



## Development of a Sensor-Based Flood Early Warning System with SMS Notification in Urban River Restoration Contexts

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### Article History

Received : December 12, 2025

Revised : January 19, 2026

Accepted : January, 27 2026

Published : January, 30 2026

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### Cite This Article [APA Style]:

Wedagama, D. A. T. A.,  
Indrashwara, D. C., &  
Suryaningrat A, D. A. N. N.  
(2026). Development of a Sensor-  
Based Flood Early Warning  
System with SMS Notification in  
Urban River Restoration  
Contexts. *Jurnal Ilmiah  
Teknik*, 5(1), 325–338.

### DOI:

<https://doi.org/10.56127/juit.v5i1.1351>

**Abstract:** Urban river restoration areas that function as public spaces and tourism destinations are increasingly exposed to flood risks due to changing hydrological conditions, urbanization, and limited early warning mechanisms. **Objective:** This study aims to design and implement an automatic flood early warning system based on water level sensors and SMS notifications in the Tukad Tagtag river restoration area, Denpasar, in order to improve flood risk mitigation and public safety. **Methodology:** This research employs a qualitative applied approach using the Action Research method, which integrates planning, action, observation, and reflection. Data were collected through field observation, system testing, stakeholder consultation, and document analysis. The analysis was conducted using a descriptive and iterative evaluation approach to assess system performance and improvement. **Findings:** The system successfully detects water level changes in real time, triggers threshold-based alerts, and delivers SMS notifications effectively. System performance improved after iterative adjustments, particularly in sensor positioning and microcontroller configuration, resulting in enhanced stability and reduced false warnings. **Implications:** The study demonstrates that simple and accessible technology can support effective flood risk mitigation. The system can be applied by local governments and river managers to enhance preparedness, response time, and safety in urban river environments. **Originality:** This research contributes a practical model by integrating sensor-based detection, real-time processing, and SMS communication within a river restoration tourism context using an iterative Action Research approach.

**Keywords:** Flood Early Warning System; Iot-Based Monitoring; SMS Notification; Urban River Restoration; Disaster Risk Mitigation.

## INTRODUCTION

Urban riverbank areas have undergone significant transformation in recent decades, evolving from purely ecological systems into multifunctional public spaces that support social and economic activities. In Denpasar City, the implementation of development based on the Tri Hita Karana philosophy has encouraged the revitalization of riparian zones, including Tukad Tagtag, into aesthetically valuable and economically productive public

spaces. However, this transformation also increases public exposure to hydrometeorological hazards, particularly flash floods caused by sudden increases in river discharge. This phenomenon is closely related to the intensification of rainfall patterns and climate change, which have contributed to the increasing frequency and severity of urban flooding events worldwide ([Hirabayashi et al., 2013](#); [Ipcc, 2021](#); [Kundzewicz et al., 2014](#)).

Globally, urban flooding has become one of the most significant natural hazards, causing substantial human and economic losses ([Jongman et al., 2012](#); [Winsemius et al., 2016](#)). In Southeast Asia, rapid urbanization, land-use change, and insufficient drainage infrastructure have further exacerbated flood vulnerability ([Aerts et al., 2014](#)). In the context of river-based tourism areas such as Tukad Tagtag, flood risk becomes more complex due to the direct interaction between environmental dynamics and human activities. Therefore, there is a growing need for mitigation systems capable of delivering fast, reliable, and widely accessible early warnings to improve preparedness and reduce potential losses ([Basher, 2006](#)).

Existing studies on urban flood mitigation have largely focused on structural approaches, such as river normalization, levee construction, and drainage capacity improvement. These approaches have been proven effective in reducing flood impacts; however, they often require high investment costs and long implementation periods ([Ashley et al., 2005](#); [Fletcher et al., 2015](#)). Moreover, structural solutions tend to be less adaptive to rapid urban development and climate variability ([Miguez & Veról, 2015](#)). This indicates that relying solely on physical infrastructure is insufficient to address the dynamic and complex nature of urban flood risks.

The second category of research emphasizes technology-based approaches, particularly the use of Internet of Things (IoT) systems for real-time hydrological monitoring. Previous studies have demonstrated that integrating water level sensors with microcontrollers and communication networks can significantly improve detection accuracy and response time to changing environmental conditions ([Alferi et al., 2012](#); [Gubbi et al., 2013](#); [Zanella et al., 2014](#)). IoT-based systems enable continuous data acquisition and remote monitoring, supporting data-driven decision-making processes. However, many of these systems primarily focus on monitoring functions and do not fully integrate effective early warning mechanisms that directly reach end users.

