iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: II Month of publication: February 2022

DOI: https://doi.org/10.22214/ijraset.2022.40429

Patalan River Basin Flood Plains Exposure and Vulnerability Assessment of Buildings Extracted from Lidar Derived Datasets

Gloria N. Ramos[1], Annie Melinda Paz-Alberto[2]
[1]College of Engineering, Central Luzon State University (CLSU), Science City of Muñoz, Nueva Ecija 3120, Philippines

Abstract: Philippines, as it is known to be a stopover for Pacific typhoons, is frequently threaten by flood and landslide that endangers the lives of many Filipinos. Great amount of monetary resources are being used up annually because of incidents by annual heavy downpour in this country. The population, their source of revenue and the area are the ones affected by these unfortunate events that causes the country for millions of peso every year. In this regard, there is an obvious need for methods and strategies that will alleviate adverse situations and which will protect human lives, properties and social infrastructure against disaster phenomena. Different important parameters in disaster risk management such as earth observations, Light Detection and Ranging (LiDAR) and Geographic Information System (GIS) were integrated and utilized in this study. This study dealt with mapping and assessment of buildings that might possibly be exposed and vulnerable to flooding based on the simulated flood maps at different rainfall scenarios in Patalan River Basin, Pangasinan, Philippines. The assessment was done through GIS overlay analysis of the CLSU PHIL-LiDAR 1 Project outputs, the 3D building GIS database and flood hazard maps. The 3D building GIS database was generated through processes and analysis of various datasets that include 1m resolution LiDAR Digital Elevation Models (DEMs), geo-tagged video captured data and high resolution images in Google Earth. The flood hazard maps with different hazard levels were generated with the use of flood models developed using the combined HEC HMS and HEC RAS. Results of this study were series of flood exposure maps and vulnerability maps with statistics at different rainfall scenarios. The number of houses, businesses and other types of building at risk of being flooded was quantified. It was observed that buildings exposed and vulnerable to flood are highest at 100 year return period. With the total of 129,800 building features extracted, results show that at 100 year return period there will be 61,377 buildings, 16,806 buildings and 23 buildings at low, medium and high hazards, respectively. Moreover, also at 100-year return period, a total of 12,569 buildings, 8,628 buildings and 17,795 buildings were identified that had high vulnerabilities to flood in terms of height at low, medium and high hazards, respectively. These produced maps can provide valuable information to the local government units and the communities around Patalan river basin in their flood disaster management through appropriate and risk-conscious development in order to prevent further build-up risks. Through these maps, it is easier to disseminate information that is more realistic to the residents about the hazardous areas and to help them act on warning and evacuating measures.
Keywords: Geographic Information System, flood, database, exposure, hazard

I. INTRODUCTION

A. Background of the Study

Philippines' geographical location greatly affects the country's seasonal changes. The Philippines is located between the South China Sea and Philippine Sea, in which the latter is known as the breeding ground for tropical cyclones that often traverse westward the Philippine Area of Responsibility (Faustino-Eslava, Dimalanta, Yumul, Servando, & Cruz, Geohazards, Tropical Cyclones and Disaster Risk Management in the Philippines: Adaptation in a Changing Climate Regime, 2013). Whenever a tropical cyclone is developed over South China Sea, where it gains more moisture through an interaction with Habagat, it is expected to move northeastward and affect the western section of Luzon. Due to the number of typhoons that hit the Philippines annually, unfortunate combination of phenomenon adversely affect the populace of this country.

Patalan River (Bued River) traverses 25 barangays in Baguio City and the municipalities of Itogon and Tuba in Benguet before it reaches Rosario, La Union, and the municipalities of Sison, San Fabian, San Jacinto and Mangaldan in Pangasinan. Parts of this river are find along the length of Kennon Road. Patalan River serves as a major source of water for agriculture and aquaculture in these areas (Lim, 2016). As one of the major factors in most types of hazard analysis is topography, the LiDAR data have become a major source of digital terrain information.

LiDAR is a remote sensing technology characterized by precise vertical and horizontal point accuracy and is significant for several applications that includes the generation of Digital Terrain Models (DEM) and Digital Surface Models (DSM) and building footprint extraction. With the existing modern LiDAR technology integrated with some forms of field data within GIS boundary, a better visualization of interactive map overlays and quickly illustrate which areas of a community are in hazard of flooding. Such maps can then be used to coordinate mitigation efforts before an event and recovery after the event.

The identification and mapping of flood prone areas are essential for risk reduction. The flood hazard maps display flood hazard information in a given area which can be used in area development and management planning. In the twenty-first century the need to study both exposure and vulnerability as fundamental components of risks has been heightened by the International Strategy for Disaster Reduction, supported by a new focus directed towards the disaster reduction through effective risk management. In the Hyogo Action Framework 2005 to 2015, governments from the whole world were certain to take measures in reducing exposure and vulnerability to natural threats.

In this study, the mapping and assessment of buildings exposed and vulnerable to flood in the flood plains of Patalan River basin in Pangasinan was conducted and the generation of the 3D building GIS database that was used for the assessments was also presented. The assessments was done through GIS overlay analysis using the CLSU PHIL-LiDAR 1 Project flood hazard maps outputs and generated 3D building GIS database. This study focuses on identifying the number of buildings exposed to different flood hazard depth at varying rainfall return periods.

The general objective of the study was to generate a 3D Building GIS database and determine the buildings exposure and vulnerability (in terms of height) to flood hazard at varying rainfall return periods in Patalan River basin. Specifically, this study aimed to:

1) Generate a 3D building GIS database for the Patalan River flood plains.
2) Map the buildings exposure and vulnerability to flood hazard in Patalan River's basin using GIS
3) Assess the buildings exposure and vulnerability to flood at different rainfall scenarios with varying intensity and duration.

II. MATERIALS AND METHODS

A. *The Study Area*

Patalan River (Figure 1), also interchangeably known as Bued River, is found in Pangasinan and has an elevation of 34 meters above sea level (The Travel Location Guide, 2017). This river is a major river in Luzon that covers the provinces of Benguet and Pangasinan and some of La Union and trace its sources from the Cordilleran region (Faustino-Eslava, Dimalanta, Yumul, Servando, & Cruz, Geohazards, Tropical Cyclones and Disaster Risk Management in the Philippines: Adaptations in a Changing Climate Regime, 2013).

This river starts at the southeastern portion of Baguio City, where it covers 25 barangays. The river enters Pangasinan through the municipality of Sison upon reaching barangay Dungon where it starts to become heavily silted. It enters San Fabian, then traverses Pozorrubio before it reaches San Jacinto and enters Mangaldan, where it merges with the Angalacan River forming Cayanga River that empties into the Lingayen Gulf at the border between San Fabian and the city of Dagupan (Sussle, 2016).

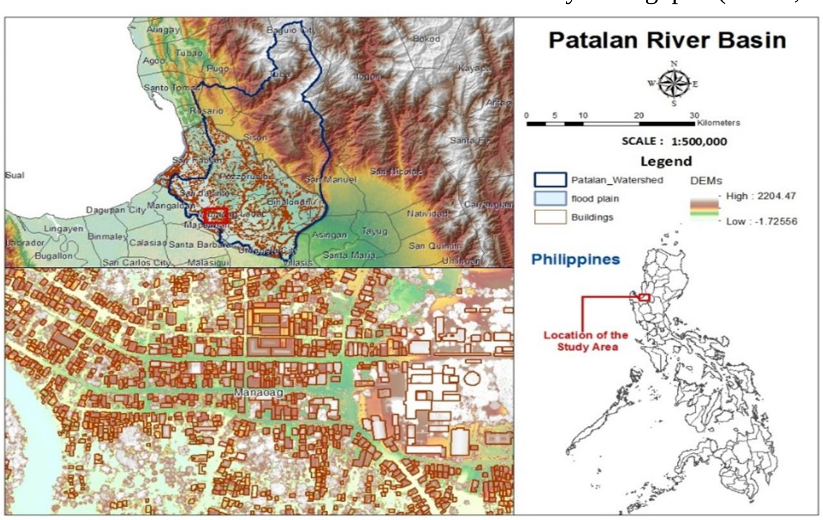


Figure 1. The Patalan River Basin in Pangasinan, Philippines

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

B. Datasets used

The LiDAR derived Digital Surface Model (DSM) and Digital Terrain Model (DTM) with 1-m resolution acquired and processed by UPD PHIL-LiDAR 1 project were used for the extraction of building footprints in the flood plains of Patalan River basin. These Digital Elevation Models (DEMs) have the Mean Sea Level as vertical datum and were delivered in ESRI GRID format with Universal Transverse Mercator (UTM) Zone 51 North projection and the World Geodetic System (WGS) 1984 as horizontal reference (Santillan et al., 2015). 1D maps produced were obtained from the project Phil-LiDAR1 maps of the LiDAR Data Processing and Validation in Luzon: Region III and Pangasinan (Region I). For improved accuracy in building footprints extraction, Google Earth images were utilized in rechecking of the existence and shapes of the extracted features from LiDAR DSM where created fishnet of rectangular cells was overlaid and served as a guide in both building footprint extraction and existence rechecking in Google Earth. Extracted building features were also verified and field validated with the use of video-tagging device or geo tagged video capturing tool wherein informations such as name and type were gathered. The provided table from UPD PHIL-LiDAR 1 project containing a summary of different types of buildings with corresponding codes for the building type attributes.

The flood depth maps generated and by CLSU PHIL-LiDAR1 project were used as input in buildings flood exposure and vulnerability assessment. These flood depth maps represent maximum depth of flooding due to rainfall events with varying intensity and duration (i.e., return period of 5, 25and 100-year). Flood depth maps were transformed into flood hazard maps by categorizing the flood depths in hazard levels as follows: low (< 0.5m depth), medium (0.5 - 1.5 m) and high (> 1.5 m). In order to determine the reliability and accuracy of the generated flood depth maps to the observed flood depths in the area, field validation was conducted.

C. Generation of Building GIS Database

1) *Building Features Extraction:* For a more accurate number of buildings in the study area, features were manually extracted or digitized. Building footprints were traced using the polygon feature type from the LiDAR Digital Surface Model using ArcGIS 10.2 software. The existence and shape of the extracted buildings were checked using the corresponding high resolution Google Earth due to the reason that some buildings and their extents were indistinguishable in the DSM.
2) *Building Features Attribution:* All building features extracted were attributed following the various building types as shown in Table 1. With the use of the integrated Spatial Analyst in GIS, automated buildings height extraction from normalized Digital Surface Model (NDSM) was performed. The normalized DSM represents the height of the object from the terrain which was produced with the difference between Digital Surface Model (DSM) and Digital Terrain Model (DTM). The building height range that was considered are greater than or equal to 2-m. Therefore, digitized buildings with height of less than 2-m were deleted. This assumes that only those features which are having the said height are considered as buildings.

Table 1. Building types with corresponding codes that were used in the buildings attribution (UP-PHIL-LiDAR).

