Rainfall Measurement And Flood Warning Systems: A Review

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Abstract: Flood is regarded as a chaotic natural disaster that threatens people's lives and properties. Flood warning and rainfall measuring systems dealing with different processes and multiple methodologies, providing data and information to maintain flood warning transportation and alternatives to crises for people around the world. To provide comparatively accurate and reliable flood prediction, prediction models are essential to be propelled by data input and further controlled by historical data and real-time observations are processed through the various algorithms. Flood prediction techniques traditionally include the use of rain gage for rainfall measurement and a simple flood warning system circuit. Emerging flood warning systems technologies and development have the potential to provide alternative solutions to allow timely and reliable flood calculations. It has shown a growing interest in investigating the use of more technological methods to anticipate floods through this. This paper reviews, therefore, from traditional flood forecasting to recent progress with the integration of emerging technologies for a more reliable and accurate flood warning system. This paper discussed patented flood warning systems, rainfall measuring systems, and published papers on flood warning systems. The result ended up with an idea that will be proposed for better accuracy and timely applications.

Index Terms: Flood forecasting, flood prediction, rainfall, technologies, flood warning systems, remote

1 INTRODUCTION

Flood is a water overflow that usually overflows dry land. Due to its ability to destroy houses, buildings, crops, and other properties, the flood can be deadly and devastating. Most urban centers in Southeast Asia found in low-lying areas next to the shores of major water bodies are prone to flooding, according to a study. Manila, along with the cities of Bangkok, Hanoi and Kuala Lumpur, is one of the identified flood risk cities at the outlets of river systems such as the Pasig-Marikina Rivers in the Philippines, Vietnam's Red River, Indonesia's Ciliwung River, Bangkok's Chao Praya, and Malaysia's Gumbak-Klang-Batu Rivers [1]. Because of its position on the globe, this country, the Philippines, is prone to tropical cyclones and low-pressure areas. The Philippines is one of the World's most prone to flooding, according to the report. Over the past 10 years, over 60 major floods have been reported in the Philippines [2]. Typhoons can enter the Philippine Area of Responsibility (PAR) even during the summer, and they can flood and damage the country every time they land. Every time the season has passed into the rainy season, this country is experiencing most of its average annual precipitation. This means that flash floods in the low-lying areas are to be expected. There are numerous reasons for flash flooding. The two main elements, however, are the duration of rainfall and intensity of rainfall. The amount of rainfall is the intensity, and how long the rain takes a while is the duration. Factors can also be soil conditions, soil, and topography [3]. The national government has a primary weather monitoring agency, the Philippine Administration of Atmospheric, Geophysical and Astronomical Services (PAGASA). They are responsible for monitoring this country's weather and climate.

They provide the public with warnings, advisories and weather data via their website, social media accounts and public announcements. They measure the amount of rainfall using rain gauges which are deployed across the country. These devices are checked every hour and measurements in liters per square meter (L/m2) or millimeter (mm) are provided. PAGASA also uses water level sensors to collect data on dam height in the vicinity of cities. To date, the most severe cause of incorrect measurement is due to wind conditions [4]. It was found that the gauge's design shape plays an important role in the measured catch of rainfall. This is based on comparisons of the rain gage performed for different types of rain gauges at a standard level. By monitoring clouds, wind, patterns, atmospheric pressure, and temperature, they also predict the coming weather. All these data are integrated, studied and published for the public flood projection, announcements, and advisories. PAGASA measures the status of the dams being monitored and advises floods depending on the amount of rainfall, particularly in the catch basin areas. In a single city or municipality as a whole, these warnings are issued. PAGASA uses its website to provide the public with warnings and advisories. The agency also uses the media to relay information and, if necessary, contact each city's local government units for evacuations. The actual amount of rainfall is not taken for a particular area. Motorists and commuters are unaware of whether the streets are still passable and can still be used safely. People who are in low-lying areas are informed to evacuate about flash floods and emergencies by local government officials. To further warn people, a study was conducted using GIS-based risk assessment of multiple criteria to improve the accuracy of flood risk assessment for Metro Manila, considering the barangay, Philippine society's smallest political unit [5]. Hence, this paper concerns on what technology will be proposed and developed for future implementation by the government to solve the stated problem. In the next section, a review of different flood warning technologies is presented. This paper, therefore, concerns what technology will be proposed and developed by the government to solve the stated problem for future implementation. A review of various flood warning technologies is presented in the next section.
2 EXISTING FLOOD WARNING SYSTEMS

The author discussed technologies in this section, starting with the early inventions of devices used for flood detection, emerging flood prediction technologies up to rainfall measurement technologies.