The third category focuses on early warning systems, which emphasize the dissemination of information to communities at risk. The effectiveness of such systems

depends on the timeliness, reliability, and accessibility of warning messages (Basher, 2006; Sorensen, 2000). While various digital platforms such as mobile applications and web-based systems have been developed, their effectiveness is often limited by internet connectivity constraints, particularly in developing regions. In this context, SMS-based notification systems remain relevant due to their wide coverage and independence from internet infrastructure (Aker & Mbiti, 2010). Nevertheless, the integration of automatic sensor-based detection systems with simple, direct SMS notification mechanisms in the context of restored urban river tourism areas has not been extensively explored.

Based on the identified research gaps, this study aims to design and implement an automatic flood early warning system based on water level sensors and SMS notifications in the Tukad Tagtag river restoration area, Denpasar. The proposed system is designed to monitor water levels in real-time, detect threshold exceedance conditions, and automatically send warning messages to relevant stakeholders. This research is expected to contribute to the development of a more operational, adaptive, and context-specific flood mitigation system suitable for urban river tourism environments.

This study hypothesizes that the integration of water level sensors with automated SMS-based notification systems can significantly improve the effectiveness of flood risk mitigation in restored river areas. The system is expected to enhance response speed, improve stakeholder preparedness, and reduce potential losses caused by sudden flooding events. Therefore, this approach represents a practical and scalable solution for disaster risk reduction in urban areas with limited digital infrastructure while maintaining high reliability and accessibility.

## RESEARCH METHOD

This study examined the implementation of an automatic flood early warning system in the Tukad Tagtag river restoration area, Denpasar. The unit of analysis was the operational performance of the system, which consisted of water level detection, threshold-based warning activation, and automatic SMS notification delivery. In addition to the technical system itself, the study also considered the implementation context involving the internal project team from the Water Resources Division of the Denpasar Public Works Office and the external technical partner from SMKN 1 Denpasar.

The research employed a qualitative applied research design using the Action Research approach. This design was selected because the study did not merely observe an existing

phenomenon, but also involved the development, installation, testing, and refinement of a technological solution in a real setting. Action Research was considered appropriate because it allows iterative cycles of planning, action, observation, and reflection, enabling continuous adjustment of the system based on field findings (O'Brien, 1998). In this study, the method was used to address a practical problem, namely the absence of a reliable flood early warning mechanism in the Tukad Tagtag tourism area, while at the same time generating context-based knowledge for future replication.

The study used both primary and secondary data sources. Primary data included system performance data collected during field implementation and testing, such as sensor response, warning activation, and SMS transmission output. Additional primary data were obtained from direct observation during installation and operation. Secondary data were derived from project-related documents, including consultation reports, team decrees, meeting minutes, installation records, and evaluation reports. These data sources were used to support both the technical assessment of the system and the documentation of the implementation process.

Data were collected through several techniques. First, field observation and documentation were conducted during system installation and testing in order to record physical conditions, system behavior, and environmental influences on sensor performance. Second, consultative interviews and coordination meetings were carried out with the project mentor, internal team members, and the technical partner to identify implementation needs and operational constraints. Third, document review was conducted to examine formal project records and supporting administrative evidence. Fourth, functional and endurance testing of the early warning system was undertaken for three weeks, from the fourth week of July to the second week of August 2024, in order to evaluate sensor reliability, warning consistency, and the periodic delivery of SMS notifications. The implemented Action Research cycle in this study is presented in Table 1.

**Table 1.** Implemented Action Research Cycle

<b>Action Research Phase</b>	<b>Activities in the Automatic Early Warning System Project (Case Study: Tukad Tagtag, Denpasar)</b>	<b>Data Sources / Outputs</b>
Diagnosis / Planning	Identifying the main problem, namely the absence of an adequate flood early warning system, and planning the proposed solution through stakeholder consultation, team formation, and equipment procurement planning.	Consultation reports, team decree, meeting minutes

Action Research Phase	Activities in the Automatic Early Warning System Project (Case Study: Tukad Tagtag, Denpasar)	Data Sources / Outputs
Action	Implementing the planned solution through procurement and modification of the flood detection device in collaboration with SMKN 1 Denpasar, followed by installation at Tukad Tagtag.	Device photos, installation documentation
Observation / Evaluation	Testing the effectiveness of the installed system through functional and endurance tests over a three-week period from late July to mid-August 2024.	System testing reports, field documentation
Reflection / Improvement	Identifying technical issues such as inaccurate sensor readings and excessive SMS frequency, followed by corrective actions including sensor repositioning and microcontroller reprogramming.	Evaluation reports, revised system documentation