Building Type	Code
Agricultural & Agro-Industrial	AG
Bank	BN
Barangay Hall	BH
Factory	FC
Fire Station	FR
Gas Station	GS
Market/Prominent Stores	MK
Medical Institution	MD
Military Institution	ML
NGO/CSO Offices	NG
Other Commercial Establishments	OC
Other Government Offices	OG
Police Station	PO
Power Plant/Substation	PP
Religious Institution	RL

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

Residential	RS
School	SC
Sports Center/Gymnasium/Covered Court	SP
Telecommunication Facilities	TC
Transport Terminal (Road, Rail, Air, and Marine)	TR
Warehouse	WH
Water Supply/Sewerage	WT

D. Generation of Flood Hazard Maps

Through the CLSU PHIL-LiDAR 1 project, Flood depth maps were generated and used as input in building flood exposure and vulnerability assessment in the flood plains of Patalan River basin. The flood depth maps were generated by the use of the developed flood model of the river basin from the combined HEC HMS hydrological model and HEC RAS hydraulic model. The flood depth maps represent maximum depth of flooding due to rainfall events with varying return periods (5-, 25-, and 100-year return periods) where the discharges or flow data inputs were the computed 5, 25 and 100-year return period of rainfall events in the Patalan river watershed. These flood depth maps were transformed into flood hazard maps by categorizing the flood depths into hazard levels as low (<0.50 m depth), medium (0.50 m – 1.50 m depth), and high (>1.5 m depth). Figure 2 display the Patalan flood hazard maps at 5-year, 25-year and 100-year return period, respectively.

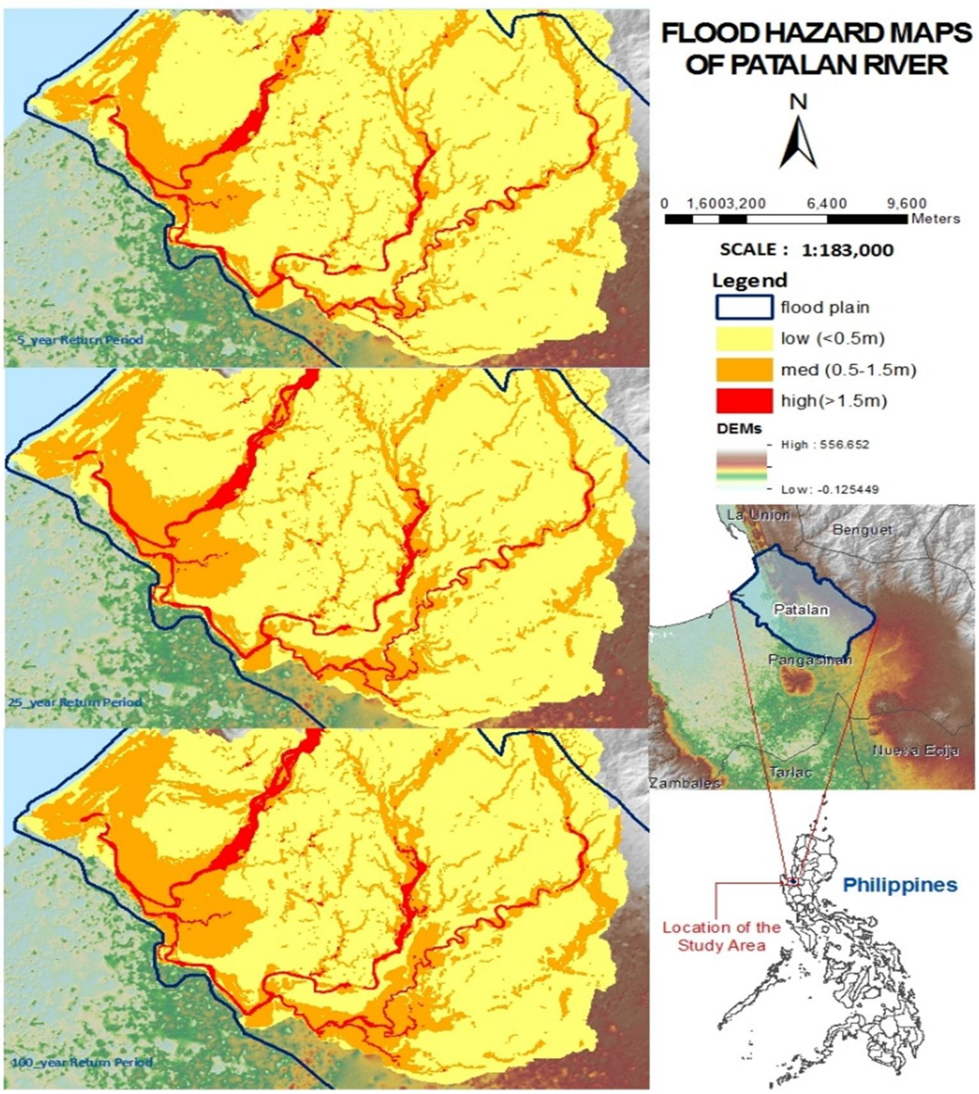


Figure 2. The flood hazard maps of Patalan River at varying rainfall return periods

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

E. Buildings Exposure and Vulnerability Assessment

GIS overlay analysis of the 3D building GIS database and flood hazard maps for the Santo Tomas river basin was conducted to identify which buildings are exposed to various levels (low, medium, high) of flood hazards. For the determination of buildings vulnerability in the flood plains of the River basin, the degree of buildings exposure to flood was characterized with the comparison of buildings height and simulated flood depths. If the flood depth is less than 0.10 percent of the building's height, then it was coded as "Not vulnerable". If the flood depth is 0.10 to less than 0.30 of the building's height, then the vulnerability was "Low". On the other hand, if the flood depth is equal to 0.30 but less than 0.50, then the vulnerability was medium. If the flood depth is greater than or equal to 0.50 of the building's height, then the vulnerability was high.

III. RESULTS AND DISCUSSION

A. Soil and Land Cover

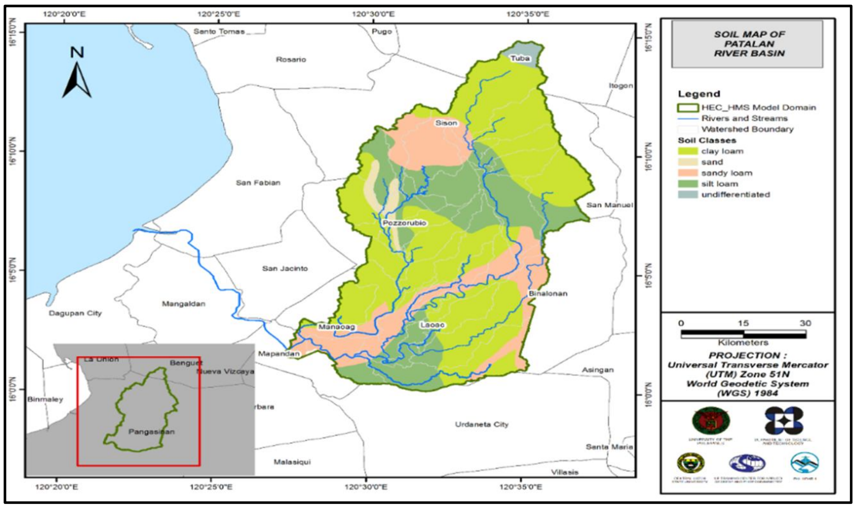


Figure 3. The soil map of Patalan river basin

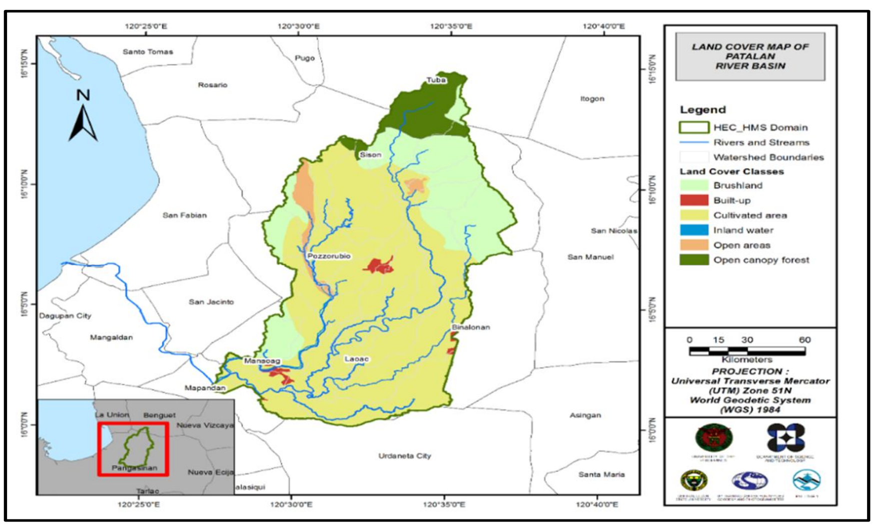


Figure 4. The land cover map Patalan river basin

The soil shape file from the Bureau of Soils and Water Management (BSWM) of the Department of Agriculture (DA) as shown in Figure 3 was utilized for the estimation of the CN parameter. The land cover shape file from the National Mapping and Resource Information Authority (NAMRIA) of the Department of Environment and Natural Resources (DENR) as presented in Figure 4 was also used for the estimation of the CN and watershed lag parameters of the rainfall-runoff model.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

B. Precipitation

Precipitation data was taken from two automatic rain gauges (ARGs) installed by the Department of Science and Technology – Advanced Science and Technology Institute (DOST-ASTI). These were the Laoac and Aloragat ARGs (located at Binalonan). The location of the rain gauges is seen in Figure 5.

The total rain recorded from the Laoac rain gauge is 40.2 mm. It peaked to 4.6 mm on 02 October 2015 at 6:45 AM. The lag time between the peak rainfall and discharge is 9 hours and 35 minutes. For Aloragat, total rain for this event is 32.6 mm. Peak rain of 5.8 mm. was recorded on 02 October 2015 at 5:50 AM. The lag time between the peak rainfall and discharge is 10 hours and 30 minutes as seen in Figure 6.

