FloodAlert: Automated Flood Warning System for DOST Region IV-A Project HaNDA

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ABSTRACT

Each year, about 22 typhoons pass through the Philippines bringing extensive flooding. To provide help in disaster prevention and awareness, the Department of Science and Technology Region IV-A with the Regional Disaster Risk Reduction and Management Council (RDRRMC IV-A) have implemented project "Hazard Notification, Dissemination, and Awareness" or HaNDA last 2012. Assessing its original version, this study aimed to develop a contemporary technology that can be used to improve dissemination of disaster-related information. Hence, this project implemented an automated flood warning system for HaNDA system to improve the rainfall and water level monitoring and promote modern information dissemination. A Raspberry-PI enabled device was built for the data acquisition and processing, using combination of cumulative algorithm and experience-based method for flood warning judgment. Cumulative algorithm was used for the rainfall intensity calculation before classification and priority determination. The experienced-based method was utilized as basis for the flood occurrence approximation. Results indicated that overall the system is purposeful. The functional system has its own unique features such as the use of ICT enabled technologies like web-enabled data manipulation and SMS real-time notifications. Further improvement may include predictive algorithm for flooding time together with better design ruggedness can also be incorporated in the future.

Introduction

Unknown to many, about 22 typhoons pass through the Philippines each year (7 of which are strong) and CALABARZON is one of the often directly affected as quoted by Project HANDA (DOST Region IV-A., 2012). Batangas province is one of the flood prone areas during heavy rains and storms especially those near the river and flat or low lying areas. Affected by seasonal heavy rains and a adjacent tropical storm, prevalent flooding often occurs. The country is often affected by flooding and landslides caused by substantial rains (CNN Staff, 2017). In order to help resolve this flooding issue through proper information and dissemination, DOST Region IV – A launched Project HaNDA (Hazard Notification, Dissemination, and Awareness) last 2012. It is an online system that was used by the Regional Disaster Risk Reduction and Management Council (RDRRMC IV - A) to disseminate disaster - related bulletins such as Daily Weather Forecast and severe weather bulletins from PAGASA, Earthquake and Taal Volcano Bulletin's from PHIVOLCS, and Situation Reports from Office of Civil Defense (OCD IV - A)/(DOST Region IV-A, 2012). But Since Project HaNDA is an online system, contemporary technology in the field of information and communications technology can be used to improve dissemination of disaster – related information up to the municipal level through fast, dependable, effective and economical electronic (Internet, Short Messaging System or SMS) solutions. Through this, issuance of timely and reliable warnings to the flood – threatened communities are ensured and therefore minimize disaster risks. Some of the system functionalities are information dissemination, data collection, public inquiry, knowledge center, DRRM directory, alerter, and early warning system.

Specifically the early warning system functions as a monitoring mechanism that conveys advisory or warning information when the system concludes that the rainfall amount and/or water level will affect an area. Project HaNDA is way on its completion stage in terms of developing decision support system using its vast amount of data collected. Hence, this research project from Batangas State University offers an ICT (Information and Communicatios Technology)-enabled alert system considering the rain gauge and water level data deployed in selected districts in the province of Batangas aimed at using the available raw data in Project HaNDA. This FloodAlert tool proposed to eliminate human factor in rainfall and water level monitoring and to use advanced technology in disseminating information through fast and reliable means of communication. The aim of the study is to alert the Local DRRMOs of the potentially affected areas through SMS technology. Along this goal, the local community members can be alerted in real-time and make appropriate decisions and actions to safeguard their family and properties at the onset of a possible disaster. Alam (2008) indicated in the briefing paper Flood disasters: Learning from previous relief and recovery operations that "early warning has little relevance if people do not have the ability to respond to warnings in terms of taking decisions on preventive actions and evacuation". Hence, to aid the local community to reach better decisions, a timely and effective information dissemination system is needed.

The FloodAlert tool makes use of raw data from hydro meteorological sensors in Comma Separated Values (CSV) file format fetched from file transfer site of DOST. The initial deployment of the tool focused on Districts III, IV and VI of Batangas province, where there are more sensors such as Automated Rain Gauges (ARG) on high elevated areas and Water Level Monitoring Stations compared to other parts of the province. However, these are just some of the numerous Automated Weather Stations (AWS), ARG and water level station arrangements in the country that were commissioned through joint efforts of the DOST-ASTI and the DOST-PAGASA (DOST, 2012).