Data analysis was conducted using a descriptive and iterative evaluation approach consistent with the Action Research framework. The analysis began with data reduction, in which relevant findings from observations, tests, interviews, and documents were selected and organized. The next stage involved data display, where the implementation process and system performance were described systematically. After that, system functionality was evaluated by examining the stability of sensor readings, the occurrence of false warnings, and the consistency of SMS transmission. Finally, a reflective analysis was carried out to identify weaknesses in the initial system configuration and formulate technical improvements. Through this process, the study generated both practical findings on system performance and procedural insights into the implementation of flood early warning technology in a river restoration area.

## RESULT

### Administrative Readiness and Resource Mobilization

The first result concerns the institutional and administrative readiness that enabled the implementation of the automatic flood early warning system. During the short-term project period from June to August 2024, the initial phase focused on stakeholder coordination, work structure formation, and technical preparation. A strategic consultation with the project mentor, who served as the Secretary of the Public Works Office, was conducted on 2 July 2024 to define the scope and implementation mechanism of the project. Based on this consultation, the implementation team was formally established through an official decree issued by the Head of Office. This process was followed by a preparatory meeting

on 5 July 2024 to clarify roles and responsibilities. Intensive coordination was also undertaken with the external partner, SMKN 1 Denpasar, which acted as the technical collaborator in the modification of the flood detection device. The flood early warning detection device installed at the Tukad Tagtag site is presented in Figure 1.



**Figure 1.** Flood Early Warning Detection Device at Tukad Tagtag

The supporting evidence for this phase consists of consultation records, official decrees, meeting minutes, and coordination documents. These administrative outputs may be presented in documentary form to show the sequence of institutional preparation before the technical deployment of the system.

Restated simply, the project did not begin directly with equipment installation. It started with formal coordination, team establishment, and verification of technical feasibility. This means that the implementation of the warning system was built on an organized institutional process rather than an ad hoc intervention.

Several patterns can be identified from these findings. First, the implementation required formal administrative authorization before technical action could proceed. Second, the project depended on multi-stakeholder coordination, especially between the public agency and the external technical partner. Third, the available device was considered technically feasible with only minor modifications, indicating that the project emphasized adaptation rather than full-scale hardware development. Fourth, the early project stage showed that organizational readiness was as important as technological readiness.

These findings imply that the success of a flood early warning system in a public riparian area depends not only on hardware capability but also on institutional preparedness. In this case, administrative readiness provided the operational foundation for technical implementation. This result supports the argument that early warning systems in urban river environments require coordination mechanisms, clear task distribution, and inter-agency collaboration in order to function effectively in practice.

## System Procurement, Installation, and Configuration

The second result concerns the physical implementation of the automatic flood early warning system, including procurement, modification, installation, and configuration. The flood detection device was procured on 17 July 2024 and then modified to improve its functionality. Initially, the device functioned only as a conventional alarm. After modification, it was able to transmit automatic SMS notifications to smartphones when water elevation reached the warning threshold. This development expanded the communication range of the system and improved the response mechanism by allowing warning information to be delivered remotely.

The installation process was completed on 19 July 2024 at Tukad Tagtag. The water level sensor was positioned on the retaining wall of the bridge, and the warning threshold was set at 15 cm above the normal water surface level. The main device module was installed in a higher and more protected area under the bridge structure in order to reduce direct exposure to rainfall and minimize the risk of flood-related damage. The visual evidence of this result is represented by Figure 1, which shows the flood detection device; Figure 2, which presents the system configuration and functional testing; and Figure 3, which documents the installation and module verification in the riparian area.



**Figure 2.** System Configuration and Functional Testing of the Automatic Early Warning System at Tukad Tagtag

In simpler terms, the technical implementation phase transformed a basic warning device into a more functional early warning system that could detect water level increase and send notifications automatically. The system was also configured to suit local environmental conditions, especially with respect to sensor position and device protection.

Three major patterns emerge from this result. First, the project emphasized functional enhancement, as shown by the modification from a local alarm device to an SMS-based

warning system. Second, the installation process was site-specific, meaning that system placement was adjusted to the physical characteristics of the Tukad Tagtag area. Third, the threshold setting and protected placement of the module indicate an effort to balance detection sensitivity and hardware durability. A fourth pattern is that the configuration was not merely technical but also operational, since the system was designed to produce warnings that could be directly used by stakeholders.