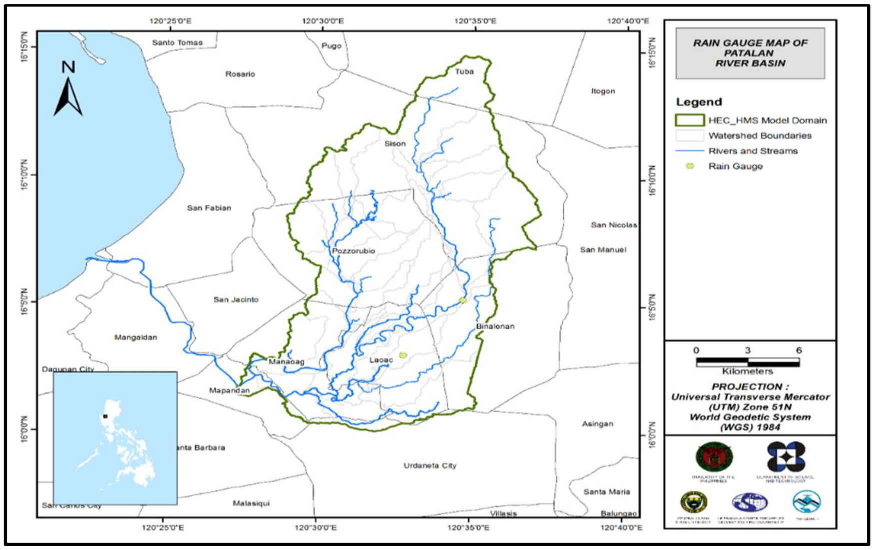


Figure 5. The location map of rain gauges used for the calibration of the Patalan HEC-HMS model

C. Model Outflow using Rainfall Intensity-Duration- Frequency (RIDF) Analysis Data

1) Patalan RIDF: The Philippines Atmospheric Geophysical and Astronomical Services Administration (PAGASA) computed Rainfall Intensity Duration Frequency (RIDF) values for the Patalan rain gauge. This station was selected based on its proximity to the Patalan watershed. The extreme values for this watershed were computed based on a 48-year record. Five return periods were used, namely, 5-, 10-, 25-, 50-, and 100-year RIDFs as shown in Figure 6. All return periods are registered for 24 hours and the peak periods were noted after 12 hours. A summary of the total and peak

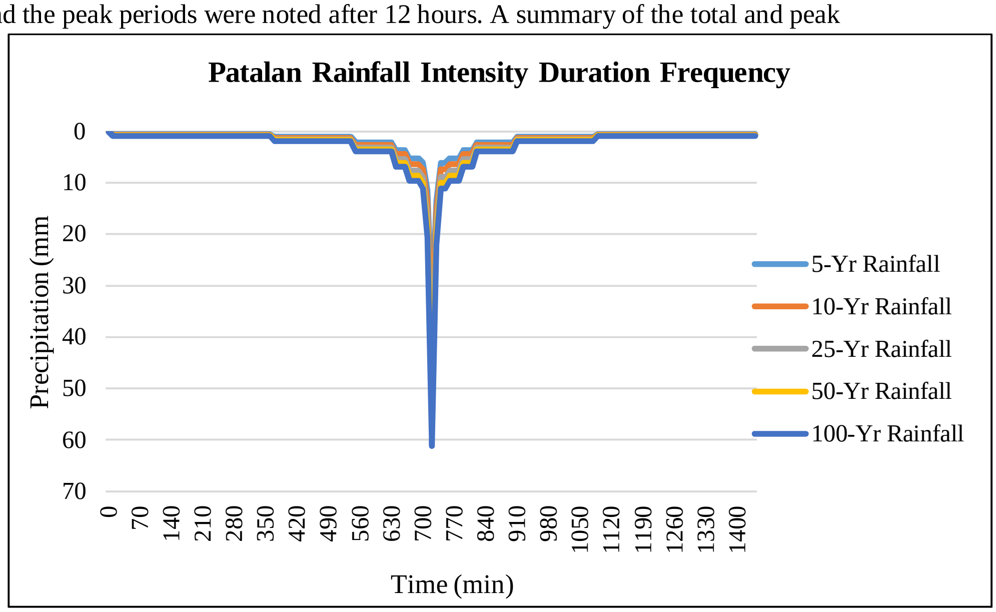


Figure 6. Patalan rainfall-intensity frequency duration (RIDF) curves

The summary graph show the Patalan outflow using the Dagupan rainfall Intensity- Duration-Frequency curves (RIDF) in 5 different return periods (5-year, 10-year, 25- year, 50-year, and 100-year rainfall time series) based on the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAG-ASA) data. The simulation results showed significant increase in outflow magnitude as the rainfall intensity increases for a range of durations and return periods. A summary of the total precipitation, peak rainfall, peak outflow and time to peak of the Patalan discharge using the Dagupan Pangasinan Rainfall Intensity-Duration-Frequency curves (RIDF) in five different return periods is shown in Table 2.

Table 2. Peak values of the Patalan HEC-HMS Model outflow using the Dagupan RIDF

RIDF Period	Total Precipitation (mm)	Peak rainfall (mm)	Peak outflow (m^3/s)	Time to Peak
5-Year	246.7	33.9	1282.3	10 hours, 20 minutes
10-Year	293.6	40.5	1518.6	10 hours, 20 minutes
25-Year	352.9	48.9	1815.1	10 hours, 20 minutes
50-Year	396.8	55.1	2034.9	10 hours, 10 minutes
100-Year	440.5	61.2	2253.1	10 hours, 10 minutes

D. 1-D Simulated Flood Hazard Maps due to Hypothetical, Extreme Rainfall Events

The unsteady flow module of HEC-RAS was used to determine the water surface profiles for flood inundation mapping. This type of simulation is made for varying flows in the river with respect to time. The input flow data (discharge values) was computed and calibrated in HEC-HMS.

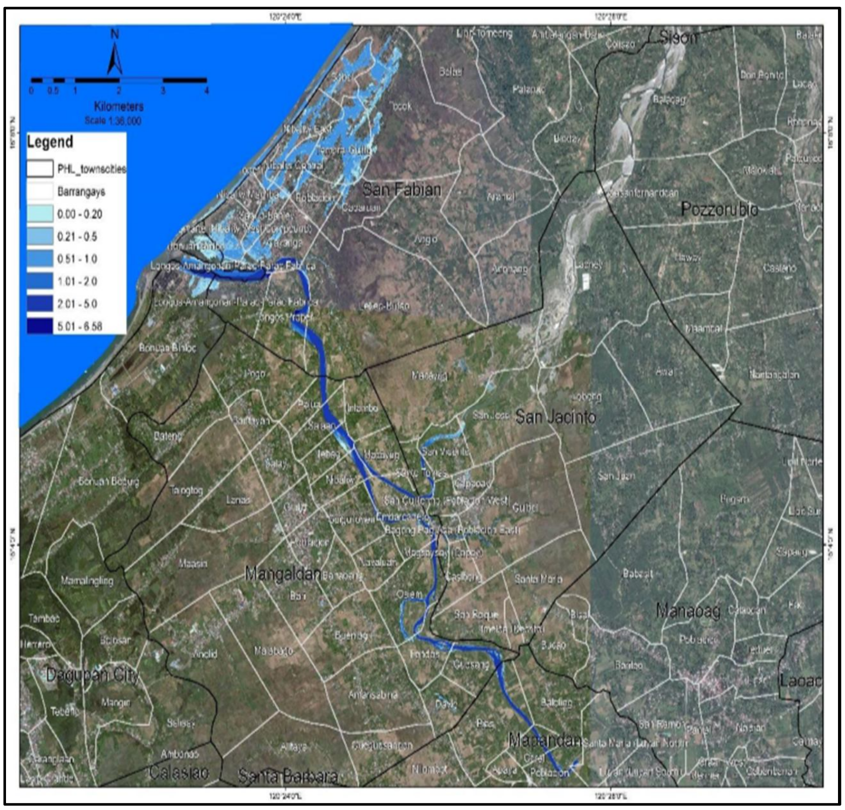


Figure 7. 1D Flood hazard map using calibrated flow discharge of Patalan river from HMS

The resulting model was used in determining the flooded areas within the model. The simulated model is an integral part in determining real-time flood inundation extent of the river after it has been automated and uploaded on the DREAM website. The sample 1D flood hazard map using the calibrated discharge of Patalan river from HMS model is shown in Figure 7.

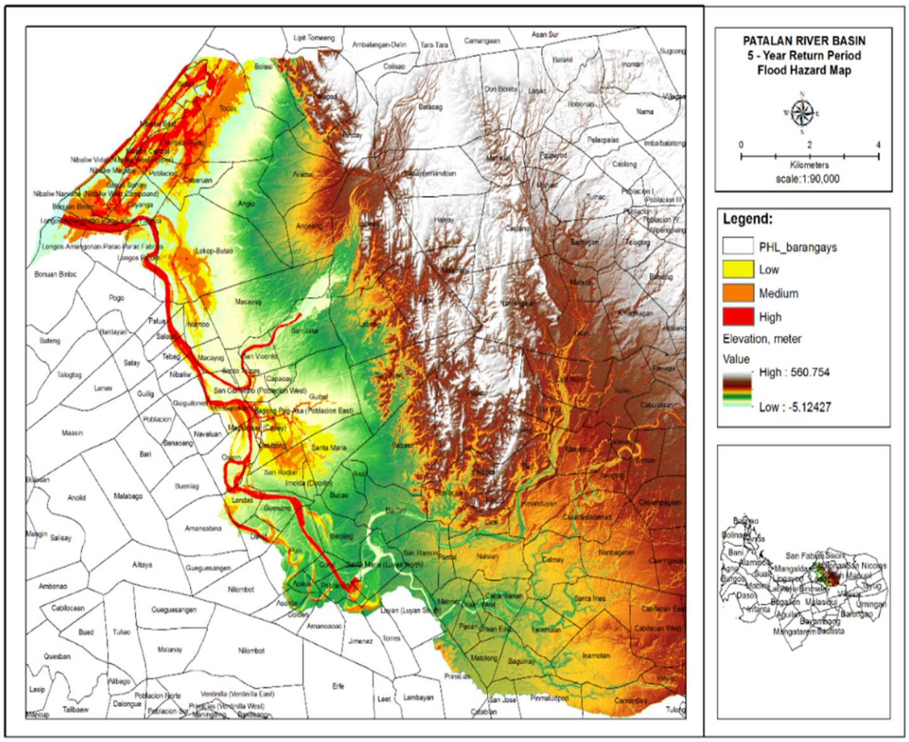


Figure 8. 1D-Simulated flood hazard map of Patalan River Basin for a 5-year rainfall event