2.1 Patented flood warning devices

An Early Flood Warning System (shown in Figure 1) is an advanced warning of likely flash floods and periodic floods by collecting and evaluating rainfall and watercourse level data to potential flood victims. This device also provides a means to spread alarms and orders in threatened areas to individuals [6].

![Fig. 1. Block diagram of the Early Flood Warnings System (adapted from [6])](image1)

A water level detector or flood alarm device was invented in 1998, which will trigger a warning once the water has reached a predetermined level and is likely already harmful or unsafe. This invention consists of a housing that maintains a traditional float switch activated by mercury, an alarm attached to the switch, a mounting device, and a mechanism for attachment [7]. Figure 2 shows the patent claims of this invention.

![Fig. 2. Alarm devise for detecting predetermined water level (adapted from [7])](image2)

In 2001, a water level calculator and water level forecasting system and the method were patented to achieve water level forecasting of a river with a limited calculation volume and high accuracy by numerical calculation. A measuring device is arranged to have water measuring part at a specified time interval to measure the water level of a river and a rainfall measuring part at a specified time interval [8]. An alarm reporting system has been invented after a year. This is an automatic alarm reporting system for mobile phone users and a mobile terminal. Those who want to know any hazards, and the like, in a relevant basin, an upstream region, an upper stream, an outer basin, or an area where danger is assumed. When the alarm trigger details (alarm reference value) are set to either telemeter water level, telemeter time rainfall, accumulation rainfall or radar rainfall (time, accumulation, rainfall region movement) and the like to start an alarm trigger, alarm information such as mails and alarm signals is automatically reported to the mobile phone user and the mobile terminal for reporting alarm information [9]. Predicting the amount of precipitation was also patented in 2003, allowing the user to see how much precipitation over the target area or point is estimated to occur. Predicted rainfall amounts are collected attributable to each cell expected to move across the target point and their output as a predicted amount of rainfall for the target point. If the target point is a multi-cell watershed, then predicted precipitation amounts are averaged for each cell in the watershed to deliver a predicted amount of precipitation for the watershed [10]. Figure 3 explains this patent’s process.

![Fig. 3. Quantitative precipitation prediction method (adapted from [10])](image3)

An invention provided an evacuation guidance system for a water disaster that accelerates a rescue operation by estimating a region with the possibility of a water disaster occurring to announce the water disaster automatically in advance and to automatically notify persons involved of optimum information on the evacuation route [11]. This system selects an optimal evacuation guide route map to an evacuation site from the region. Another flood warning system was invented to provide a simplified rainfall alarm with a simple and inexpensive structure that can easily and easily measure cumulative rainfall, inform residents of the rainfall by lighting an alarm lamp and an alarm buzzer easily performs its
maintenance and facilitate it [12]. In 2006, a nationwide combined radar rainfall information system was patented to solve a problem where continuous radar rainfall cannot be precisely determined since, in combination with the observation results of an adjacent radar rain gage, the difference in observation characteristics in each radar rain gage cannot be perfectly corrected and a step takes place at the junction therebetween [13]. In 2008 an invention relates to a method and system for automated location-dependent recognition of flood risks, the measurement of flood states and the determination of location-dependent probability values. In particular, the invention relates to a system and method in which a country-specific flood zone table, such as the First American 100-year flood zone table, is used for generalized insurance risk factors to derive high-resolution data on vulnerability factors [14]. Figure 4 provides a schematic overview of an incarnation of this invention.

![Fig. 4. System for automated location-dependent recognition of flood risks (adapted from [14])](image)

In the year 2008 when image processing was used for water level observation. This system is equipped with a photographing means such as a CCTV camera, a static image acquisition for acquiring image data from the photographing means as a static image. It also contains a water level device for measuring the water level by image processing. I also feature a water level display for displaying the water level longitudinally and an alarm/delivery for issuing an alarm to a river manager [15]. Another development came when a prediction system was discovered for concentrated heavy rainfall. In this concentrated heavy rainfall prediction system, an insolation amount meter is installed at such points as not shaded, in other words on an electric pole and upper surface of a building, for measuring insolation amount for each several seconds [16]. Sudden flood risk avoidance system and method a flood detection device were installed on a road on which a vehicle pass is configured to compute the water height of a flood on the road. This also compares the increase rate of the pertinent water level with a preliminarily set risk increase rate and detects whether or not it is put in a flood risk state due to locally heavy rainfall. Following the result of the comparison, a road information display device was installed on the road and is configured to display a flood occurrence situation [17].