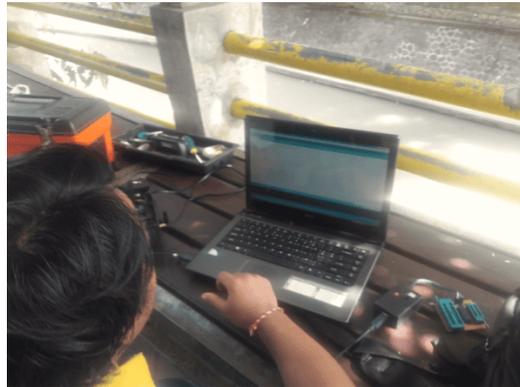
**Figure 3.** Installation and Verification of the Early Warning System Module in the Tukad Tagtag Riparian Area

The implication of this finding is that the practical value of a flood early warning system depends on how well the system is adapted to local field conditions. The results suggest that appropriate positioning of sensors, protected module placement, and clear threshold definition are critical to the operational reliability of the system. This finding adds to the understanding that flood warning technology in restored urban river areas must be context-sensitive and not simply transferred from one setting to another without adjustment.

### **Functional Testing, Endurance Evaluation, and System Improvement**

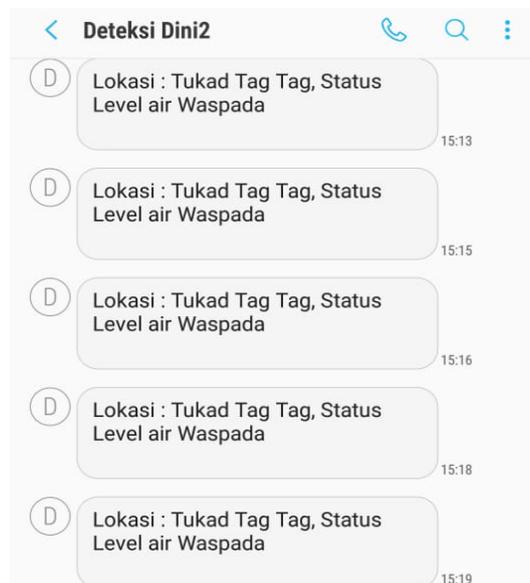
The third result concerns the operational performance of the system during testing. Functional testing was first conducted through a simulation of increasing water level by immersing the sensor from the warning position to the danger position. The test showed that the system was able to detect changes in water elevation and automatically transmit warning messages according to the intended design. After the initial functional test, the system underwent an endurance and reliability test for three weeks, from the fourth week of July to the second week of August 2024. During this period, the system was evaluated

in terms of stability of operation, detection accuracy, and consistency of SMS notification delivery.



**Figure 4.** Functional Testing of the Automatic Flood Early Warning System

The relevant visual evidence is provided by Figure 4, which shows the functional test of the early warning system, and Figure 5, which presents the result of SMS-based warning transmission after system modification. In addition, field documentation from the testing period supports the observation that the system continued to operate under real environmental conditions.



**Figure 5.** SMS-Based Early Warning Notification Output After System Modification

Restated more simply, the system did not only work during a single demonstration. It was also monitored over a continuous testing period to determine whether it could remain stable and reliable under repeated operation. The testing process further revealed technical

issues related to sensor reading and SMS periodicity, which were then addressed through sensor repositioning and microcontroller reprogramming.

Several patterns can be identified from this result. First, the system showed basic functional success, as it was able to detect water level changes and send warnings automatically. Second, the longer testing period revealed that field reliability differs from initial laboratory-style functionality, because real conditions exposed problems such as inaccurate readings and excessive SMS frequency. Third, the system demonstrated adaptability through iterative correction, as technical issues were followed by improvement measures. Fourth, the final testing stage indicated that system stability improved after modification, suggesting that performance optimization was achieved through reflection and refinement.

The meaning of this result is significant for the study objective. It shows that the implementation of an automatic flood early warning system is not a one-step engineering product, but an iterative technical process that requires testing, evaluation, and adjustment. The findings support the usefulness of the Action Research approach because system weaknesses could be identified directly in the field and corrected in real time. More broadly, this result indicates that practical flood mitigation technology in urban river tourism areas can function effectively when it is continuously evaluated and refined based on operational evidence.

## **DISCUSSION**

The study demonstrates that the automatic flood early warning system implemented in the Tukad Tagtag river restoration area was able to function as intended through a structured process of planning, installation, testing, and refinement. The system successfully detected changes in water level, activated threshold-based alerts, and transmitted SMS notifications to relevant stakeholders. These findings indicate that the integration of water level sensing, automated warning logic, and SMS communication can provide a practical flood mitigation mechanism for urban river environments.