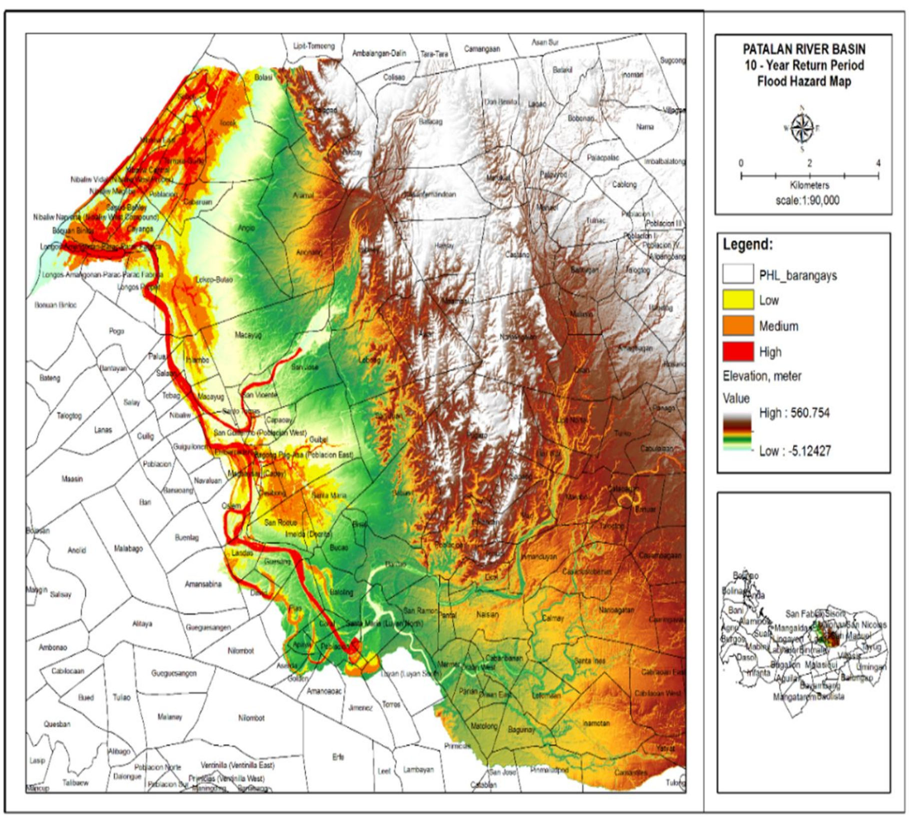


Figure 9. 1D-Simulated flood hazard map of Patalan River Basin for a 10-year rainfall event

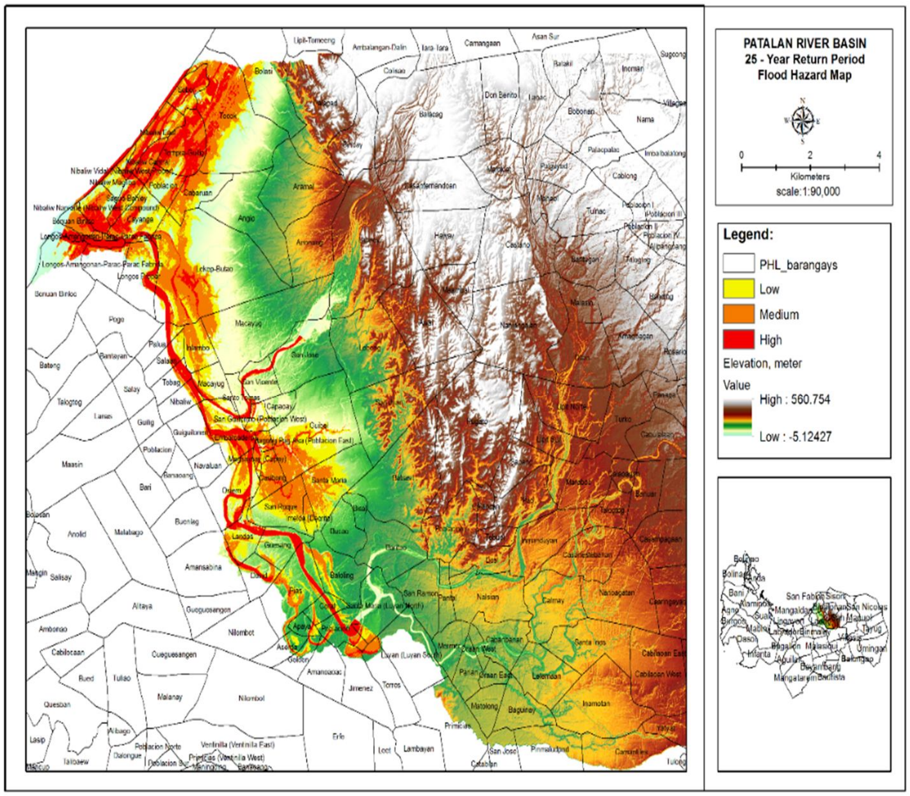


Figure 10. 1D-Simulated flood hazard map of Patalan River Basin for a 25-year rainfall event

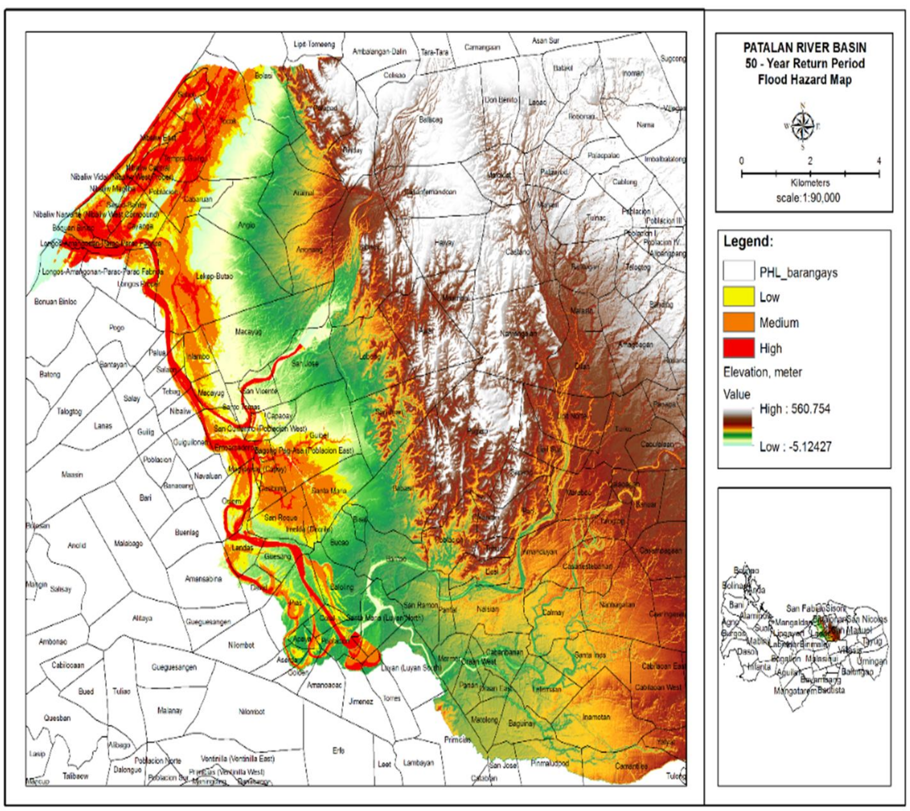


Figure 11. 1D-Simulated flood hazard map of Patalan River Basin for a 50-year rainfall event

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

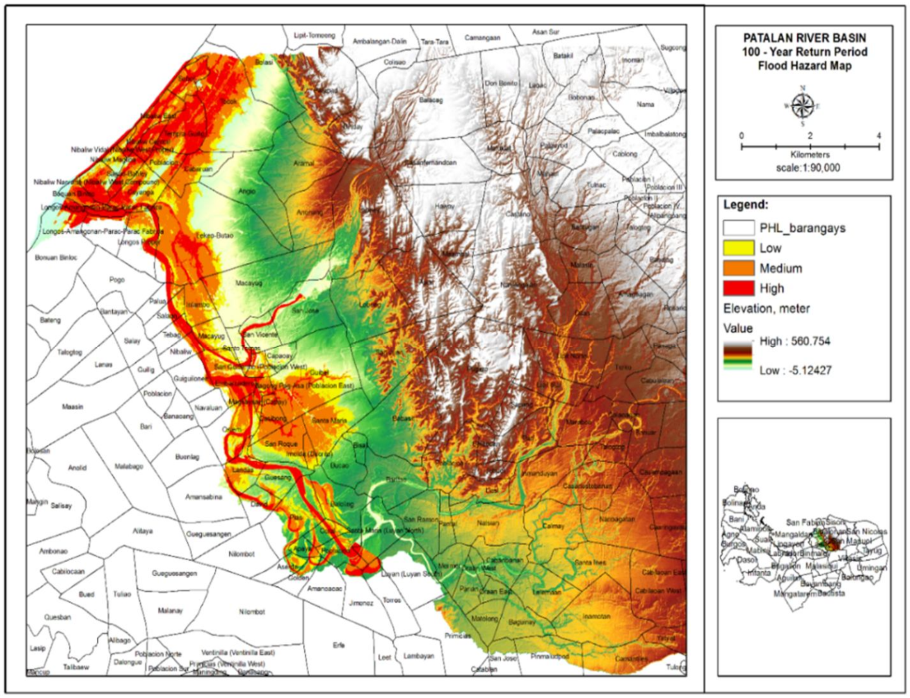


Figure 12. 1D-Simulated flood hazard map of Patalan River Basin for a 100-year rainfall event

Most of the barangays affected by flood was found in the downstream portion of Patalan river located in municipality of San Fabian province of Pangasinan as shown in Table 3. Flooding in these areas were found to be significant with 5-100 year return period, particularly in barangay Poblacion, Nibaliw Vidal, Bonuan Binloc, Langos-Amagonan, Cayanga, Nibaliw Central, Tempra-Guilig, Tocok, Sobol, Cabaruan, Sagud-Bahley, and Lekep-Butao. These areas have low to high flood hazard levels. The municipality of San Fabian with an estimated area of 269.89 hectares will experience high flooding in case a 5-year return rainfall event will occur (Figures 8-12).

Table 3. Areas (hectare) of municipalities affected by flood at different return period.