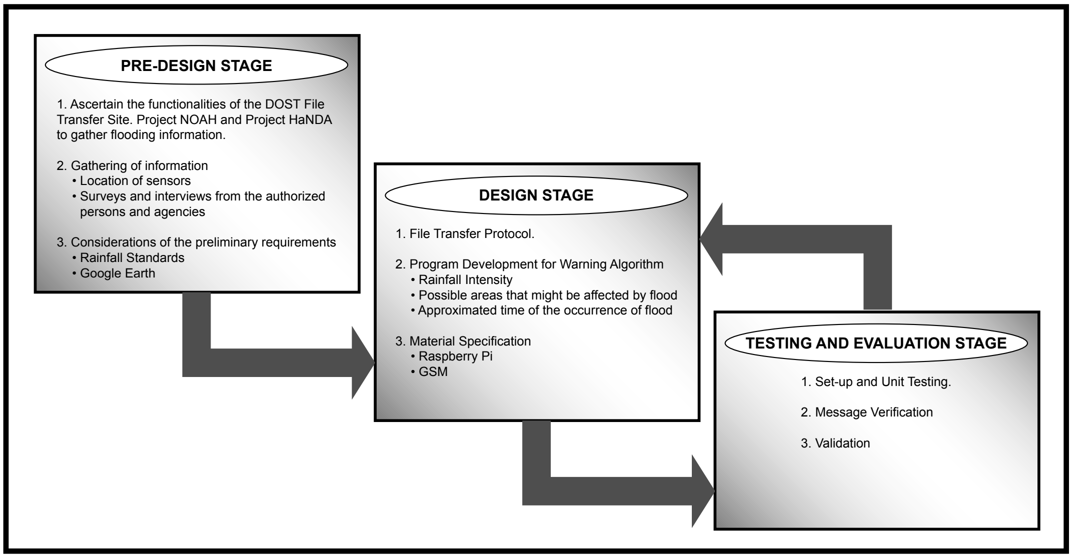


Figure 1. Design Methodology

A Raspberry-PI enabled device was built for data acquisition and processing using combination of cumulative algorithm and experience-based method for flood warning judgment. A cumulative algorithm as defined by Stepp et al. (2013) is one where you incrementally accumulate a larger value by repeatedly adding, multiplying, etc., and storing the result into a variable over and over. On the other hand, experience-based method is a traditional process whereby it depends on the empirical knowledge or mastery of a person or system over an event or subject gained through involvement in or exposure to it.

Purpose of the Research

The FloodAlert tool aimed to determine the value of how the above methods, when joined together, will be able to make use of available raw data to create new meaningful interpretations that can be used for informed decision making on risk management.

Methodology

Figure 1 shows the methodology that the research had carried out. It is consists of Pre – Design Stage, Design Stage and Testing and Evaluation Stage.

A. Discovering the Existing System

Raw data in the form of CSV file were fetched from the DOST file transfer site. Each sensor has different CSV file located at the Philippine E-Science Grid (2010). The research study covers seven hydro met sensors in Batangas Province. Six of them are rain gauges and one is a water level monitoring system as shown in Figure 2.

Figure 2. CSV File Data in DOST File Transfer Site

```
region: 4-A
province: Batangas
location: BRGY. DAYAP ITAAS
posx: 14.05535
posy: 120.85189
elevation: 625.0
sensor_name: Rain2
dateTimeRead(YYYY-MM-DD HH-mm-ss),rain_value(mm),air_pressure(hPa)
2016-01-01 00:00:10,0.0,943.6925
2016-01-01 00:15:06,0.0,943.4475
2016-01-01 00:30:06,0.0,943.49
2016-01-01 00:45:06,0.0,943.415
2016-01-01 01:00:13,0.0,943.3375
2016-01-01 01:15:06,0.0,943.1575
2016-01-01 01:30:06,0.0,943.105
2016-01-01 01:45:06,0.0,942.9125
```

Figure 3. Rain Gauge Sensor Raw Data in CSV File

Rain gauge sensor has an equivalent rain gauge CSV file which contains date in the format of year-month-day and time as hour-minute-second), rain value in mm and air pressure measured in hPa of the sensor. Air pressure data is not about the real-time air pressure of the environment instead, it is the pressure inside the sensor which indicates if the sensor is damaged. Consequently, a water level sensor has an equivalent water level CSV file which contains date (year-month-day), time (hour-minute-second) and water level (m). Screenshot of rain gauge level CSV file is are shown in Figure 3.