The system performance can be explained by the complementary roles of its main components. Real-time sensing enabled continuous monitoring of water level conditions, while the threshold setting allowed the system to distinguish normal conditions from potentially hazardous ones. The use of SMS notification strengthened the operational value of the system because warning messages could be delivered directly without depending on

internet-based platforms. The improvement observed after field adjustment also shows that system reliability was strongly influenced by local environmental conditions. False warnings and irregular notification frequency were not caused by the concept of the system itself, but by the initial sensor position and the interaction between the sensor and site-specific water disturbances. Once the sensor location was corrected and the microcontroller logic was reprogrammed, the system became more stable. This confirms that flood warning technology in river environments requires field calibration rather than relying solely on initial technical setup.

These findings are consistent with previous studies showing that IoT-based monitoring systems can improve real-time environmental detection and support rapid response mechanisms (Gubbi et al., 2013; Zanella et al., 2014). They also support earlier arguments that early warning effectiveness depends not only on detection capability but also on the speed and accessibility of message delivery (Basher, 2006; Sorensen, 2000). In contrast to many previous studies that mainly emphasize monitoring and web-based visualization, this study demonstrates the value of combining sensor-based detection with direct SMS transmission in a restored urban river setting. This makes the system more operational for locations where internet availability may be limited or where stakeholders need a simpler communication channel. Compared with structural flood mitigation approaches, which often require greater investment and longer implementation time, the present system offers a more adaptive and lower-cost alternative for localized risk reduction ((Ashley et al., 2005; Fletcher et al., 2015). The novelty of this study lies in the application of an iterative Action Research framework to develop and refine a sensor-based and SMS-enabled warning system specifically for a public river restoration area used for tourism and community activities.

The results also carry a broader implication for disaster risk reduction in urban public spaces. In a restored river corridor such as Tukad Tagtag, flood mitigation is not only a technical matter but also a matter of public safety, infrastructure protection, and sustainable area management. The warning system therefore contributes beyond hazard detection; it supports quicker operational response, improves stakeholder preparedness, and strengthens the safety dimension of river-based tourism management. The study also shows that relatively simple technology can still provide meaningful mitigation benefits when it is properly adapted to field conditions.

At the same time, the findings reveal several limitations. System performance remained sensitive to environmental disturbances such as turbulence and surface fluctuations, and SMS delivery may still depend on network reliability. These issues indicate that the system should not be viewed as a final solution, but as an operational prototype that requires routine maintenance, periodic recalibration, and possible integration with additional warning channels. Even so, its successful deployment suggests that local governments and river management agencies can adopt similar systems as part of practical flood preparedness strategies. Future implementation should prioritize site-specific sensor placement, regular performance evaluation, communication redundancy, and stakeholder training so that warning information can be interpreted and acted upon effectively.

## CONCLUSION

This study demonstrates that the implementation of an automatic flood early warning system based on water level sensors and SMS notifications in the Tukad Tagtag river restoration area can effectively support flood risk mitigation in an urban riparian environment. The main finding indicates that the integration of real-time sensing, threshold-based detection, and direct communication enables timely warning delivery and enhances operational responsiveness. The system not only functions technically in detecting water level changes and sending alerts, but also proves to be adaptable through iterative improvements, particularly in addressing issues related to sensor positioning and system stability under real field conditions.

The scientific contribution of this research lies in the development of a practical and context-specific early warning model that integrates sensor-based monitoring with SMS communication within an urban river restoration setting. Unlike many previous studies that focus primarily on monitoring systems or internet-based platforms, this study offers an alternative approach that emphasizes accessibility, simplicity, and operational applicability. In addition, the use of the Action Research approach provides a methodological contribution by demonstrating how engineering systems can be iteratively developed, tested, and refined directly in the field, thereby bridging the gap between theoretical design and real-world implementation.

However, this study has several limitations. The system performance is still influenced by environmental conditions such as water turbulence and sensor placement, which may affect detection accuracy. Furthermore, the reliance on SMS communication introduces

potential constraints related to network availability and message delivery reliability. The study is also limited to a single case study location, which may restrict the generalizability of the findings. Therefore, future research is recommended to incorporate more advanced sensor technologies, integrate multiple communication channels such as mobile applications or siren systems, and conduct testing in various environmental conditions and locations to enhance system robustness and scalability.

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