RIDF	Category	Municipalities of Pangasinan					
		Dagupan City	Manaoag	Mangaldan	Mapandan	San Fabian	San Jacinto
5 - year	Low	5.7	0.01	95.26	44.34	359.19	225.14
	Medium	39.79		74.97	43.05	464.82	98.57
	High	8.47		143.38	37.16	269.89	33.81
10 - year	Low	4.8	0.58	138.44	57.79	353.04	228.92
	Medium	39.89	0.03	100.84	65.38	545.13	191.54
	High	10.39		154.84	42.2	327.03	40.58
25 - year	Low	5.13	2.78	173.58	77.5	314.45	225.46
	Medium	30.96	0.08	143.89	92.72	633.42	286.55
	High	21.18		169.83	56.03	401.85	51.7
50 - year	Low	5.24	5.9	177.47	91.03	274.38	215.47
	Medium	24.16	0.14	181.51	108.76	669.81	347.97
	High	29.24		180.99	70.5	465.69	60.89
100 - year	Low	5.47	9.41	167.36	101.09	234.84	202.19
	Medium	19.73	0.36	221.82	128.05	689.91	398.27
	High	34.59		192.6	84.45	528.43	72.01

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

E. GIS Buildings Database

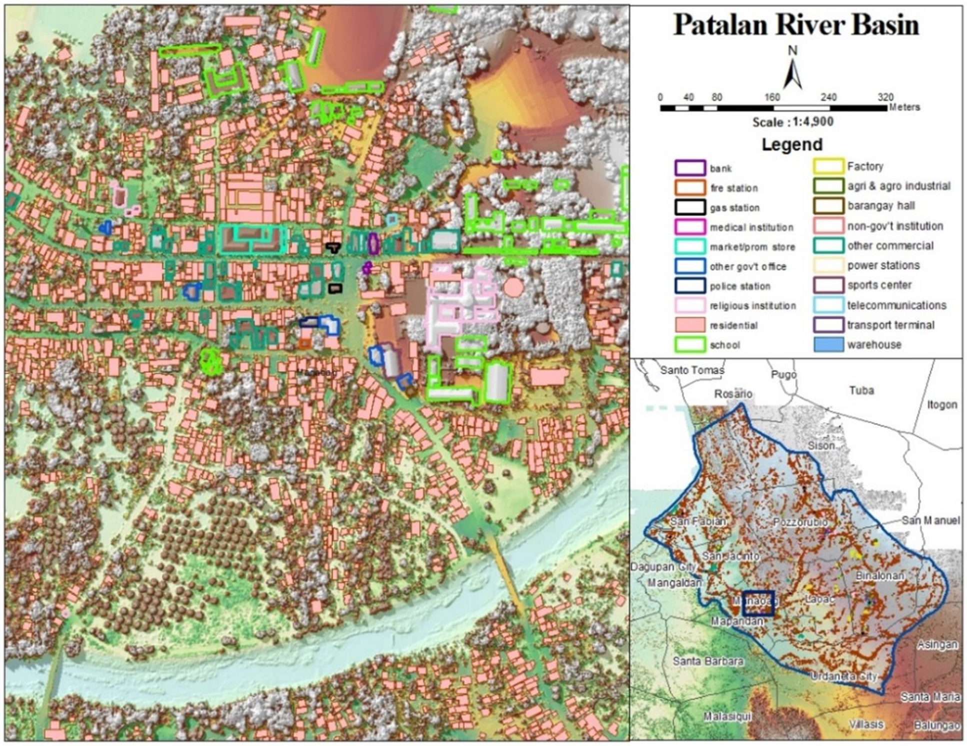


Figure 13. The extracted building footprints in the flood plains of Patalan River

Using ArcGIS, LiDAR data were processed and buildings from the floodplains of Patalan were extracted as shown in Figure 13. The GIS shape file of Patalan floodplain consisted of of 129,800 buildings, which were further subdivided to its type (Figure 14). Each building type was represented by different colors in the figure to be easily identified. Of the 129,800 buildings, 126,956 (97.81%) were categorized as residential, making the remaining 2,844 buildings (2.19%) to be categorized as other building types.

For this study, the flood hazard extent is not the same with the floodplain extent and since the main concern is the flood hazard extent, this was the one considered as the extent of the study. Figure 14 further illustrates that the building type with the most number in this hazard extent is the residential type making the area a priority towards preparedness against calamities such as flood. The building types with the least number are military institution and telecom facilities.

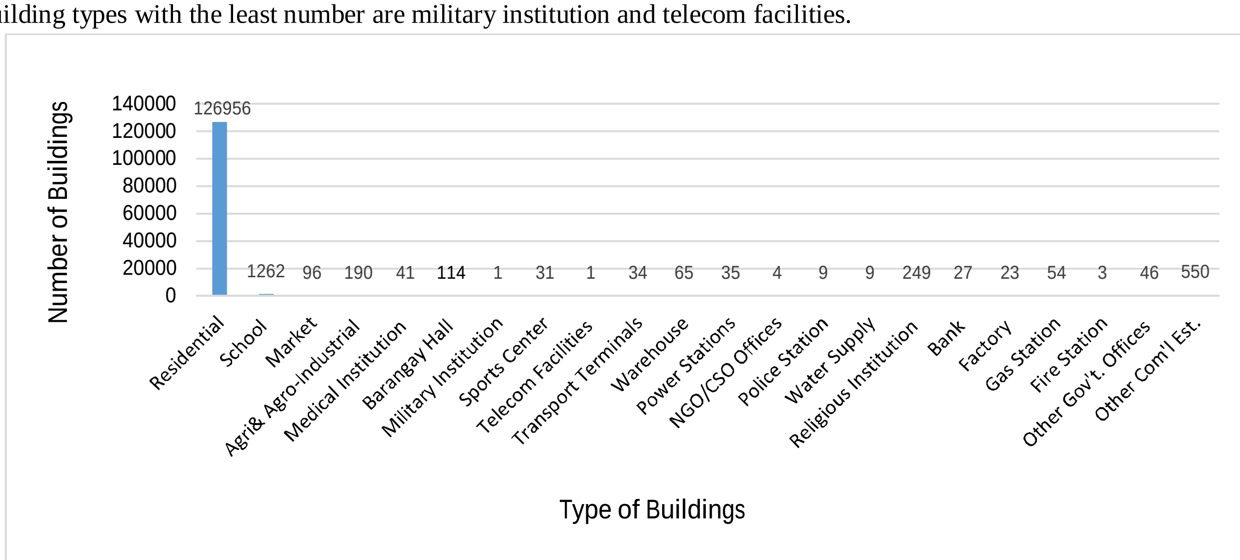


Figure 14. Extracted buildings with attributes in Patalan River flood plain according to type

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

F. Buildings Exposure to Flood Hazard

Further data analysis yields the results of the buildings' exposure to flood hazard. Figure 15 quantify the results the exposure of the different buildings to flood hazards in the flood plains of Patalan once heavy rain pours over the area. As the results shown below, 51,595 buildings (39.75%) is predicted to be unexposed to flood during the 5-, 25- and 100-year rainfall return period. However, 68,864 buildings (88.05%) of the buildings to be exposed at 5-year rainfall return period is predicted to be at low depth of flood, while 9338 buildings (11.94%) will be at a medium depth and 3 buildings (0.004%) will be exposed to high depth. For the 25-year rainfall return period, a drop to 65,013 buildings (83.13 %) of will be exposed to low depth of flood that corresponds to an increase to 13,179 buildings (16.85%) will be exposed to medium flood and 14 buildings (0.02%) will be exposed to high depth. Moreover, the percentage of buildings to be exposed at low flood depth will continuously be decreased to 61,377 buildings (78.48%), however, those buildings that will be exposed to medium flood depth could be increased up to 16,806 buildings (21.50%) and 23 buildings (0.03%) will be exposed to high depth in 100-year rainfall return period.

Throughout the recognized rainfall return periods, predictions indicated that buildings flood exposure would eventually increase where buildings will become more susceptible to flood. Increasing flood exposure of buildings is depicted in Figures 16-18 showing the locations of the expected affected buildings in Patalan river flood plains during a 5-, 25- and 100-year rainfall return period, respectively.

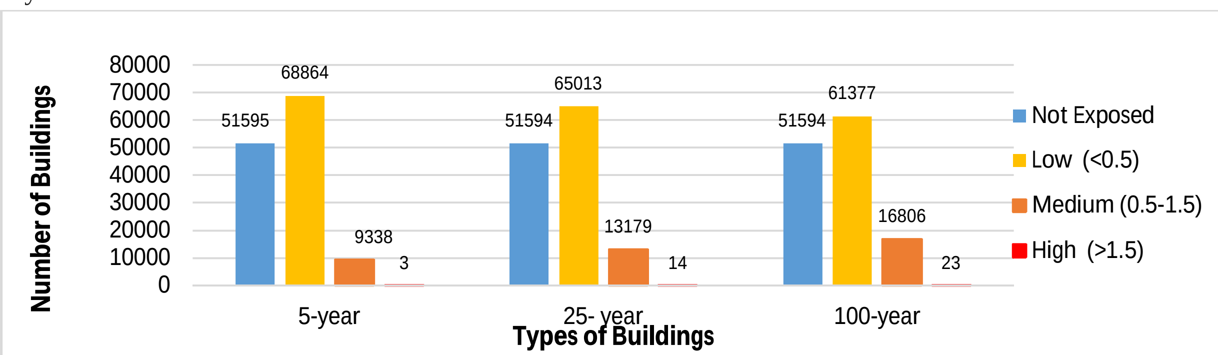


Figure 15. The number of buildings exposed to different hazard levels at varying rainfall return periods

The severity of buildings exposed to flood is shown as the orange (medium level) and red (high level) colors diffuse in the maps. Figure 19 shows the total number of buildings on the different rainfall return period according to the building types. Among the exposed buildings to flood, residential-type buildings are mostly affected followed by schools and other commercial establishments. Meanwhile, the rest of the building types fell on the side of the graph since these are far less in number compared to the occurrence of residential building types in the area.

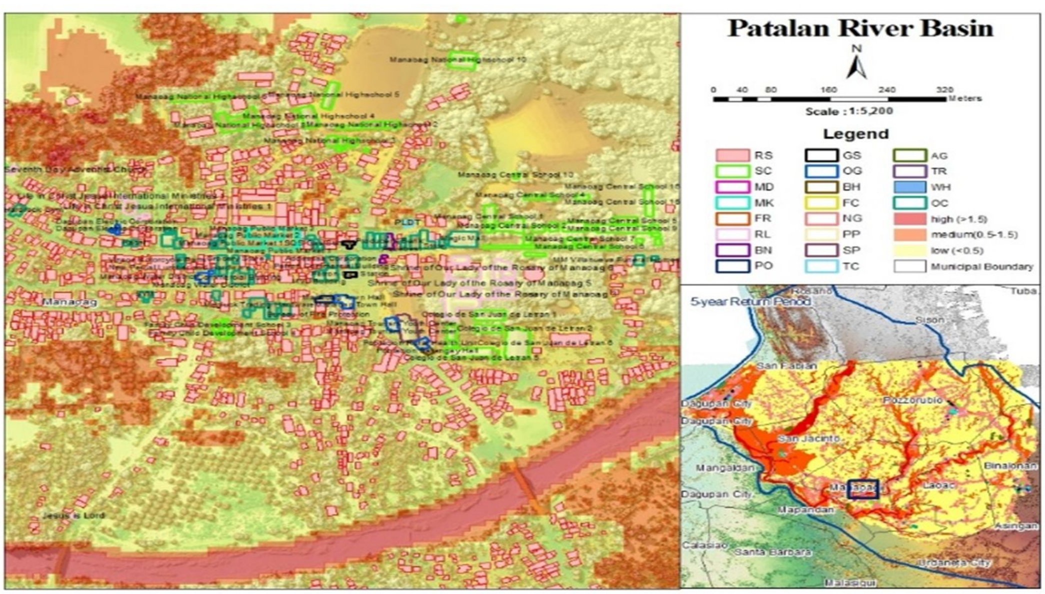


Figure 16. Buildings exposed to different hazard levels at 5-year return period of rainfall events