Figure 4 shows the geo-hazard map of Project HaNDA that monitors rain gauges and water level. Information about the type of sensor and location of sensor under the subjected areas of the study were gathered at this site. The color green indicator on the map indicates a water level monitoring station deployed on that area, while the indicator of sun with a cloud indicates a rain gauge sensor deployed on that area.

Figure 5 shows the Rainfall Advisories, Classification and Measurement from Project NOAH which was used in this study as a rainfall standard. The rainfall standards are *No Rain, Light Rain, Heavy rain, Intense Rain, and Torrential Rain*. The sum of rain value was classified according to its equivalent rainfall intensity in Figure 5.

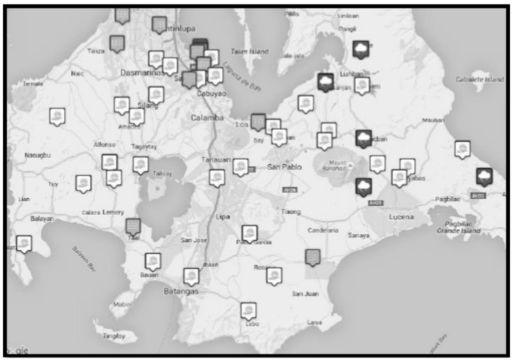


Figure 4. Real-Time Monitoring Geo-Hazard Map

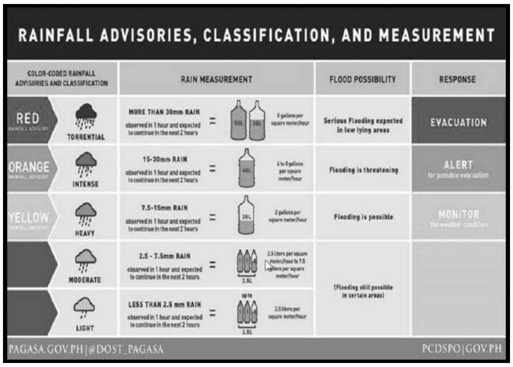


Figure 5. Rainfall Advisories, Classification and Measurement from Project NOAH

B. Site Identification

The complete list of names and contact numbers of assigned Local Disaster Risk Reducton and Management Office (LDRRMO) in Batangas province was given the Provincial Disaster Risk Reduction Management Officer of Batangas Province. Additional information which will be another basis for the calculation of flood time of occurrence were achieved from several interviews conducted. Apparently, the elevation of each area was obtained using Google Earth and compared to get the first to last priorities of every sensor and distinguish areas affected by flood. The researchers verified the reliability of the map through interviews to the LDRRMOs of each municipality of District III, IV and VI of Batangas Province.

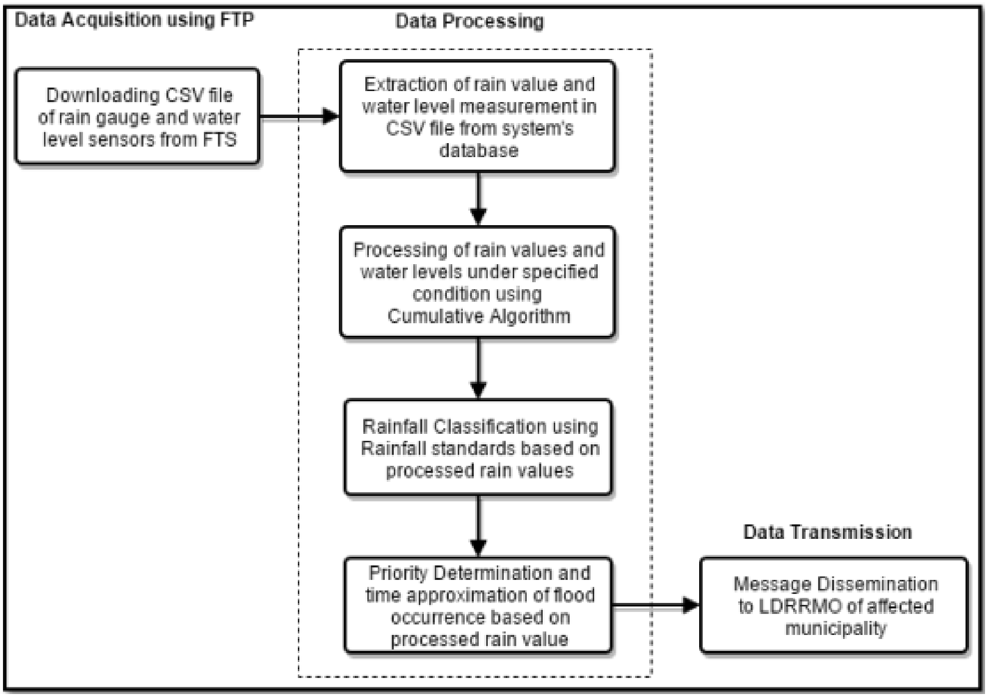


Figure 6. Block Diagram of Flood Warning Algorithm

C. Flood Alert Algorithm Design

Figure 6 shows the block diagram of the flood alert algorithm. It consists of data acquisition, data processing and data transmission.

