Development of Warning System for Mitigation of Urban Flood Hazard

Ranjith Premasiri[1], Rashi Chandranath[2]
[1]University of Moratuwa,
Katubedda, Moratuwa, Srilanka, ranjith@uom.lk
[2]University of Moratuwa),
Katubedda, Moratuwa, Srilanka, rashif@uom.lk

KEY WORDS: Digital elevation model (DEM), Flood level warning, Arc Hydro Model

ABSTRACT: Urban flooding has become one of severe problems faced by many countries leading to various social and environmental interruptions. With the increasing of the occurrence of floods, it has become a necessity to find a proper solution to overcome the problem. This study mainly focuses to develop a warning system for mitigation the urban flood hazard and a case study was carried out in Panadura urban council area. A system was Developed using GPS, Remote Sensing (RS), Geographical Information System (GIS) techniques, PIC Control circuit, Google API, Arc Server, PHP, Java Script and Google My maps to monitor and warn real time flood event.

Digital Elevation Model (DEM) was used to delineate requisite mini water catchments using GIS Analysis Model. DEM processing and accuracy assessment was performed based on the ground truth elevation data measured by GPS surveys. Current drainage system in the area was assessed as alignment and capacity for large water volumes in heavy rainfalls along and delineated natural drainage system. Highly flood vulnerable locations in the current drainage system were identified. A wireless circuit with water level sensing was developed it locater where flood level need to be detected. All these sensors are networked to controlling station. The controlling station process the received information and produces water level with the location. The system automatically updates the SQL database with attributes, and water level values in using PHP files. When java script run it displays flooding area in the web system. Finally adjustments to the current drainage network and new drainage paths were proposed to minimize the flood hazard.

1. Introduction

A flood is an excess of water (or mud) on land that's norm ally dry and is a situation where in the inundation is caused by high flow, or overflow of water in an established watercourse, such as a river, stream, or drainage ditch; or ponding of water at or near the point where the rain fell (Testa, *et al*, 2007). When a flood takes place very rapidly and within a very short period of time disaster can occurred. Therefore the flood can strike anywhere before issuing any kind of warning.
In urban areas has characteristics land-use pattern which has mostly built lands leading to decreases ground infiltration and increases the flow speed and runoff. The water rushes down suddenly into the streams from their catchment areas leading to a sudden rise in water level and flash floods. Unplanned urbanization is the key cause of urban flooding. Various kinds of depression and low lying areas near or around the cities which were act as cushions and flood absorbers are gradually filled up and built upon due to urbanization pressure. This results in inadequate channel capacity causing urban flooding.

Urban flooding has become a severe problem in Colombo, Kalutara, Gampaha, Kegalle and Matara districts in Sri Lanka for last few years. During last two years the problem has gone up to a more vulnerable level due to frequent flash floods causing several social interruptions such as traffic congestions, delays of trains, closure of schools, electricity interruptions, disruption of several services and temporary loss of income (DMC Report, 2010). Considering these facts of urban flooding, it is required to propose a long term solution for the problem through detail studies.

Several physical studies based on topographic surveying have been conducted to propose a solution for this severe problem. But most of them were failed during the implementing phase although they utilized both high cost and time. Therefore, as an applicable approach, this study was carried out to propose an appropriate solution to minimize urban flooding in Panadura urban area. Present study is mainly focuses for decision making according to the GIS analysis. Main objective is Develop Urban flood Conceptual Warning System which included development of a GIS Database, analyses of flood hazard and development of a flood mitigation plan. Secondary objectives is assess current available drainage network with respect to the delineated actual flow path.

2. Methodology

2.1 Study area

The extent of the study area is about 5.85 km^2 which falls in Panadura Urban Council area in Kalutara district, Sri Lanka. Topographically, it is flat low elevated area belongs to coastal plain where elevation varies from 0 m to 15.91 m. It is within latitude of 6°40′46"-6°43′11"and a longitude of 79°53′57"- 79°55′40".The area consists with few canals (Karapan, Moda, and Thalpitiya canal) and Bolgoda Lake. The area belongs to wet zone of Sri Lanka and receives over 5000 mm annual rainfall from southwest monsoon and inter-monsoon rainfalls. Intense rainfall periods cause the major flash floods.

As Remote Sensing data, processed Digital Elevation Model (DEM) created by LiDAR images was used for the study. The main causes of urban flooding and seasonal rainfall intensities and condition of present drainage system were studied. As the area is considered as highly urbanized terrain, soil infiltration, soil type, land use type were not considered for the study due to area is mostly covered by built land. Also most recent development activities such as road construction, building of new factories and government and private building were also assessed. Because most of these activities obstruct the natural and manmade water paths.

2.2 Preparation of Accurate Digital Elevation Model

XY coordinates and elevation data were collected using GPS and Total Station (TS) in the study area and prepared .shp files for point data. Accuracy of available LiDAR DEM was accessed using ground truth data which were collected from GPS and Total Station surveys. The accuracy assessment was performed using point map file created for 84 TS locations and corresponding coordinates. After that Elevation values of corresponding points in LiDAR DEM was extracted using same TS Locations shape file. Then the error for each location was estimated and the LiDAR DEM was corrected. Prepared DEM was used for rest of the GIS analysis and for development of warning system.

2.3 Hydrological Processing: Delineation of natural flow path

Natural flow path was derived using ESRI Arc Hydro tool. Firstly, DEM was filled using fill Dem function to fill the sinks on DEM. To increase the accuracy, fill sink function was used. Then flow direction was derived. Then flow accumulation was derived using generated flow directions. Finally, stream network (Natural flow path) was derived using flow accumulation.

2.4 Designing Water Level Circuit

Water level circuit need to indicate the level of water automatically. The present study used PIC Microcontroller for this purpose. The developed circuit has few sections such as Water Level Sensing Senses (WLSS) section which is to detect the level of water during the rainfall sending signal (wireless) to the Receiver Section. And other important section developed was Power Supply Sections. Receiver section is connected to the Controlling Section, which process the received information and produces visual, sound indicators and controls the operation of the motor whenever required.

Power Supply Section

Power Supply section provides required supply for Receiver and Controlling modules. Receiver module requires +5V power supply. Controller module requires +5v and +12v supply. Circuit Diagram:

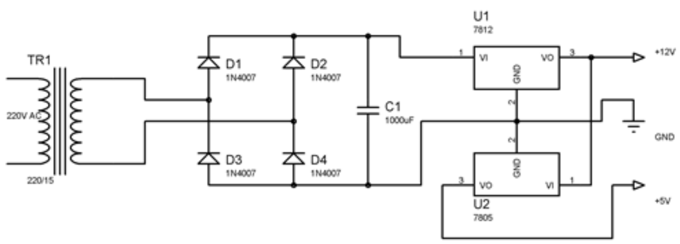

Figure 1 Power Supply Section

Water Level Sensing Section

Level Sensor module is made of with HT12E encoder and ASK (Amplitude Shift Keying) RF transmitter. This circuit can be drive using 9V battery. This circuit is placed near the Water Tank and connected to the water level tank

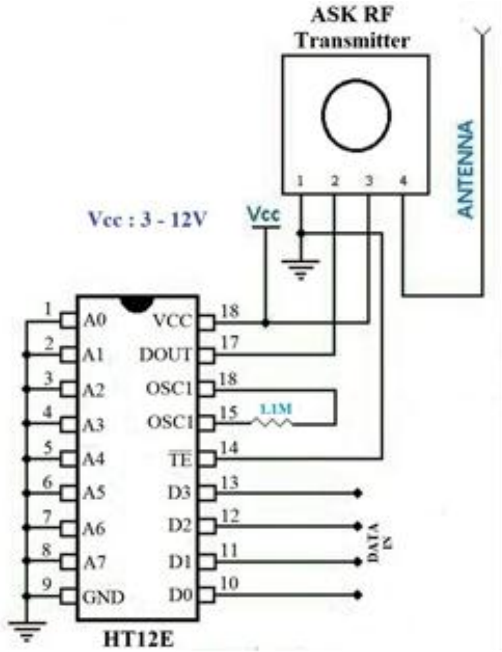

Figure 2 Water Level Sensing Section Circuit

Receiver Section

Receiver Module is made of with HT12D decoder and ASK RF receiver. The data transmitted by the Sensor module is received by this module and is given to the Controlling Module.

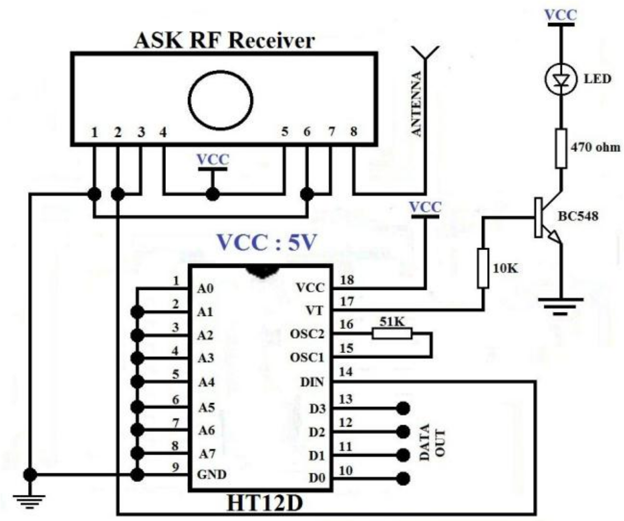

Figure 3 Receiver Section Circuit Diagram

Data Base Section

Database section was based in Receiver Section and the data format is CSV. My SQL was used for this section. Database has one table and four attributes. Four attributes were X (Eastern coordinate),Y(North coordinate), ID (point number), rainfall intensity.

Supports for Real-time GIS

The developed system was connected with virtually and any type of streaming data can feed and which is giving automatic alert near real time. ArcGIS for Server (with the ArcGIS GeoEvent Extension for Server) enables to connect to Receiver. Therefore, processed and filtered real-time data can used to update maps and attributes and to send notifications as instant messages.

Proposed Web base system

Conceptual web base system Using google API, Arc server, PHP, Java Script, Google My Map and HTML.PHP file read the database attributes then assign the value for java Script. Using google API and Arc server developed KML file. After this process, Google My Map was used to display the updated flooding Area.

3. Results and discussion

3.1 Result

Accuracy assessment of DEM
Variation of elevation on DEM and ground truth values: 0.337 m
Variance of elevation differences: 0.33771437

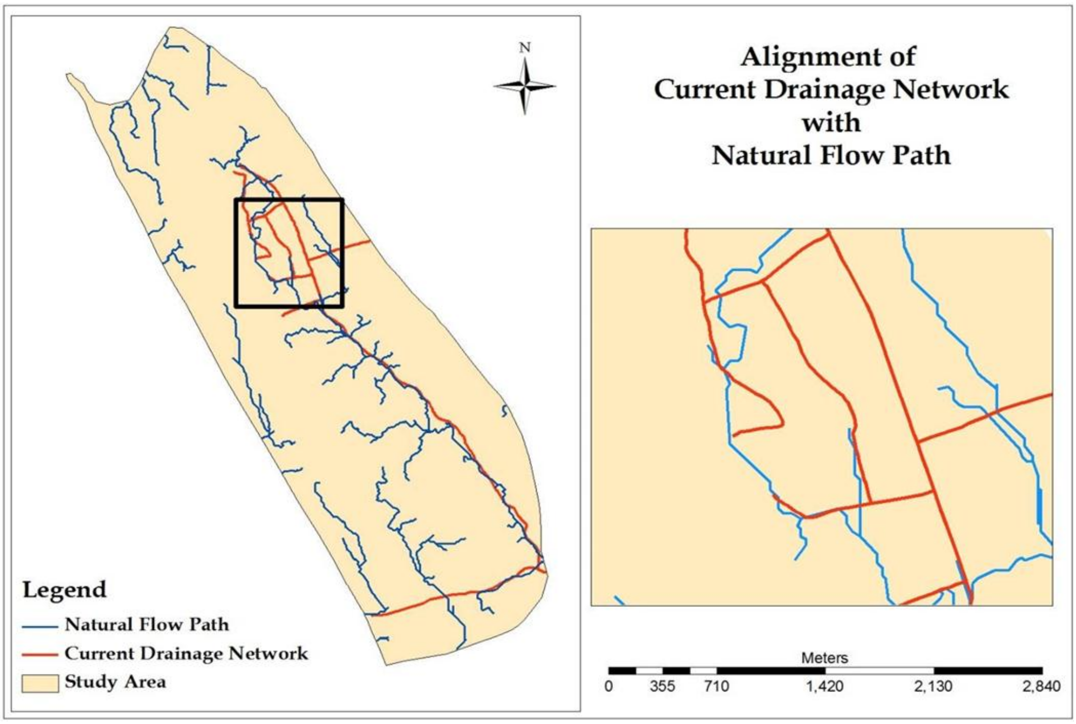

Figure 4. Alignment Assessments

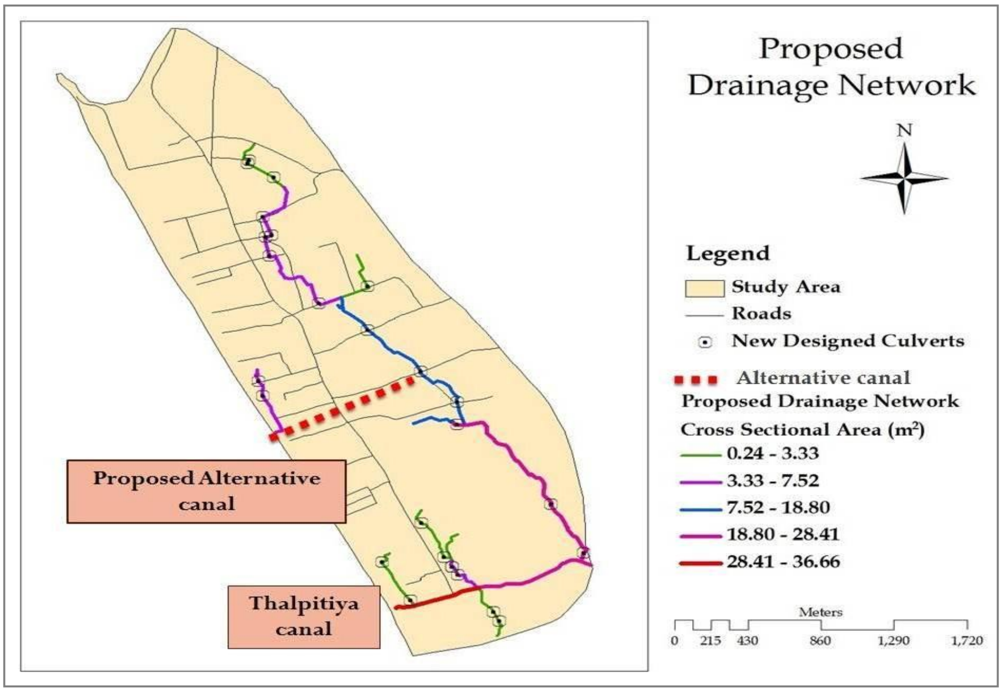

Figure 5. Proposed new drainage design for Panadura

Drainage network should be modified in both alignment and the volume at least in the severe flood vulnerable locations. This is the most practicable solution in the implementing to minimize flood problem to a greater extent. Modification of current available drainage network should be preceded at the identified flood vulnerable locations where either locations of misalignment or lesser volumes. But available engineering mitigation methods for flood are mostly not practicable due to many reasons such high cost, social and other environmental issues and political issues etc. Therefore minimizing of damages caused by flood hazard can be done through proper awareness and effective warning system. Effective warning system needs real time updating facilities, less manual operations, reliable information, updating and up grading facilities etc.

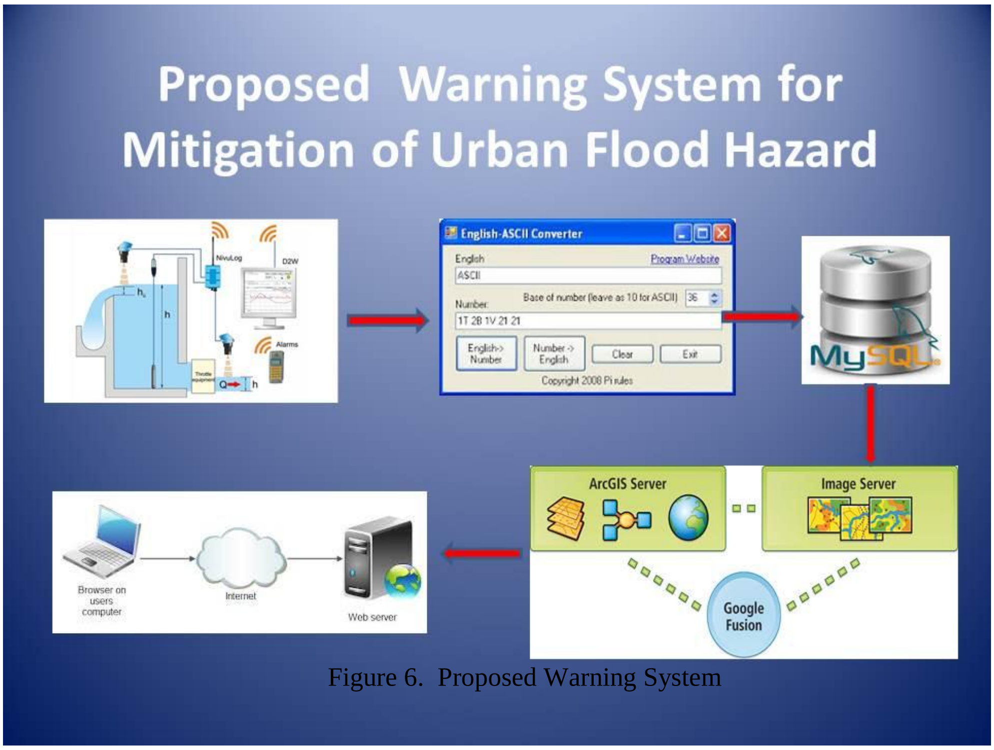

Figure 6. Proposed Warning System

The developed water level circuit transmitted the data into the server, then the receiving ASCII files are converted into MY SQL data base format and stored the data in SQL database. Using SQL data base, ArcGIS Server works with spatial data and stored in relational database management systems of Microsoft SQL Server. Multiuser geo-database was used to apply sophisticated rules and relationships; defined data models such as topologies, geometric networks, and network datasets, maintain data integrity and enable multiuser editing. It can be processed and filtered real-time data, which makes facilities to monitor, assess and update maps and data, and send notifications via e-mail, text massage or instant messages.

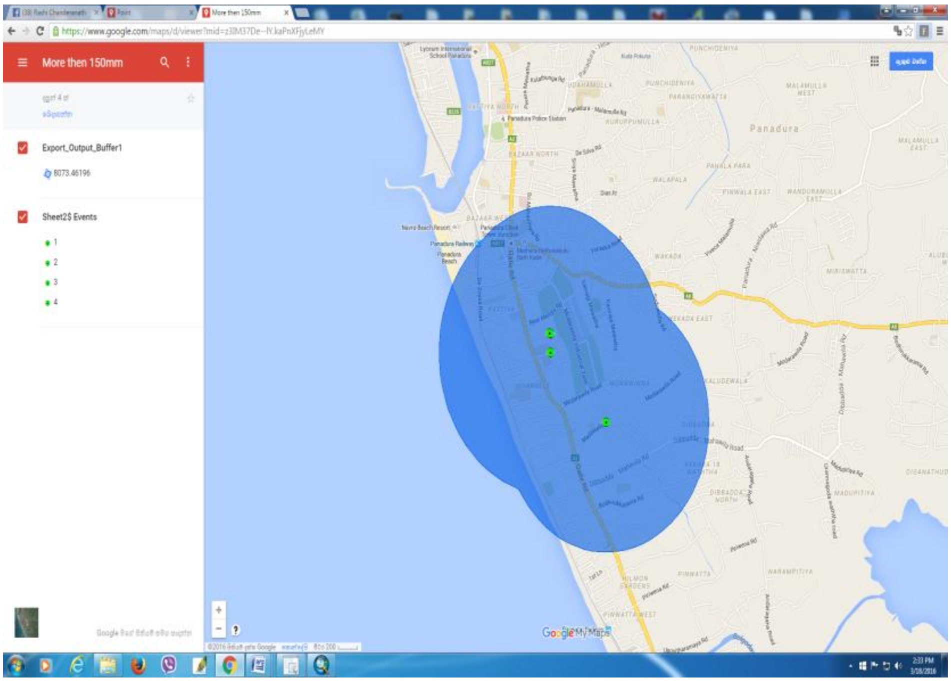

Figure 6. More than 150 mm rainfall showing in Web

4. Conclusions and recommendations

Since urban areas very often affected by flash floods, which has very limited time for issuing warning to the public, an automated GIS based warning system is immensely helpful to minimize the flood hazard damages. The methodology used in the present research to developed flood model using both RS and field measurement was mostly accurate. Therefore, the flood model developed could be used to developed GIS based warning system. Web and GIS based flood warning system including real time water level monitoring system is one of the solution for mitigating flood damages in urban areas.

According to results, there is no proper alignment of current available drainage network in the study area with natural water flow paths which were delineated from Hydrological processing. Specially, upper most region of the network in a severe threat of flood because most of the drainage paths do not align with the natural flow path in that region. The capacity of the drainage network is only sufficient for average rainfall. Even with average rain fall in heavy rainy season the drainage network fails to handle the water according output. Since the drainage does not sufficient for above mentioned rainfall values, excessive amount of water will be flooded over the flat area. Therefore the warning system developed will be use full for such areas**.**

Soil Infiltration, Soil Type, Landuse Type, and wind speed factors affect for the flood, thus such factors are also need to consider for the warning system. Radio transmission is a very highly expensive method, therefore GSM signal transmission is much useful in this system.

For the designing new drainage system for the area, amount of surface runoff and capacity of presently available drainage network need to be considered with all obstruction for water flowing. Surface runoff was calculated using maximum rainfall of 450 mm/day predicted with respect to the rainfall data collected by the Meteorological Department, Sri Lanka over last five years. While calculating the surface runoff following important assumption was met. That was given sensible results which is acceptable with past flood events occurred.

6. References

Earthsky, 2015, A clear voice for science, Definition, Inselburgs

Fowze, J. S., Nandalal, H. K., Welideniya, D. P., Samarasinghe, S. M., Senevirathne, A., Borumudai, A., 2010. Flood Inundation Modeling in the Lower Reach of the Kalu river, Sri lanka, Proceeding ACRS conference .

http://www.sciencedictionary.com/definition/inselberg.html [Accessed on: 25/07/2015]

Joint Rapid Assessment by the Disaster Management Centre (DMC) of the Ministry of Disaster Management, World Food Programme, Office for the Coordination of Humanitarian Affairs (OCHA) supported by the United Nations Development Programme (UNDP), Date: 12 November 2010.

Smith, J., 1989. Disaster Management Center, Flood situation update no.2, 2010 – Sri Lanka,18 May 2010 at 1830 hrs GLIDE: FL-2010-000092- LKA

Maduranga H.,R., Balasooriya B.,M.,R.,K., 2009, Design Of Surface And Subsurface Drainage System For Johnston Estate Resettlement Site, Nuwaraeliya Using GIS Techniques, National Building Research Organization

Rosenqvist A., Shimada M. and Watanabe M., 2004. ALOS PALSAR: Technical outline and mission concepts, Paper presented at 4th International Symposium on Retrieval of Bio- and Geophysical Parameters from SAR Data for Land ApplicationsInnsbruck, Austria, November 16-19

Frederic G. Snider, R.P.G2, GPS: Theory, Practice and Applications, Available from: http://www.pdhonline.org/courses/l116/l116content.htm [Accessed: 30/07/2015]