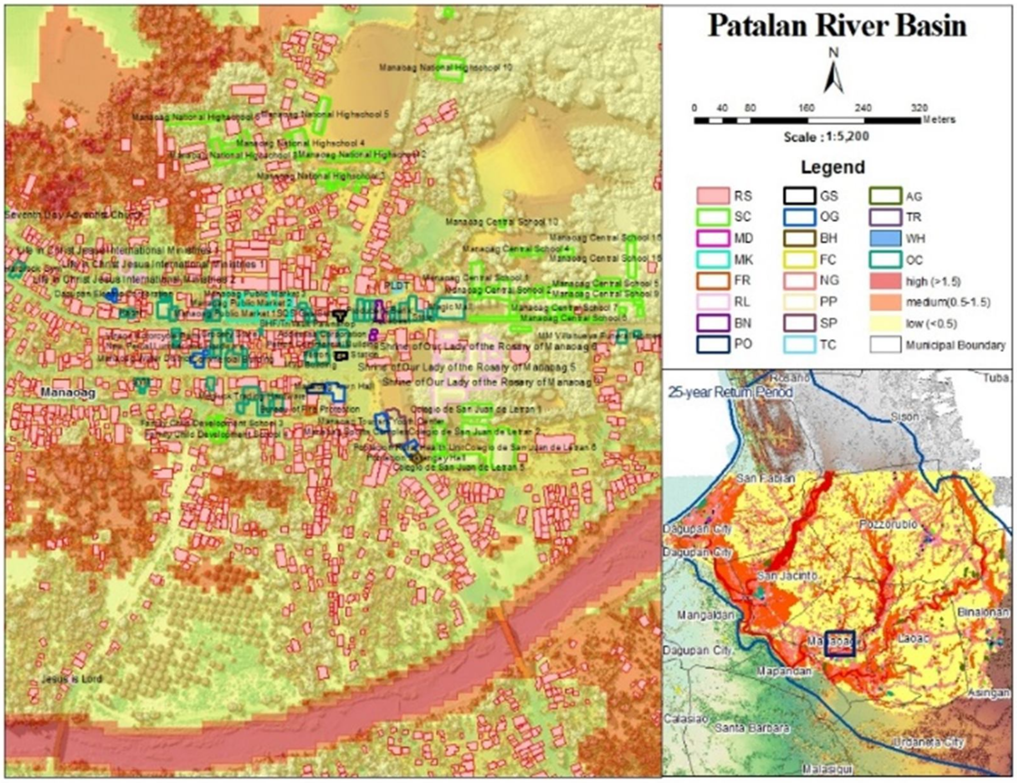


Figure 17. The number of buildings exposed to different hazard levels at 25-year return period of rainfall events

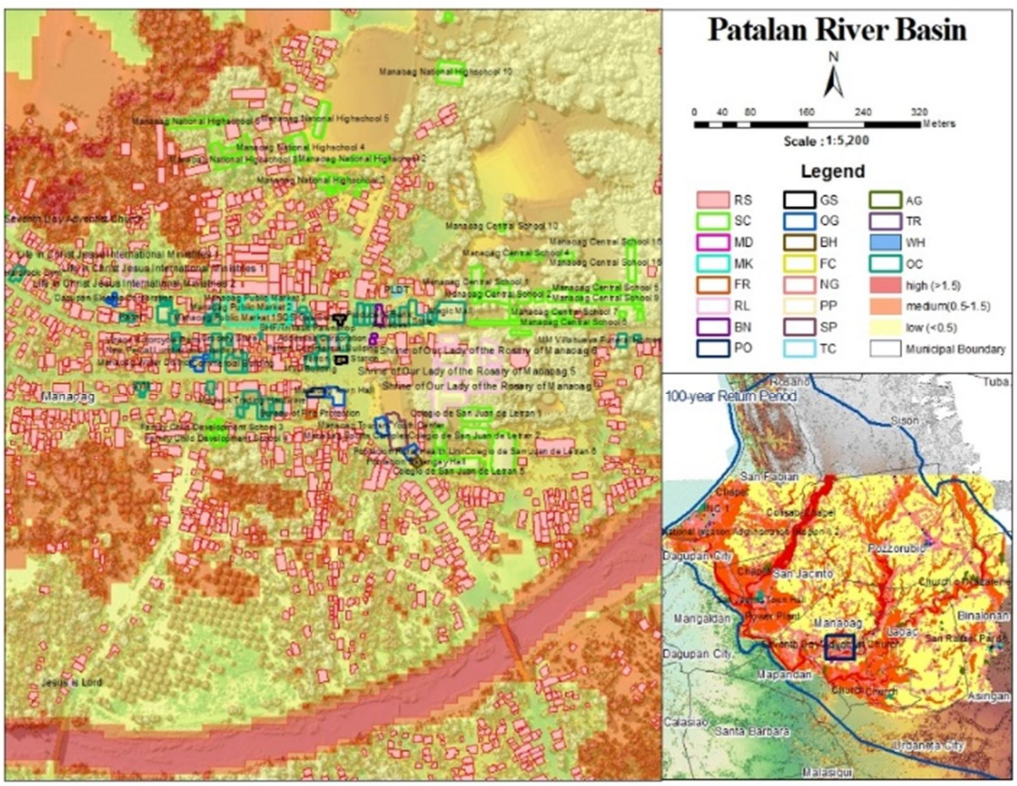
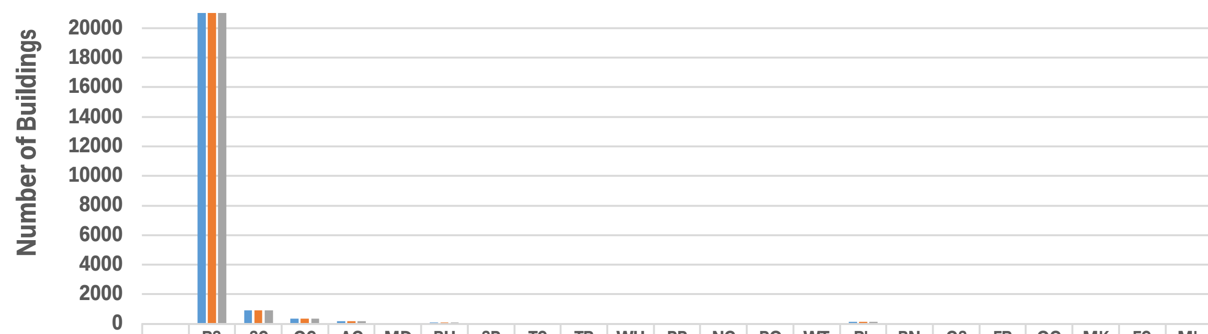


Figure 18. The number of buildings exposed to different hazard levels at 100-year return period of rainfall events

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com



	RS	SC	OC	AG	MD	BH	SP	TC	TR	WH	PP	NG	PO	WT	RL	BN	GS	FR	OG	MK	FC	ML
5-Year	7630	897	344	157	30	83	14	1	28	47	5	0	4	3	153	11	36	2	37	49	0	1
25-year	7630	897	344	157	30	83	14	1	28	47	5	0	4	3	153	11	36	2	37	49	0	1
100-year	7630	897	344	157	30	83	14	1	28	47	5	0	4	3	153	11	36	2	37	49	0	1

Figure 19. The number of buildings exposed to flood hazard according to type at varying return periods

G. Buildings Vulnerability to Flood Hazard

Further data analysis was performed to predict the vulnerability of the buildings to flood during 5-, 25- and 100-year rainfall return periods. The vulnerability of the building refers to the building's inability to withstand the effects of disasters. In this study, the vulnerability of the buildings in the Patalan floodplain was assessed through the comparison between the building's height and simulated flood depths. As shown in Figure 21, the analysis concluded that out of the 78,205 buildings to be exposed, an increasing trend in the number of vulnerable buildings is predicted for the 5-, 25- and 100-year period at 28.66%, 42.55%, and 49.86%, respectively.

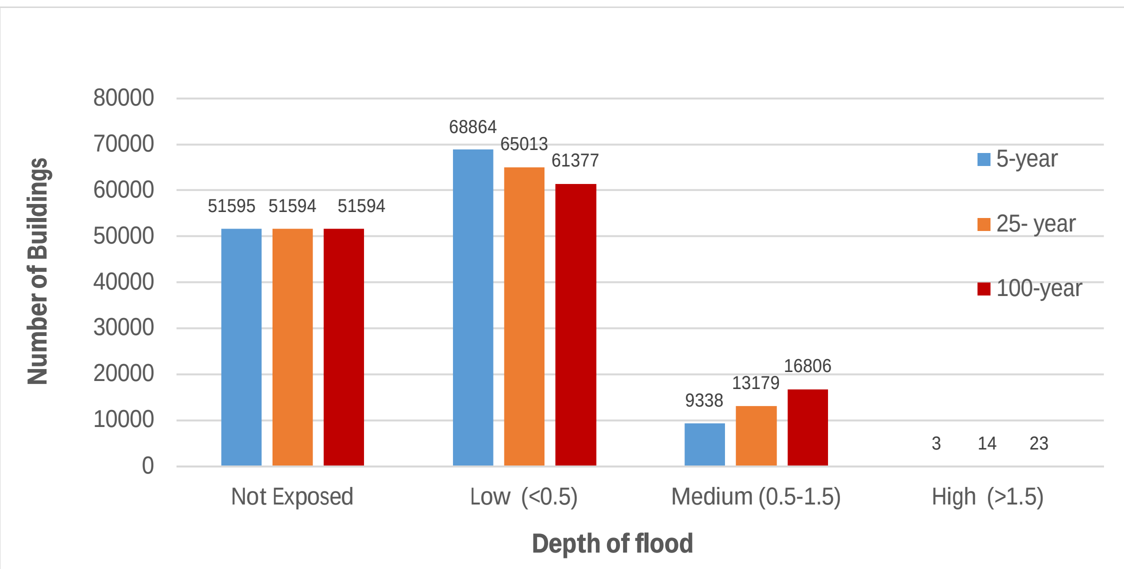


Figure 20. The number of buildings vulnerable to flood in terms of height at different hazard levels

Meanwhile, Figure 20 shows the number of buildings vulnerable to flood depths in the flood plains of Patalan river. In a 5-, 25- and 100-year rainfall return period, 51,595 buildings (39.75%) of the total number of buildings will be invulnerable to flood. While the number of vulnerable buildings in 5-year rainfall return period is proportioned around 68,864 buildings (53.05%) for vulnerable to low flood hazard level, 9,338 buildings (7.19%) for medium level and a very little portion of 3 buildings (0.002%) will be vulnerable to high flood hazard level.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

Furthermore, in a 25-year rainfall return period, 65,013 buildings (50.09%) will be under a low flood hazard level, 13,179 buildings (10.15%) will be under medium level and 14 buildings (0.01%) will be under a high level. For the 100-year rainfall return period, 61,377 buildings (47.29%) of the total number of vulnerable buildings will be under low flood hazard level, 16,806 buildings (12.95%) will be under medium flood hazard level, and 23 buildings (0.02%) will be exposed to high flood hazard level.