The data acquisition includes the extraction of 7 sensors in Batangas and the fetching of data from the original data. As stated earlier, the data were acquired from the file transfer protocol site for a fetching time of two minutes. Sensors use SMS protocol to send data to file transfer site. Sensors update data every 15 minutes, if the time exceeds 15 minutes then the rain value will be set to zero. This time duration was chosen because 15 minutes is stated by the U.S. National Weather Service in its 2008 report on Multisensor Precipitation Estimation and Nowcasting for Flash Floods as the prevailing time wherein one rain “event” is understood as distinct from another rain “event”.

The data processing includes the rainfall extraction, the summation of 4 values in one hour using Cumulative Algorithm, the rainfall intensity classification where the rain values are classified as Heavy, Intense, and Torrential Rain, and the approximation of time of flood.

The data transmission includes the message dissemination of the constructed message consisting of the rain values, rainfall intensity, flood prone areas, and the approximated time of the occurrence of flood. Results from respondents’ interview was used in determining the approximated time of flood.

D. Hardware Development

A hardware system employing Raspberry Pi and GSM module was assembled. Raspberry Pi 2 Model B, which is the latest model of raspberry pi, was used for data acquisition and data processing of rain value and water level. Python was the key programming language utilized since it is the most suitable for Raspberry Pi. Furthermore, the device used a 5V power supply and a rechargeable battery that will be the backup

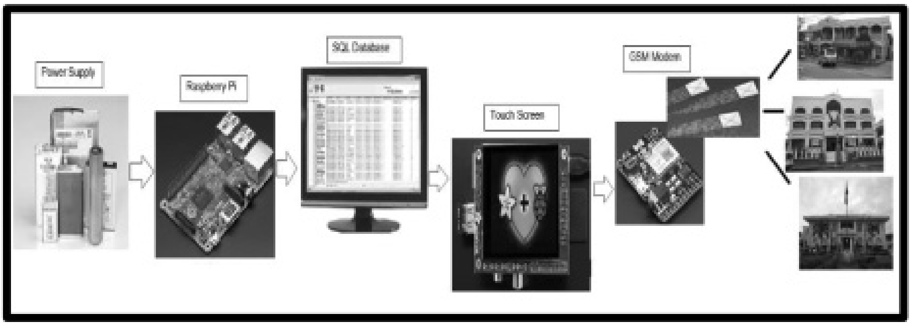


Figure 7. Hardware System

supply in case of power outage. The GSM module was used for the transmission system as shown in Figure 7.

Results and Discussion

It is important to understand how the FloodAlert system can be related to the DOST Projects NOAH and HaNDA as depicted in Table 1.

Table 1

Comparison of FloodAlert with DOST Projects

Project NOAH	Project HaNDA	Automated Flood Warning System for DOST Region IV-A Project HaNDA
	CHARACTERISTICS	
Envisions a disaster-free Philippines where communities are empowered through open access to accurate, reliable and timely hazard and risk information.	Website based system that updates and spread disaster-related announcements including earthquake, volcano, and weather bulletins as well as humid typhoon to concerned government agencies within the Region IV-A.	Using Raspberry Pi, the database will predict the rainfall intensity (No Rain, Light Rain, Moderate Rain, Heavy Rain), detect the possible areas that might be affected by flood (Priority 1, Priority 2 & Priority 3), and predict the time of the possible occurrence of flood.
Contains high-resolution hazard maps for various type of natural hazards using frontier science and cutting-edge technology.	Stores CALABARZON Region hazard maps, vulnerability ratings and DRRM-related information.	Using GSM modem, SMS will be sent at LDRRMOs of the possible affected areas and their low lying areas when "Moderate Rain" is detected.
	OUTPUT	
Online geohazard maps	Online geohazard maps	SMS sent to LDRRMOs

The DOST projects are larger in scope while the FloodAlert covers only flood parameter measurements and data processing. While the DOST projects also handle many parts of the country, the proposed tool focused on sensors deployed in Balete, Dayap Itaas, Mayasang, Laurel, Padre Garcia, Sico and Sto. Tomas parts of Batangas province.

a. Area Elevation

Elevation of the subjected area was important in the analysis of the next priority area in sending warning message in times of typhoons and calamities. Using Google Earth, the researchers distinguished the elevation of the prone areas where the rain gauges have been deployed. Elevation of each sensor's location was used to trace priority areas of sending warning message.

