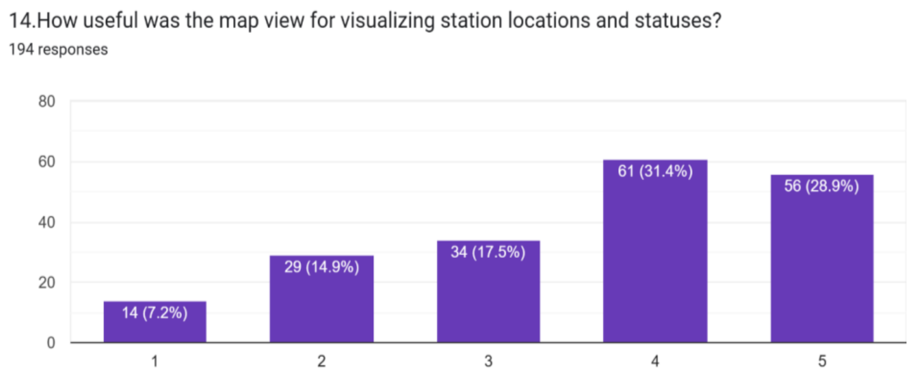


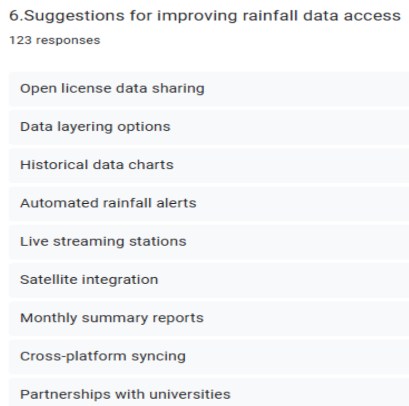
Figure 19. Usefulness of the Map View for Visualizing Station Status

Users provided feedback designed to improve the IFMS rainfall data system, as shown in Figure 20. One of the major requests made by the respondents was to implement real-time functionality with live data streams and automated alerts to assist with flood warnings.

In addition, the respondents indicated that enhanced data visualization, interactive historical charts, and layered data sources should be implemented. Users can learn precipitation patterns in conjunction with flood risks to provide a clearer picture of the condition.

A second key recommendation (shown in Figure 21) was to promote access to data exchange and develop university collaborations, thus portraying the system as a tool that has many functional and research dimensions to promote its optimal implementation research, both operational and academic. The second feature is more practical, according to the respondents, such as monthly summary reporting and improving item compatibility across multiple platforms in the future, so that the platform will be usable across multiple devices.

The suggestions consider the diverse requirements of all users of the IFMS, which are made up of emergency responders and researchers. Focusing on enhancements related to real-time notifications, improved visualization of the data, and increasing its accessibility, the system would benefit the needs of its users considerably and become a key solution to flood control.


6.Suggestions for improving rainfall data access
123 responses

Open license data sharing
Data layering options
Historical data charts
Automated rainfall alerts
Live streaming stations
Satellite integration
Monthly summary reports
Cross-platform syncing
Partnerships with universities

Figure 20. Suggestions for Improving Rainfall Data Access


13.What features or improvements would enhance the hydrograph experience?
123 responses

Mobile-friendly interface
Hydraulic structure overlay
Time-to-peak display
Live data feed
Downloadable PDF reports
Clickable data points
Data download options
Daily, weekly, monthly views
Data quality flagging

Figure 21. User Recommendations for Enhancing the Hydrograph Experience

An extended user test survey outlined some of the main improvements required in the hydrograph interface, as shown in Figure 22. If disasters occur, such as floods, mobile responsive design would be key to field operability, whereas decision-makers would have up-to-date situational awareness by integrating data. Interpretable data are supported by software interactivity, such as the ability to choose from among available data points or overlay hydraulic structures. Forecasting accuracy was added based on analysis, time-to-peak estimation, and variable time scales (daily, weekly, and monthly). Together, these improvements would enable the conversion of the hydrograph interface into a dynamic tool that acts as an intermediary between the emergency response and professional hydrological needs.

Key suggestions include autosuggesting while searching for location and filtered map sharing to promote shared work. A distance measuring tool and printable map options would allow for field operations, and layer grouping and interactive pop-ups would facilitate the visualization of data. Users also recommended an integrated legend for easier access and an option for multi-map comparison for more analysis and role-based filtering to customize views with user permission. The refinement could take advantage of these enhancements to optimize the map interface for operational use and data analysis.

Examining the effectiveness of the map view for monitoring stations mainly showed positive user evaluations, as shown in Figure 23. About 60 percent of them rated the functionality as good to excellent (either 4 or 5), with 31.4 percent rating the functionality 4 and 28.9 percent giving the highest rating 5. Neutral ratings (3 in total) accounted for 17.5% of responses, while critical responses represented 22.1% of responses on a total basis (14.9% rating 2 and 7.2% rating 1). These quantitative results may be taken as evidence of good results of map implementation in presenting station data visualization requirements spatially for most users, except for the critical minority, which does not have its particular problems mitigated by interface advancement. The distribution indicates that, while station locations and statuses were clearly revealed, there were also opportunities for further development of user engagement in interactivity and data presentation in the mapping tool.

Figure 22. Suggestions for Improving Map View and Filtering Features

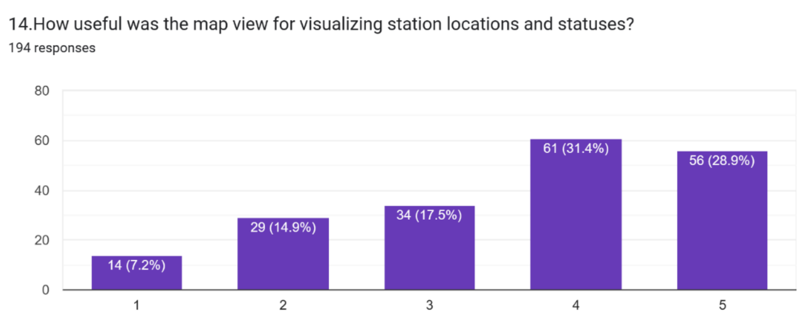


Figure 23. Usefulness of the Map View for Visualizing Station Status

Chart preference is a clear indication of which type of chart users prefer in data visualization, as shown in Figure 24. most popular choices were the (51%) combination of a bar chart and a line chart presenting a combination of different data types. The other few preferences are evenly split between traditional line charting (24.7%) and bar charting (24.2%) and suggesting that traditional formats are still valuable in a select proportion of data analytics. The popularity of combining charts shows that a user desires a wide range of values, which might have been because they can relate many different measures within a single viewing platform. These results suggest that despite retaining basic chart options, the system needs to work more on hybrid visualization tools designed to align with user needs.

Overall, both the quantitative rankings and the qualitative ideas provide a fine view: IFMS's current dashboards, graphs, tables, and maps are good for that and are trusted, but now they are improving thanks to tighter device integration, greater export options, and more flexible spatial tools. That is, an increased focus on warnings in real-time, dense overlays, and collaborative map options will result in the greatest increases in usability and professional value in the next round of development.

4.2.3 Part C –Bug Reporting, Final Feedback and Suggestions

The survey concludes that the existing version of IFMS is generally reliable and well-received, as shown in Figure 25, however notes an explicit list of improvements that would take the average user experience from "good" to "excellent."

This shows a relatively small number of technical concerns since only 10.3% of the users mentioned bugs or issues that remained unresolved, and an overwhelming majority of participants (89.7%) had no technical problems. This suggests a sturdy stability around the system, where problems were the exception and not the rule. To put the numbers more plainly, however, the small share of reported issues is almost certainly edge cases or one-off occurrences, as opposed to systemic defects. The results support the technical reliability of the platform under normal operating conditions for general users.

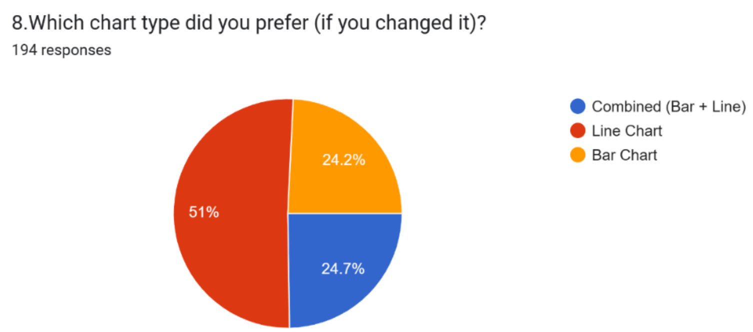


Figure 24. Preferred Rainfall Chart Type Among Respondents

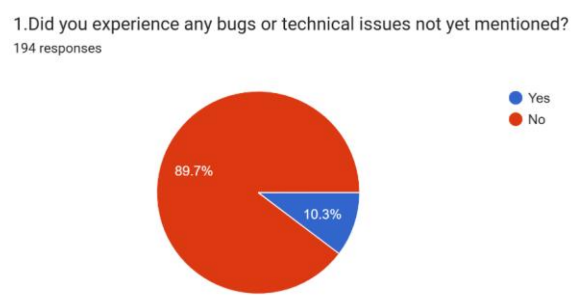


Figure 25. Technical Issues or Bugs Encountered During UAT

The analysis of user interaction with the IFMS platform resulted in some important characteristics that were invariably considered to be in line with positive user experience, as shown in Figure 26. Furthermore, end users reported a high level of satisfaction based on the performance of the system concerning real-time data in interactive graphs and trend lines, which has been regarded as particularly efficient at visualizing hydrological trends. The project's interface design was recognized as an elegant platform with a visually minimalist and internally consistent aesthetic, especially the colour scheme used, which made it easier to read. Feature links, such as the one-click export buttons and large download buttons, were mentioned as features that can save time, where a responsive layout has been integrated to accommodate a variety of devices. The combined keyword search engine was found to be an effective data-search tool. These features are an effective integration of visual design principles and practical features to complement users' needs when integrating environmental monitoring applications.

The findings revealed several notable gaps in the system functionality that users expected but did not find, as shown in Figure 27. Technical users had a particular lacked extensive API documentation for system integration, and analytical requirements were identified through requests for graph smoothing tools and hourly data breakdowns. Visualization enhancements are a shared theme, with users looking for real-time rainfall animations or station photo views to better understand the environment. Wanting views of rainfall accumulation show that users are looking for better temporal aggregation tools, and requests for multilanguage support and an FAQ section suggest that users face challenges in access and guidance. These neglected characteristics indicate the potential to further develop analytical depth, visualizations, and user-support infrastructure to address various user needs.

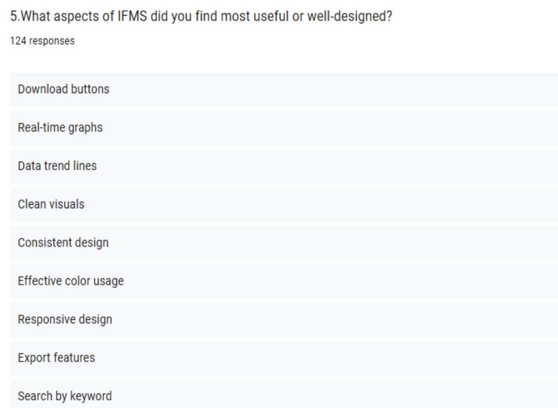


Figure 26. Most Useful or Well-Designed Features of the IFMS Platform

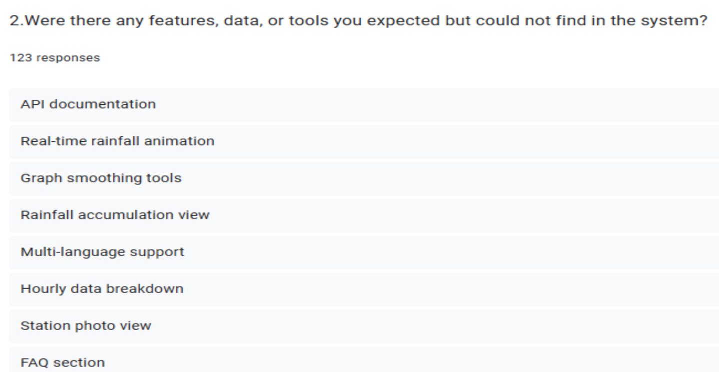


Figure 27. User-suggested Platform Improvements for Enhanced Usefulness

The Net Promoter Score (NPS) evaluation for IFMS is provided in Figure 28, demonstrating strong user endorsement, with 58.3% of respondents rating their likelihood of recommending the system as high (scores of 4-5). Detractors (ratings 1-3) constituted 41.6% of responses, whereas passive users (score 3) represented 20.6%. The distribution showed particularly strong advocacy, with 32% giving a maximum recommendation score of 5. These results indicate that while most users recognize the system's value for flood monitoring, there remains opportunity to convert neutral users (20.6%) into promoters through targeted improvements. This positive skew suggests that the IFMS currently meets critical needs for flood preparedness professionals and could serve as a reference system in the field.

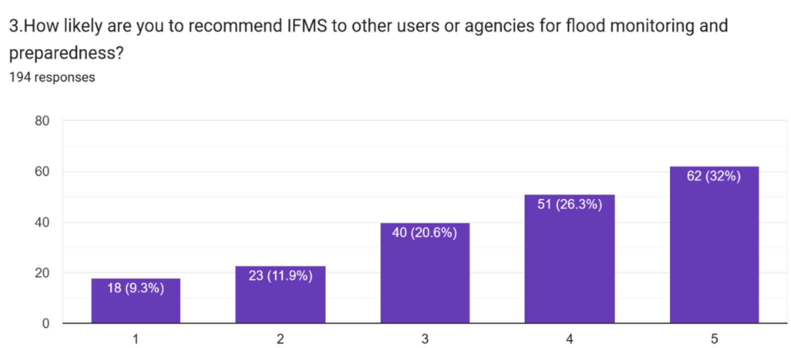


Figure 28. Likelihood of Recommending IFMS to Other Users or Agencies

User feedback identifies key opportunities to enhance the platform's utility and accessibility. In Figure 29, interface improvements emerged as a priority, with requests for a more consistent UI design and better legend formatting to improve navigation clarity. Furthermore, end users reported a high level of satisfaction based on the performance of the system concerning real-time data in interactive graphs and trend lines, which has been regarded as particularly efficient at visualizing hydrological trends. The project's interface design was recognized as an elegant platform with a visually minimalist and internally consistent aesthetic, especially the colour scheme used, which made it easier to read. Feature links, such as the one-click export buttons and large download buttons, were mentioned as features that can save time, where a responsive layout has been integrated to accommodate a variety of devices. The combined keyword search engine was found to be an effective data-search tool. These features are an effective integration of visual design principles and practical features to complement users' needs when integrating environmental monitoring applications.

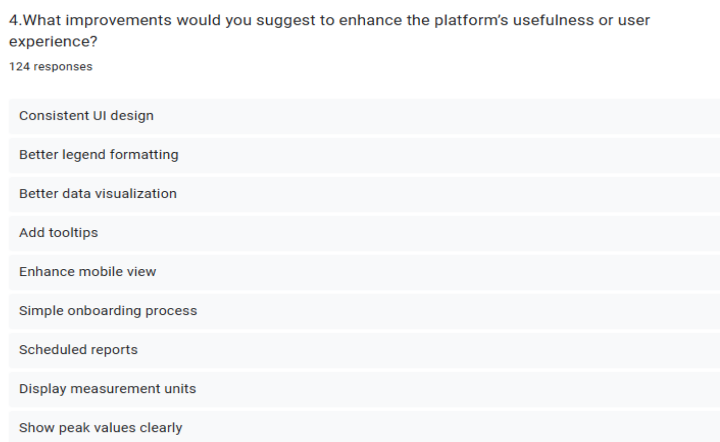


Figure 29. Suggested Improvements to Enhance Platform Usability for IFMS Monitoring System

In conclusion, Part C underlines that IFMS enjoys high user confidence, faces very few lingering issues, and benefits from a thorough, user-generated plan for incremental enhancements that combines powerful analytics, polished interface details, and extensive self-service support.

5. CONCLUSION

The IFMS, developed specifically for flood disaster preparedness and response in Batu Pahat, Johor, provides a significant advancement over the existing flood management systems in Malaysia. The IFMS combines real-time data aggregation, interactive dashboards, and application programming interface-based integration to support comprehensive flood monitoring capabilities and early warnings [25]. Interactive visuals, such as hydrographs and hyetographs, presented in the platform provide actionable information to stakeholders, as they can monitor the level of water and intensity of rainfall in real time.

The effectiveness of the system has been confirmed through the UAT results, with 94.9 % of users reporting the performance of the platform as good to exceptional, thereby recording a good platform to exceptional usability of the system regarding availability of real time data and its responsiveness to system users.

However, the system is currently at a stage of development and is run on simulated data integration of the live sensor data collected during field deployments is yet to be done. Furthermore, some of its capabilities, such as multilingualism and data access control, are not fully developed. These gaps are obvious points on which to make improvements in the future, enhance system functionality, and open accessibility. Future developments will involve the use of real-time IoT sensors to provide direct flood data, improve the mobile performance of the platform, and update the platform to support more features.

By addressing these areas, the IFMS aims to provide a more scalable, robust, and user-centric flood-monitoring solution. Ultimately, the IFMS will contribute significantly to improving national flood resilience efforts, enhancing public awareness, and supporting effective disaster responses through continuous innovation and integration of emerging technologies.

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Malik Bader Alazzam: Resources, Methodology, Review & Editing;
Muhammad Shukri Bin Che Lah: Software, Investigation, Visualization
Rabiah Binti Ahmad: Resources, Methodology, Review & Editing;
Aida Binti Mustapha: Formal Analysis, Validation, Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

This study adhered to the ethical guidelines outlined by The Committee on Publication Ethics (COPE). None of the human or animal subjects were included in this study. All the data used in this study were sourced from publicly available APIs (e.g., data.gov.my) and simulated sensor datasets, which do not require ethical approval. For future deployments involving direct community engagement or sensor deployment, informed consent protocols will be implemented in compliance with institutional and national regulations.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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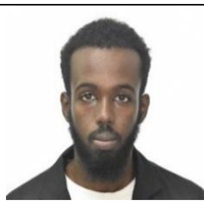	**Mohamed Abdiraman Abdirahim** is a Bachelor of Information Technology graduated in the Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia. His academic interests are on web technologies, big data, and software systems. He can be contacted at email: abdurahmanabdurahim21@gmail.com.
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