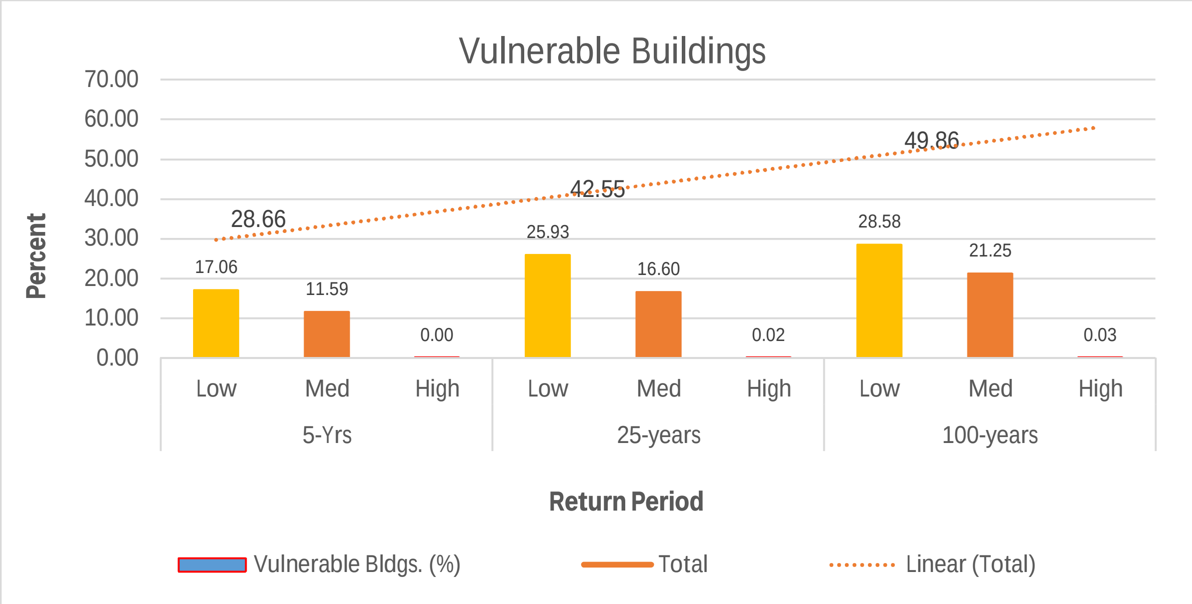


Figure 21. Buildings vulnerable to flood trend at different return periods

The sum of buildings expected to be vulnerable to flooding is increasing throughout time according to the assessment using the building height and simulated flood depth height in the flood plains of Patalan river. The following figures (Figures 22-24) are the illustrations of the locations of the buildings that are projected to be vulnerable to flood during the 5-, 25- and 100-year rainfall return period. Meanwhile, Figure 25 shows the number of buildings vulnerable to flood at different rainfall return period according to type. The number of buildings vulnerable to flood increases for correspondingly to increase in the years of rainfall return periods. It can be observed from the results that residential types of buildings are the ones that are affected by flood in terms of exposure which corresponds to vulnerability.

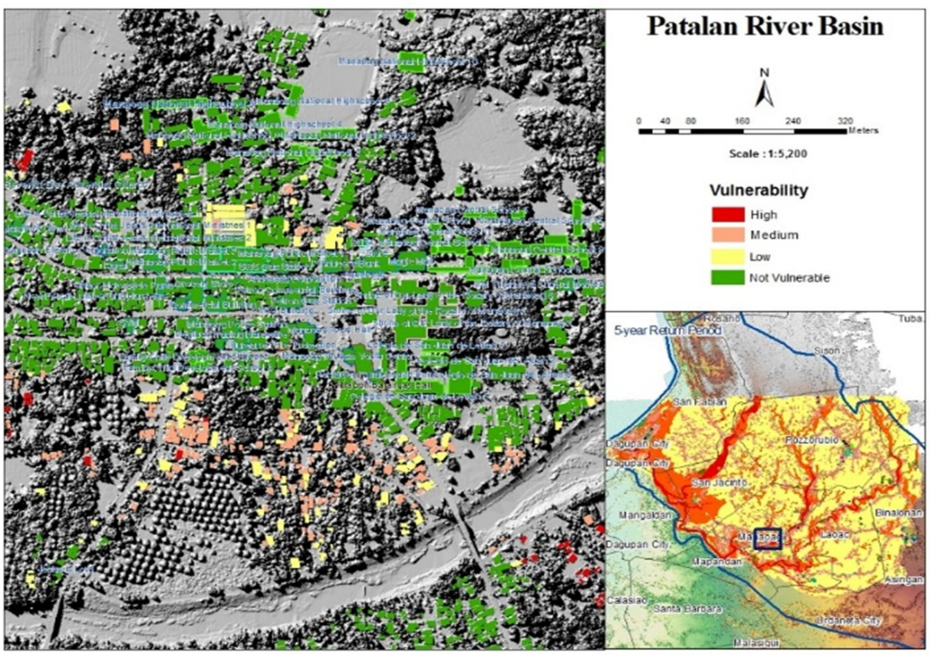


Figure 22. Location of buildings vulnerable to flood hazard at 5-year rainfall return period

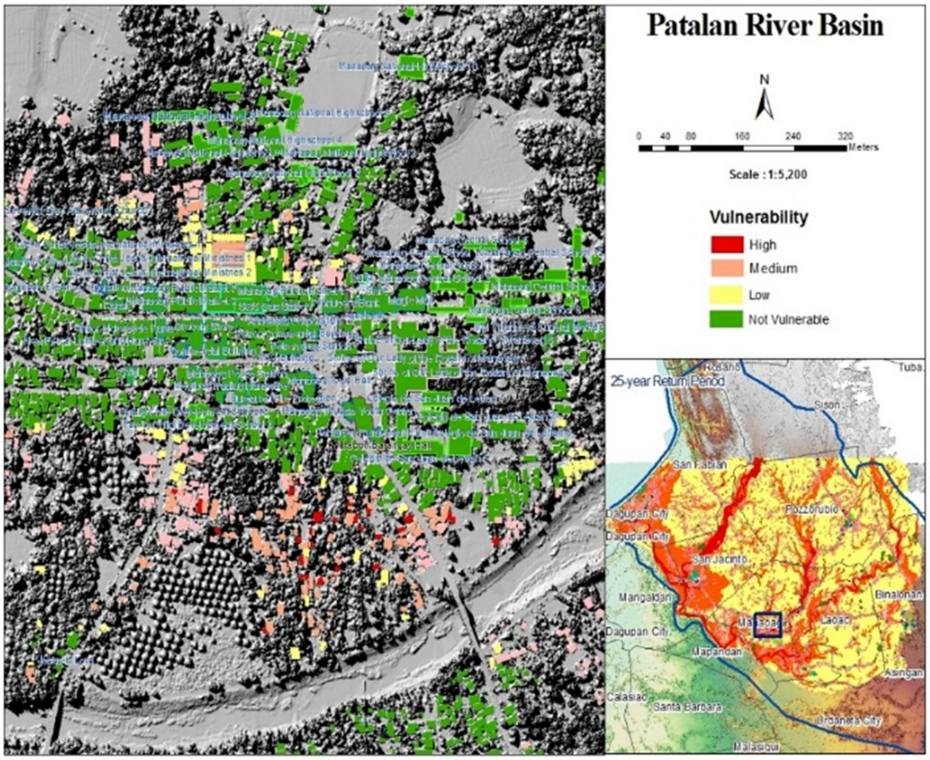


Figure 23. Location of buildings vulnerable to flood hazard at 25-year rainfall return period

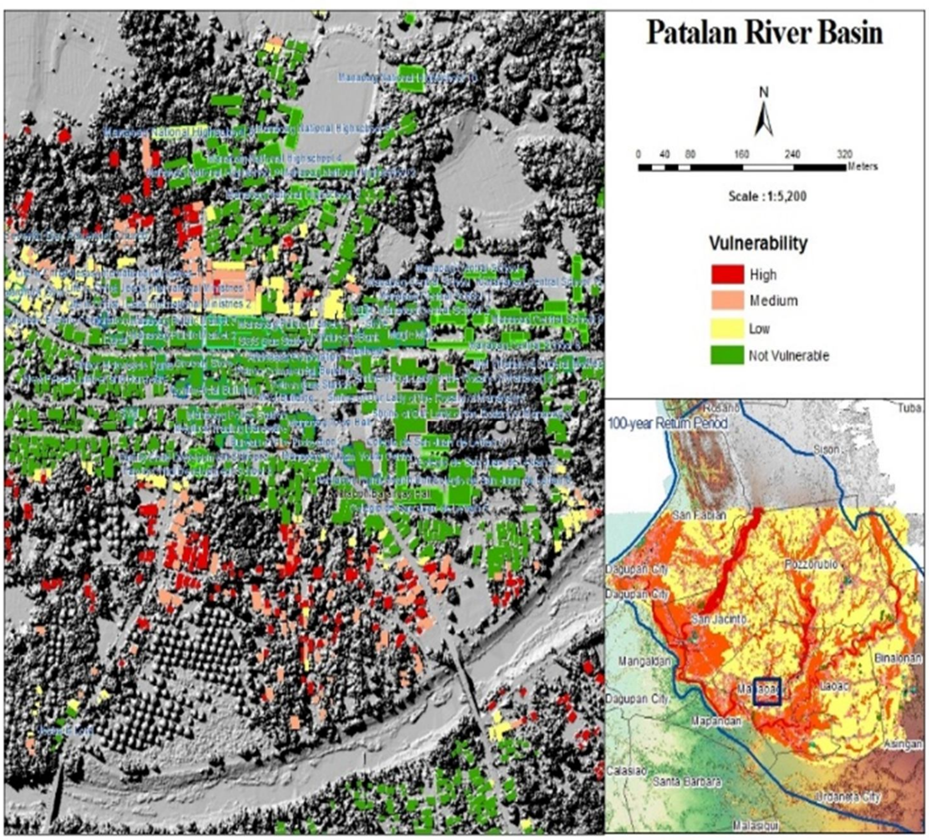
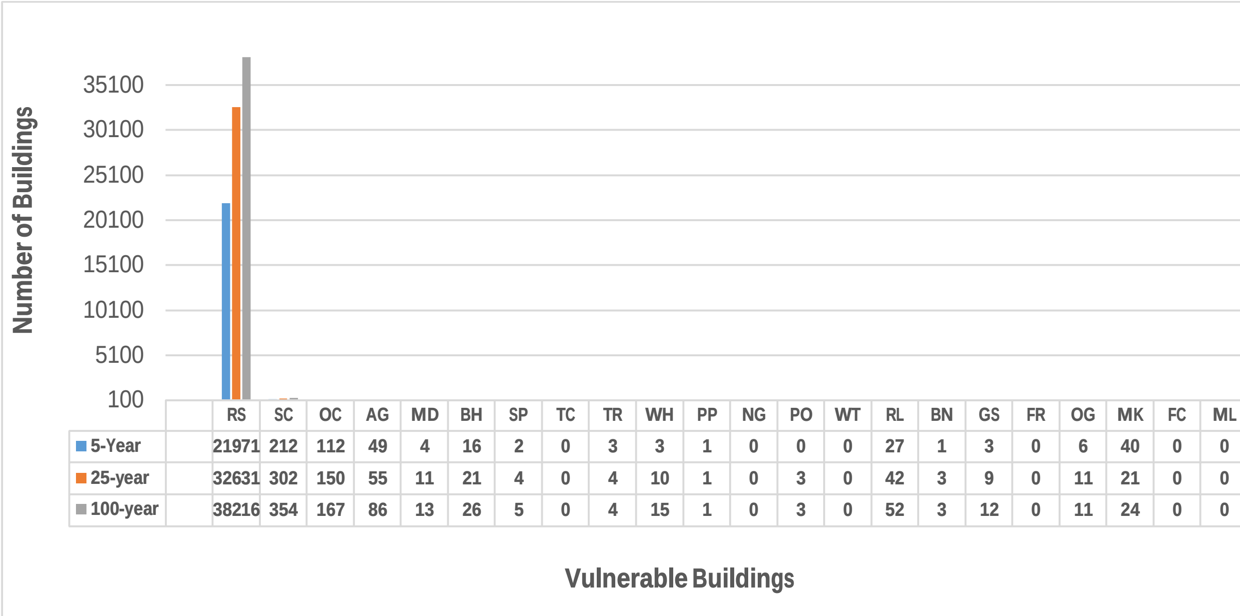