Table 2.

Elevation of the Sensor's Location

Location of the Sensors	Elevation
Balete	99 ft.
DayapItaas/Laurel	449 ft.
Sto. Tomas	630 ft.
Rosario	485 ft.
Padre Garcia	580 ft.
San Juan	66 ft.

Elevation data has many purposeful uses in the areas of tourism, route planning, to optimize views for developments, to lessen visibility of forest clear cuts from major transportation routes, and even golf course planning and development. They are also integrated into the programming of cruise missiles, to guide them over the terrain. In this research, the elevation of an area serves as one of the key inputs for priority assignment.

b. Priority Assignment

The elevation of each area was needed to assign priorities 1, 2 and 3. The high elevated areas and low lying areas were determined based on their elevations. Assigning priorities were also based on the gathered data from the surveys and interviews to LDRRMC of the cities and municipalities of District III, IV and VI. Table 3 shows the conditions on approximating time of the occurrence of flood. Every sensor has different conditions with their priority 1 and 2 based on the gathered data.

Furthermore, the topology of the priorities just like what is seen in Figure 8 shows the location of the rain gauges with their corresponding priorities, considered as their low lying areas. The topologies were made based on their priorities.

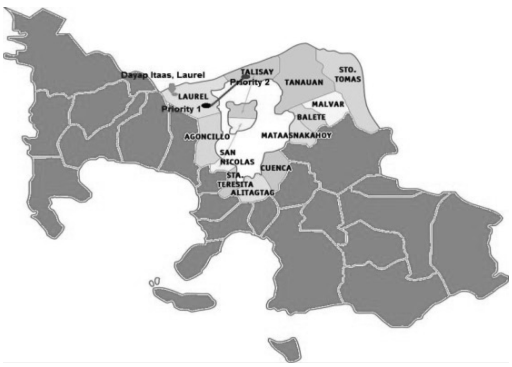


Figure 8. Priority of DayapItaas, Laurel, Batangas

c. Hardware Specifications

The components used for the hardware system were chosen in accordance with the specifications and desired performance. Compatibility of components and design optimization technique were the primary design requirements. Table 3 highlights the technical specifications of the hardware system.

Table 3.
Hardware Specifications

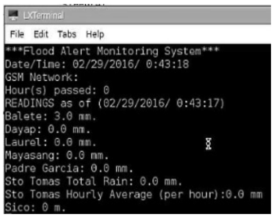
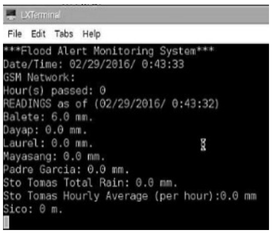
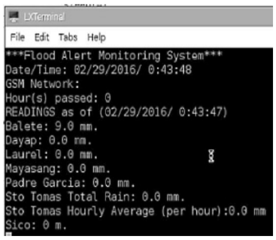
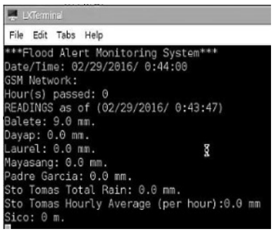
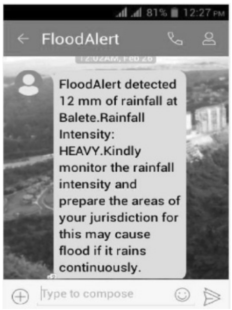
Main Processor	Raspeberry Pi 2 Model B
Transmission	Mini Cellular GSM with Antenna, SIM800L
Power Supply	3.7V, 2000mAH Rechargeable Lithium Ion Polymer
Display	Capacitive touch screen
Others	DC to DC Boost Converter

The research preferred to use GSM rather than other wireless technologies because of its long range capacity without considering the line of sight. SIM800L was specifically selected because it has better interface capabilities. Lithium Ion Polymer Battery satisfied the need of the system since it has a standard charge is nominal 2000mAh and minimum 1900mAh with a cycle lifespan is 500 or 1000 times. It runs with a charger and in case of brownout, it will automatically run the battery that can last up to 3 hours. Since the system is automated, a capacitive touch screen was used to monitor its status. Finally, the DC to DC converter was used to manage the lithium ion battery from 3.7V to 5V which is the needed voltage of Raspberry Pi.

d. System Evaluation

In order to test the functionality of the system, a set of dummy data was initially used. The accuracy of the fetched data was tested in the data acquisition. The data were fetched with the same content as seen on the file transfer site of the DOST. An example of the system simulation is given in Table 4.

Table 4.
Balete Rainfall Testing

<table>
<tr><th>Simulation</th><th>Reading Measurement</th></tr>
<tr><td>
</td><td>The reading started at 17 seconds which is 3mm.</td></tr>
<tr><td>
</td><td>After 32 seconds the reading is 6mm.</td></tr>
<tr><td>
</td><td>After 47 seconds the reading is 9mm.</td></tr>
<tr><td>
</td><td>After 02 seconds the reading is 12mm</td></tr>
<tr><td>
</td><td>After 02 seconds the message is automatically initialized and send.</td></tr>
<tr><td>
</td><td>This is the message sent by the system.</td></tr>
</table>

It is evident in the above table that the system worked well as conceived and designed. During the testing period, several findings were noted. The processor frequency and temp limits settings are important in the configuration set-up. . The ARM frequency or the core frequency must not be less than 900MHz and the temperature limit must not be greater than 50°C. Likewise, internet speed affected the accuracy of the data acquisition. A minimum download speed of 3.45 Mbps is desirable in order to acquire fast download of the CSV file. Finally, the program executed the algorithms perfectly well as long as the fetched data are accurate and the hardware performance is at its optimal conditions.

Conclusions and Recommendations

The research aimed to develop a system that will be able to fetch raw CSV data from a secured database of rain gauges and water level data. In order to achieve this, the system must execute operations performed by a tiny and affordable computer like a Raspberry Pi that is able to communicate with an economical platform like GSM.

In support of DOST IV-A projects, the system developed has its own unique features such as the use of ICT enabled technologies like web-enabled data manipulation and SMS real-time notifications. Likewise, the project had investigated the performance of combined effects of cumulative algorithm and experience-based method for warning decision matrix. Hence, enhancement initiatives for Project HANDA system are highly necessary in the form of using instrument data to provide meaningful information that are critical in decision making. Moreover, proper and quick information dissemination to the authorities' agencies, LDRRMO's and residents of the affected community is highly essential in any risk management efforts. Finally, system integration was delivered carefully and properly through simulations and testing the system components.

In essence, this project reveals that engineering educators and research institution of Region IV-A can work together to address the pressing needs of the community. Faculty, undergraduate and graduate students will be motivated to pursue research projects that are worthy to society in general.

Meanwhile, some recommended actions for further enhancement and smooth deployment were established. Web based system and android application of the upgraded system can be developed to broaden the information dissemination and utilization of the system. The prediction of time for flooding can be done after necessary and sufficient information about the previous measurements has already been obtained.

For future directions, the research project will look at evaluating the system components to achieve better design ruggedness, improved energy consumption, and application of real-time control hardware devices.

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■ ■ ■

References

CNN Staff. (2017). *Flooding brings chaos to Philippine capital - CNN.com*. *CNN*. Retrieved from http://edition.cnn.com/2012/08/07/world/asia/philippines-floods/index.html

DOST. (2012). *Jolo receives AWS, ARG and Water Level Monitoring Station*. from http://embedded.asti.dost.gov.ph/jolo-receives-aws-arg-and-water-level-monitoring-station/

DOST Region IV-A. (2012). *About Project HANDA*. Retrieved from http://drrm.region4a.dost.gov.ph/about.html

Philippine E-Science Grid. (2010) Retrieved from https://www.repo.pscigrid.gov.ph

Sen, S. (2014). *Types of Rain-Gauge: Non-Recording and Recording Types*. *YourArticleLibrary.com: The Next Generation Library*. Retrieved from http://www.yourarticlelibrary.com/water/rainfall/types-of-rain-gauge-non-recording-and-recording-types/60407/

Stepp, M., Reges, S.and Brand, W. (2013). *Building Java Programs, 3rd edition, Lab: Cumulative* Algorithms. Retrieved from http://www.buildingjavaprograms.com/labs/3ed/ch04-cumulative-algorithms.shtml#