### 2.2 Rainfall Measurement Systems

The sound produced by huge raindrops is highly associated with rainfall rate and can be used to sense and measure rainfall rate according to a paper presented. An algorithm about the acoustical rainfall rate is proposed in their study for intense rainfall. This algorithm is susceptible to the relative proportion of large raindrop sizes within the raindrop size distribution [18]. A paper has presented an integrated methodology using C-band polarimetric radar measurements which can obtain the best estimate of rainfall. The methodology exploits the collaboration of reflectivity factor, differential reflectivity, and specific differential phase radar measurements. This contributes to the principle of self-consistency of radar polarimetric measurements in rain [19]. The products of Rain Gauge which are manual, semi-automatic or use data from loggers are still unable to accurately measure rainfall. This is therefore improved through development research on rain gauge, which reads using Bluetooth and RF-FSK modems simply and promptly [20]. The behavior of the tipping bucket rain gauge in various rain intensities, from light rain to extreme rain was described in a certain study. The authors also identified the problem that ordinary tipping bucket rain gauge suffers, the calibration and how to improve the accuracy in the lab and its results. The modified tipping bucket rain gauge (TBRG) has proven to be an effective method for minimizing these errors. A new TBRG with an obstacle sheet modified gives better accuracy than the original one with a little modified [21]. In another paper, the weather natural disaster prevention for quantitative daily rainfall forecasting derived from the weather pattern SACZ-ULCV is presented using intertwined statistical downscaling (SD) and soft computing (SC) approaches. Results showed that the FSD and the NSD are possible alternatives to achieving communication on the daily rainfall variable from meteorological and thermo-dynamic variables [22].

![Fig. 5. The classic downscaling diagram (adapted from [22])](image)

A study was also developed to assess the effects of 23 mother wavelet functions on the function of the rainfall-runoff models of the hybrid wavelet-based ANN. In this study, the hybrid Multilayer Perceptron Neural Network (MLPNN models) ans the Radial Basis Function Neural Network (RBFNN) were developed using both the discrete wavelet and the types of continual wavelet transformation [23]. A study aims to explore the efficacy of multiple rainfall sources (gage measurement, and radar and satellite products) for assimilation-based multi-sensor precipitation estimates and to make multi-step-ahead precipitation predictions based on assimilation. The results of the forecast obtained are very valuable information for the flood warning during typhoon periods in the study watershed [24]. In another study, a Vantage-Vue Integrated Sensors Suite (ISS) weather station was used to measure rainfall intensities of one-minute integration time from June 2013 to February...
The study examines the pattern of rainfall distribution, temporal and cumulative rain rate distribution, and their contribution to total rainfall [25]. Another paper presented a cheap and efficient rain gage tipping bucket with an internet-enabled data logger for rainfall measurements. The data logger posts the rainfall data via a microcontroller interfaced with a GSM / GPRS module [26] to a SQL database located on our server. In another paper, a hybrid wavelet neural network (HWNN) model is developed by incorporating multi-resolution analysis (MRA), mutual information (MI), and particle swarm optimization (PSO) into artificial neural network (ANN) models to effectively forecast monthly rainfall from preceding monthly rainfall and climate indices. The results show that the HWNN model improves the predictive accuracy of the monthly rainfall over Australia compared to the reference models, and the improvement is more significant for the inland stations in south-east Australia and stations in Western Australia [27]. Another work aimed at detecting and calculating the sources of ambiguity present in interpolated maps of rainfall from the depths of the link precipitation. This study also tested the actual and optimal performance of one of the cellular providers in the Netherlands on one commercial microwave network [28]. A previous study also found out that the flood prediction can be determined if convective rains happen continuously beyond 9 hours [29]. Figure 6 shows the size distribution of drop-downs.

Other remote sensor hubs have been utilized for surge checking and alert framework. It includes the grid-based savvy and versatile approach. It was examined within the paper that this framework can too finish on-site surge modeling, separated from joining farther fixed-network for computationally-intensive surge modeling focuses. The paper points to boost the sensors to lattice objects of the most elevated quality. It bolsters adjustment to WSN and makes a difference make strides the tangible modalities [33]. In another paper, the artificial intelligence model was established to determine the water level at short notice. The water level was predicted using the artificial neural networks (ANN), the support vector machine (SVM) and the adaptive neuro-fuzzy inference system (ANFIS). This study shed some light on the best practices in using different artificial intelligent methods for hourly water level prediction with different model settings. Further studies with the availability of short-term [34] were desired to issue an early warning. In a paper comprised of the battery as its power source, a receiver, and a transmitter, the flash flood warning system was introduced. For the upstream, the transmitter has a data logger, water level gauge sensors, a rain gauge and a device with warning alarm and SMS transmitter. The receiver, on the other hand, is downstream and is composed of an SMS receiver and an alarm system [35]. Polarization Ratio temporal trends at some AMSR-E bands (C, X, and Ka) were studied to demonstrate their potential in flood and rainfall monitoring. End ground truth data were used for rainfall and water level measurements in Argentina’s lower Bermejo Basin, and a general correlation between variations of the polarization ratio and ground parameters was found at the different AMSR-E frequencies [36]. The level of rainfall can be predicted through a neural backpropagation network which was used as a technique in another study to determine the water level to improve the prediction technique. In this study, a novel Extended Kalman Filter (EKF) optimization algorithm was used to overcome the nonlinearity problem and to come out with an optimal ANN for
flood water level prediction 3 hours in advance [37]. This study has a BPN model for the prediction of the floodwater level, as shown in Figure 8.

![Fig. 8. BPN Model for flood water level prediction (adapted from [37]).](image)

A combination of Kalman filter and BPN can enhance flood performance and prediction [38],[37]. The introduction of the extended Kalman filter at the BPN output shows significant improvement in predicting and tracking the actual flood water level performance. Figure 9 shows the artificial neural network structure used in this study, whereby BPN is the most popular supervised ANN model.

![Fig. 9. Structure of artificial neural network (adapted from [38]).](image)

A real-time measuring system can be employed for energy-efficient, with vigorous communication potential [39]. This study is a real-time flood surveillance measurement system. Its deployment is in Southern Spain, in a flash-flood prone to 650 km of the semi-arid watershed. DatalogV1A, a low-power, and long-range communication device developed to deliver automatic data collection and reliable communication. A new model has been developed for a flood warning system using an Artificial Neural Network (ANN) and Wireless Sensor Nodes (WSN). It includes six (6) hydrological factors, such as variation in water speed, air moisture, atmospheric pressure, rainfall, wind speed, and water level. The WSN measures these parameters. These vectors are verified and tested in theoretical terms [40]. Figure 10 shows the ANN model used in that study.

![Fig. 10. Basic ANN model used for simulation (adapted from [40]).](image)

Warning transmitters and flood detection systems can be combined with electrical cabling, and flood prediction can also be designed for the common residential building's electrical system [41]. This study relates to the safety of people at risk of electrical shock caused by floods. In Figure 11 the system explains.

![Fig. 11. Flood Detection System (adapted from [41]).](image)

Also integrated with an early flood warning system was SMS technology via SIM300 GSM Modem. The system is capable of predicting the time a flood happens in advance. The system can determine three types of water level or flood level, low tide level, and early flood level. In three conditions it transmits out three warning or notification messages thru SMS. The system used a stand-alone PVC pipe, used for 24 hours, and may be requested for the statues of water level [42]. Figure 12 shows the principal design used in this study.
The research focused on calculating the water-courses unpredictable water level and flow rate. There are several sensors installed along the watercourse from the upper stream into the village area. IT uses the SCADA (Supervisory Control and Data Acquisition) industrial control system to function as a central flood warning system control program. There is an HMI (Human Machine Interface) designed based on the focused area contour map [43]. The authors proposed a flood alerting system based on neuro-fuzzy (NF). The input data was gathered via a Wireless Sensor Network (WSN). The proposed model has gathered input parameters from a specific site, such as rainfall, river water level, and river water flow, and sent the data to the decentralized node. The flood possibility index [44] has been determined by the Adaptive Neuro-Fuzzy Inference System (ANFIS) model based on the inputs. Computer and mobile networks also served as instruments for the design and development of a flood warning system in an area. The water level, rainfall quantity, and image data were gathered and sent to a server using mobile data networks through the internet. These data are then processed for flood warnings and can be determined. The system uses mobile and web systems to view the measured data and to inform warning messages for the flood possibility [45]. Figure 13 shows the system architecture for this study.

An easy method to automatically monitor a specific area’s flood object, based on the currently widely used remote cyber-surveillance systems and image processing methods to get instant feedback from flooding and waterlogging events. In this study, in which a flood is considered a possible object of invasion, the mode of intrusion detection of these surveillance systems is used. Automatic flood risk-level monitoring of specific river segments, as well as automatic urban flood detection, has become possible through the detection and verification of flood objects [46]. NASA developed the use of a technology called SensorWeb which leverages Open Geospatial Consortium (OGC) Sensor Web Enabling (SWE) standards to facilitate the interoperability of different satellite and ground sensors. This is for the rapid collection and dissemination of both space- and ground sensor data and flood disaster management data products [47]. A flood monitoring system in real-time was implemented in two streets near España Boulevard to give visual data and actual flood information through web services and mobile phones. The system is consists of a rain gage and ground-based pressure sensor connected via the GPRS network to a locally planned data logger with telemetry capabilities. A TCP server receives data from the stations and is processed through mobile and web services to provide an update on real-time flood as well as its graphical information. An early flood estimation system was implemented using a Random Forest algorithm to give motorists and system users an early warning advisory [48].

Back Propagation Neural Network (BPN) was also implemented to predict the level of water in which the result based on a study is high precision. Relative Absolute Error and Mean Square Error were used to measure the prediction model’s accuracy between the actual water level and the water level predicted [49]. In mobile areas, another paper presented the automated wireless flood warning system for informing people during floods. The level of floodwater was measured using a wireless sensor. Using RF signals, the data was sent to the raspberry pi microcontroller. Once the water level reaches its threshold, an ad hoc network, a set of mobile devices is created. This network can be embedded in smartphones that are used to transmit flood warning messages as a device [50]. The wireless water level sensor is positioned on the measuring scale that is used to measure the water level. The measured water levels are continuously transmitted to this microcontroller through the XRF Module Transceiver, using Radio Frequency signals. The Department of Science and Technology (DOST)-Advanced DOST-Advanced Science and Technology Institute has installed various hydro-meteorological devices throughout the Philippines, including Automated Rain Gauge (ARG), Tandem Stations and Water Level Monitoring Stations (WLMS). This paper addresses the need for the development of a predictive model that provides a water level for an early nowcasting system. This also includes flood hazards providing the local

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**Fig. 12. The main design of the early flood alert system (adapted from [42]).**

**Fig. 13. System architecture (adapted from [45]).**

**Fig. 14. Urban Flood Monitoring System (adapted from [48]).**
communities with a decision support tool. The model was able to deliver an accurate and early prediction of the water height or level without depending on the rainfall-runoff models [51]. To measure the water level changes in a river for this technology, an additional ultrasonic sensor is integrated with the system. Figure 15 shows the system layout.

Fig. 15. Remote River Nowcasting system in Cagayan, Philippines (adapted from [51])

Another research paper that is based on the E-Noe project has demonstrated a flood warning system for the dangerous areas. The system monitors the water level of a runway or river. If the height is at the alert level, it notifies the authorities through text messages and phone calls. Microcontroller and Sonar systems are used. The microcontroller manages the data that will then be stored via cloud computing [52]. Figure 16 shows the study's system flow.

Fig. 16. System flow (adapted from [52])

A flood warning system for Korea's Muslin Stream Watershed has also been developed. The project employed smart technology to send early flood warnings to end-users. The model used HEC-HEM which provides a forecast for floods. The aim of the server-client based program used in this study is to predict the flooding situation in real-time [53]. The detail of the system configuration for the flash flood guidance (FFG) was explained in figure 17.

Fig. 17. FFG System Configuration (adapted from [53])

2.4 Systems employing Rainfall measurement and Flood warning

A prediction of rainfall may also be based on linear stochastic auto-regressive moving average (ARMA) models, artificial neural networks (ANN), and the non-parametric nearest neighboring method whereby the results emphasized that the time series analysis methods offered a significant development in flood projection accuracy contrasted to simple rainfall prediction approaches of an experimental nature [54]. Multi-sensor data rainfall inputs from the geostationary meteorological satellite, Doppler weather radar, and numerical weather prediction (NWP) models [55] were used to develop a new technique in rainfall prediction and flood control. This research study also investigated the relationship between visible and infrared geostationary meteorological satellite (metsat) images to rainfall depth, and developed a rainfall estimate based on satellite. There has been a proposal for an original early alert system for heavy rainfall in Europe in which its goal is to identify projections of tremendous accumulations of rainfall over a short period of time and in small catchments that is risky to flash flooding. This is based on the recently developed European Precipitation Index based on Simulated Climatology (EPIC), which is measured using weather forecasts from the COSMO-LEPS joint and then suited with gamma distributions at each time step of the forecast horizon [56]. A paper examines the applicability of the Numerical Weather Prediction (NWP) model for flood prediction ensemble forecasts. In this study, the hydrological model used a 10-km-resolution rainfall forecast and its downscaled 2km-resolution forecasts as input data for flood forecasting and early warning application [57].

3 SUMMARY OF RESULTS

All studies discussed in this research paper are related to the prediction or forecasting of rainfall, flood detection, and prediction of rainfall. Others comprised of discussion of rain
gauges for measuring rainfall, real-time flood detection devices or sensors. These studies or articles have provided the researcher with enough knowledge and information pertaining to rainfall measurement and predictive sequence modeling. The next tables illustrate and summarize the outcome of several patents and articles reviewed:

### TABLE IA
**Patented Flood Warning Devices**

<table>
<thead>
<tr>
<th>No.</th>
<th>Title of patent</th>
<th>Year patented</th>
<th>Description or Method</th>
<th>System type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Early Flood Warning System</td>
<td>1999</td>
<td>Used electronic system to provide flood or flash flood warning to individuals or stationed areas.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>2.</td>
<td>Water level detection alarm</td>
<td>1995</td>
<td>Alarm for detecting predetermined water levels.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>3.</td>
<td>Water level and velocity sensing system and method</td>
<td>2001</td>
<td>Forecasting of water level at a river with a limited volume of calculation and at a high accuracy by statistical calculations.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>4.</td>
<td>Alarm reporting system</td>
<td>2002</td>
<td>An alarm automatically operating system for the use of a cellular phone and a mobile terminal regarding danger of flood or the like.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>5.</td>
<td>Quantitative precipitation prediction method</td>
<td>2005</td>
<td>It allows the user to see how much precipitation is expected to occur over the target point or area.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>6.</td>
<td>Inundation level warning system</td>
<td>2004</td>
<td>This system selects an appropriate inundation, early warning and evacuation route for an evacuation plan.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>7.</td>
<td>Stabilized rainfall alarm</td>
<td>2006</td>
<td>A stabilized rainfall alarm which can simply and easily measure a cumulative rainfall, easily inform users.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>8.</td>
<td>Automatic combined radar radar information providing system</td>
<td>2006</td>
<td>Continuous rainfall can be precisely determined using radar data.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>9.</td>
<td>Method and system for automated location dependent recognition of flood risk flood states being measured and location dependent probability values being determined</td>
<td>2007</td>
<td>A method and system for automated location dependent recognition of flood risk.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>10.</td>
<td>Water level observation system by image processing</td>
<td>2008</td>
<td>A water level detection system for measuring the water level by image processing.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>11.</td>
<td>Concentrated heavy rainfall prediction system</td>
<td>2009</td>
<td>A concentrated heavy rainfall prediction system through an innovative analysis model installed at such places.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>12.</td>
<td>Flood risk avoidance system and method</td>
<td>2012</td>
<td>A flood detection device was installed on a road on which a vehicle passes in order to measure the water level on the road.</td>
<td>Flood Warning System</td>
</tr>
</tbody>
</table>

### TABLE II
**Rainfall Measurement Systems**

<table>
<thead>
<tr>
<th>No.</th>
<th>Title of study</th>
<th>Year studied</th>
<th>Descriptions or Methods</th>
<th>System type</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Remote Measurement using Twelve Underwater Acoustic Sensors</td>
<td>2015</td>
<td>An accurate rainfall rate algorithm is used in an indoor system. This algorithm is validated by rainfall measurements in a case study.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>2.</td>
<td>An integrated approach for rainfall estimation</td>
<td>2009</td>
<td>An integrated methodology which estimates the real-time rainfall rates measurements that allows to obtain the best results.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>3.</td>
<td>Rain gauge design employing Bluetooth and TVI system</td>
<td>2014</td>
<td>A rain gauge that can precisely record and present real-time information using Bluetooth and video camera (TVI).</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>4.</td>
<td>High accuracy tipping bucket rain gauge</td>
<td>2016</td>
<td>A high accuracy tipping bucket rain gauge with an automatic rotation mechanism.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>6.</td>
<td>Comparative study of different rainfall based rainfall runoff model for accurate rainfall modeling</td>
<td>2016</td>
<td>A comparative study of different rainfall based rainfall runoff model for accurate rainfall modeling.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>7.</td>
<td>Water level metering utilizing acoustic networking with the assistance of radio sensor networks</td>
<td>2014</td>
<td>A water level metering utilizing acoustic networking with the assistance of radio sensor networks.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>8.</td>
<td>Internet enabled tipping bucket rain gauge</td>
<td>2014</td>
<td>A internet enabled tipping bucket rain gauge.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>9.</td>
<td>A hybrid real-time rainfall network model with neural network and microcontroller for overcoming rainfall variation</td>
<td>2015</td>
<td>A hybrid real-time rainfall network model with neural network and microcontroller for overcoming rainfall variation.</td>
<td>Flood Warning System</td>
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</table>

### TABLE III
**Flood Warning Systems (Part I)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Title of study</th>
<th>Year published</th>
<th>Descriptions or Methods</th>
<th>System type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The use of GIS models for flash flood management</td>
<td>2010</td>
<td>The GIS models for flash flood management.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>2.</td>
<td>Design of early warning flood detection systems using fuzzy logic</td>
<td>2007</td>
<td>This project uses simulated neural network consisting of communication.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>3.</td>
<td>Flood Modelling in Padma-Brahmaputra River Basin</td>
<td>2008</td>
<td>ICIDL-ICWB was used as a measurement tool capable of simulating the system behavior due to the presence of gates.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>5.</td>
<td>Water level and velocity sensing system using remote sensing technology</td>
<td>2005</td>
<td>Water level and velocity sensing system using remote sensing technology.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>6.</td>
<td>Monitoring flood in the lower basin and banks using multifrequency wave attenuation algorithms</td>
<td>2011</td>
<td>It uses the temporal trends of Pollutant Ratio at some ANRQ.</td>
<td>Flood Warning System</td>
</tr>
<tr>
<td>7.</td>
<td>An intelligent real-time flood warning system using an enhanced Kalman filter</td>
<td>2012</td>
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<td>8.</td>
<td>Flood warning and monitoring and prediction using artificial neural network</td>
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<td>10.</td>
<td>A real-time measurement system for large-scale flooding and monitoring and warning applications</td>
<td>2012</td>
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<td>11.</td>
<td>An improved flood warning systems using GIS and spatial analysis</td>
<td>2005</td>
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<td>12.</td>
<td>Design of flood detection system using Artificial Research Group of Civil Engineering and Time-Based.</td>
<td>2015</td>
<td>Design of flood detection system using Artificial Research Group of Civil Engineering and Time-Based.</td>
<td>Flood Warning System</td>
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4 CONCLUSIONS

This paper has reviewed patented and articles about rainfall measurement and flood warning systems. The review is categorized based on patented flood warning devices, published papers about technologies in rainfall calculation and flood forecasting. Some papers include both rainfall measurement systems and flood warning systems. Those studies and patents are arranged chronologically. The review finds out that several methods or algorithms were used based on the purpose and location. Most of the patents involve an alarm device as a sign that a predetermined level of water has reached. As early as 1979, there is already a flood warning system but it only involves conventional electronic board. Today, micro boards are widely used to replace this. There are also several rainfall measurement systems presented and published in different proceedings and journals. One study used an acoustic rainfall rate algorithm while others used several models in measuring the rainfall size. Flood warning technologies have emerged from 2006 to present. Several algorithms and models were established and presented. It is found out in this review that is still technologies that can be applied in measuring the rainfall size and forecasting the flood level. One emerging technology is through the application of predictive modeling used in python programming in a raspberry pi platform. Since the raspberry pi microcontroller is compatible with many applications, web service application systems can be integrated as one of the features of the flood warning system.

5 REFERENCES