Figure 24. Location of buildings vulnerable to flood hazard at 100-year rainfall return period



	RS	SC	OC	AG	MD	BH	SP	TC	TR	WH	PP	NG	PO	WT	RL	BN	GS	FR	OG	MK	FC	ML
5-Year	21971	212	112	49	4	16	2	0	3	3	1	0	0	0	27	1	3	0	6	40	0	0
25-year	32631	302	150	55	11	21	4	0	4	10	1	0	3	0	42	3	9	0	11	21	0	0
100-year	38216	354	167	86	13	26	5	0	4	15	1	0	3	0	52	3	12	0	11	24	0	0

Figure 25. The number of buildings vulnerable to flood hazard according to type at varying return periods

IV. CONCLUSIONS AND RECOMMENDATIONS

The 3D building GIS database of Patalan river basin in Pangasinan was generated thru the integrated modern LiDAR technology and Geographic Information System software. The buildings identified and attributed had a total of 129,800 that consists of 97.8 percent residential buildings and 2.2 percent non-residential building types such as government and private owned buildings. The created building database and flood hazard maps used for the GIS overlay analysis produced a series of building exposure and vulnerability maps corresponding to the 5-year, 25-year and 100-year return period rainfall events. Out of the 129,800 buildings, 60.25 percent or equal to 78,206 was predicted to be exposed to flood and out of the total number of exposed buildings to flood hazard, the number of buildings that might be vulnerable and at risk will be 22,410 (28.65%), 33,278 (42.52%) and 38,992 (49.86%) at 5-, 25- and 100-year rainfall return periods, respectively.

Vulnerability assessment was done thru the height of each buildings present in the floodplain of Patalan floodplain. Though vulnerability is usually assessed by using a number of parameters, the result that derived from the buildings' height are still valuable and can be used to inform and warn the population in the floodplains of Patalan river in Pangasinan during the heavy downpour in the area.

Due to lack of other necessary data for the analysis during the time that this study was conducted, the analysis were only based on the height of the buildings extracted. It is recommended to expand the analysis where formal engineering decision analysis will be considered.

V. ACKNOWLEDGEMENT

Sincere gratitude is due to the Department of Science and Technology (DOST) which funded this study. This work is an output of the Central Luzon State University (CLSU) Phil-LiDAR 1 project entitled "LiDAR Data Processing and Validation in Luzon: Region III and Pangasinan (Region I)" of the "Phil-LiDAR 1: Hazard Mapping of the Philippines using LiDAR" program. The Digital Elevation Models (DTM and DSM) used were provided by the University of the Philippines Disaster Risk and Exposure for Mitigation (UP-DREAM)/Phil-LiDAR 1 Program. Heartfelt thanks to all CLSU Phil LiDAR 1 research assistants who helped in the production of 1D Flood Hazard Maps of Patalan River and validation of this study.

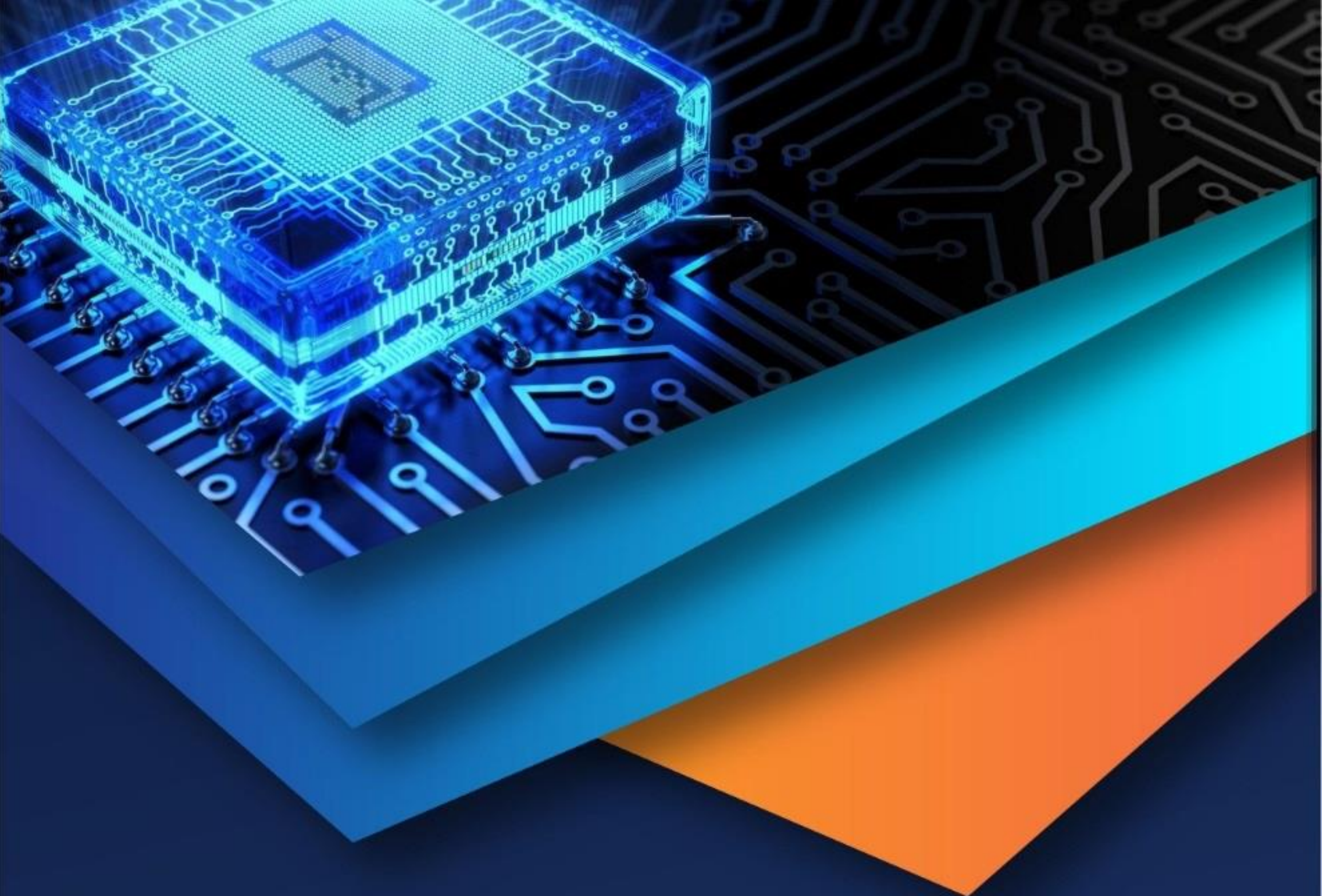
REFERENCES

[1] Faustino-Eslava, D. V., Dimalanta, C. B., Yumul, J. G., Servando, N. T., & Cruz, N. A. (2013, June). Geohazards, Tropical Cyclones and Disaster Risk Management in the Philippines: Adaptation in a Changing Climate Regime. Journal of Environmental Science and Mangement, 84-96.

[2] Faustino-Eslava, D. V., Dimalanta, C. B., Yumul, J. G., Servando, N. T., & Cruz, N. A. (2013). Geohazards, Tropical Cyclones and Disaster Risk Management in the Philippines: Adaptations in a Changing Climate Regime. Journal of Environmental Science and Management, 84-97.

[3] Japan International Cooperation Agency. (2003). The study on sabo and flood control for western river basins of Mount Pinatubo in the Republic of the Philippines : final report. Tokyo: Japan International Cooperation Agency.

[4] Lim, J. C. (2016). Business World Online. Retrieved March 15, 2017, from http://www.bworldonline.com/content.php?section=Economy&title=management-of-baguio-naga-river-systems-upgraded-by-environment-dep&8217t&id=126888
[5] Official website of Pangasinan. http://pangasinan.gov.ph/wp-content/uploads/2011/06/ pangasinan-facts-figures-2010.pdfit. Retrieved on March 25, 2016.
[6] Philippine Statistics Office. (2010, May 1). Municipality/City:Botolan. Retrieved from PSGC Interactive: http://nap.psa.gov.ph/activestats/psgc/municipality.asp?muncode=037101000&regcode=03&provcode=71
[7] Rodolfo, K. S., Umbal, J. V., Alonso, R. A., Remotigue, C. T., Paladio-Melosantos, M. L., Salvador, J. H., . . . Miller, Y. (1996). Two Years of Lahars on the Western Flank of Mount Pinatubo: Initiation, Flow Processes, Deposits, and Attendant Geomorphic and Hydraulic Changes. Quezon City: University of Washington Press.
[8] Sagala, S. A. (2006, March). Analysis of Flood Physical Vulnerability in Residential Areas. Retrieved from https://www.itc.nl/library/papers_2006/msc/upla/sagala.pdf
[9] Santillan, J., Makinano-Santillan, M., Cutamora, L., & Serviano, J. (2015). 3D Building GIS Database Generation from LiDAR Data and Free Online Web Maps and Its Application for Flood Hazard Exposure Assessment.
[10] Sussle. (2016). Sussle Visual Encyclopedia. Retrieved from Bued River: https://sussle.org/t/Bued_River
[11] The Travel Location Guide. (2017, February 22). The Philippines. Retrieved from Chinci World Atlas: http://www.chinci.com/travel/pax/q/1723497/Bued+River/PH/The+Philippines/0/



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY