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IMPACTS OF FLOOD INTENSITY FROM RAPID URBANIZATION IN MARIKINA RIVER BASIN, PHILIPPINES AFTER 1970'S

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Various literature established a strong correlation of the effects of human activity to water systems in river basins. Land use change due to urbanization is an important indicator in determining the extent of anthropogenic activity and its effects to the hydrological processes in river basins, particularly its effects on floods. The Marikina River Basin, east of Metro Manila, provides a good example of this interaction; where flooding is a problem at the highly-urbanized low-lying areas at the downstream. These areas were severely affected by floods in 2009 and 2012 which could be attributed to land use change driven by rapid urbanization and population increase. The Philippine government had several plans in the 1970's, including the Metro Manila Transport, Land Use, and Development Plan (MMETROPLAN), which recommended to regulate the urban growth along the Marikina River Valley due to existing natural hazards. However, various issues jeopardized the completion of the plans which resulted to an urban sprawl extending to the upstream. The importance of such plans were realized after the disasters happened, and became the start for local governments to integrate disaster and risk mapping in their future land use plans. This research aims to discuss the impacts of rapid urbanization to flood on the basis of the historical plans in Marikina River Basin. Finally, we discuss the importance of sustainable implementation of land use plans to mitigate flood in the basin.

Key Words : *flood intensity, flood impacts, urbanization, Marikina River Basin, Metro Manila*

1. INTRODUCTION

(1) Background

Urbanization, an anthropogenic phenomena, has led to the conversion of forested and agricultural lands into buildup areas[1)]. The continued cycle of land use change, when uncontrolled, have effects on both human and environment systems, particularly water systems[2,3)].

Several literature have connected urbanization-induced land use change to the changes in the hydrological behavior of water systems, specifically on river basins. Recent studies quantified the extent of effects of urbanization in terms of streamflow, peak runoff, and discharge[4,5,6,7)]

Such phenomena is present in Marikina River Basin, Philippines, where a vicious cycle of floods, construction of flood control structures, and urban development continues to exist. The combination of natural hazards and human-induced factors, such as urbanization, are catalysts for disasters.

Severe flooding has been a problem in Metro Manila and Marikina River Basin, and the most notable was the September 2009 flood caused by Tropical Storm Ondoy (International Name: Ketsana). The storm brought 540 mm of rainfall within 24 hours and surpassed the previous records set in 1970 (403.1mm) and 1976 (371.6mm)[8,9)]. The devastation caused by the flood placed Metro Manila and several other provinces in state of calamity[10)]; and brought a total damage cost of Php1.3 billion[11)].

Researchers and experts have attributed urbanization as one of the causes of flooding in Metro Manila and Marikina River Basin[12,13)]. However, the uncontrolled and rapid urbanization in the river basin was a result of various accumulated problems that

were failed to be solved in the past. There are several existing plans to solve the flooding problems in Metro Manila and Marikina River Basin – some were implemented, some were not. The Philippine Government tried to solve the problem with big flood control structures but gave the other connected problems the least attention. This resulted into a vicious cycle of events that shaped the current situation of the metropolis and the river basin.

(2) Purpose and Methodology

This research aims to discuss the impacts of rapid urbanization to flood on the basis of the historical plans in Marikina River Basin, and has two parts: first; it reviews relevant articles, previous plans, and past studies related to the historical process and interaction between urbanization, land use change and floods in Metro Manila and Marikina River Basin. The importance of looking at historical accounts is to determine the drivers that shaped the current scenario of Metro Manila and Marikina River Basin and its relation to the floods that happened throughout the course of time.

The second part is determination of the extent of urbanization using ArcGIS and Landsat images from 1979 and 2016; and simulation of discharge and peak time using HEC-HMS. The purpose of the simulation is to determine the impact of urbanization in terms of the changes in peak time and discharge.

Landsat images dated February 11, 1979 (Landsat 2 MSS, Path = 124, Row = 50) and February 13, 2016 (Landsat 8 OLI-TIRS Path = 116, Row = 50) at WGS (1984) UTM Zone 51N were used to represent the land use and urbanization conditions for 1970 and 2016, respectively. Each of the Landsat bands were subjected to radiometric and topographic corrections (using ArcSAGA plugin) before generating the land use map using Maximum Likelihood Classification in ArcGIS. The generated land use maps will also be used for hydrologic simulation in HEC-HMS.

The HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System) is an open source software created by the US Corps of Engineers to simulate rainfall-runoff processes such as losses, recession flow, runoff transform, and channel routing in a river basin. For this research, we used the SCS Curve Number for the losses, SCS Unit Hydrograph for the runoff model, exponential recession for the recession model, and Muskingam-Cunge Model for channel routing. Further details about each of the hydrological models were provided in the software's manual. Aside from the land use maps; observed rainfall, discharge, and water level data during the period of TS Ondoy were used for the simulation, and were provided by the Metropolitan Manila Development Authority – Effective Flood Control Operating System (MMDA-EFCOS). ASTER 1arc-second DEM (from USGS Earthexplorer), basin shapefiles (provided by the DENR-River Basin Control Office), and soil profile (from DA-Bureau of Soils and Water Management) were used for the basin characteristics and are processed in GeoHMS plugin in ArcGIS. We also assume in the simulation that there are no significant changes in the slope (caused by erosion or landslides) of the river basin.

2. SUMMARY OF TARGET AREA

Metro Manila (or the National Capital Region), a conglomerate of 16 cities and a municipality, is the political and economic center of the Philippines. With a land area of 636 sq. km., it is also one of the most densely-populated cities in the world with a population of 11,855,975 people[14,15]. The metropolis is bounded by the provinces of Bulacan at the north, Rizal at the east, and Cavite and Laguna at the south. It is also in between the Manila Bay at the west and Laguna Lake at the southeast. These large bodies of water are connected via the Pasig River which meanders across the metropolis (see Fig. 1).

The region can also be separated into three distinct physical geographical features: the coastal lowlands (near Manila Bay) and the Marikina floodplain at the western and eastern sides of the region, respectively; and between the two plains is the Guadalupe Plateau rising from 40masl to 70masl[16]. The geographical characteristics of the metropolis is what makes it prone to floods and the Marikina River Basin significantly contributes to the flooding problems of Metro Manila[17,18].

Marikina River Basin, located at the east of Metro Manila, has an area of approximately 698 sq. km. and encompassing several cities and municipalities of Metro Manila, Bulacan Province, and Rizal Province[18] (see Figure 1). It is situated at the tail-end of Sierra Madre Mountain Range on the north, and the Laguna Lake at the south. The river basin has numerous tributaries which are connected to the Pasig River via the 31-km long Marikina River[8]. It is also the largest and the most critical of the river basins surrounding Laguna Lake[19].

3. RESULTS AND DISCUSSION

(1) Historical Interaction between Urban Metro Manila and Marikina River Basin

Before 1970's

In the 1590s, the Spanish Colonial Government implemented the guidelines of King Philip II for the design of Intramuros (old city of Manila, the *walled city*), but left the land planning of the suburbs to the local councils and friars[20].

Small tributaries of the Pasig River delta were utilized as runoff and sewage drainage of the walled city and the outer districts[21] but were subjected to siltation and pollution due to the increased economic activity and population in the 19th century[22].

Modern urban planning and civil works were started during the American Occupation in the 1900's. They implemented the Burnham Plan in 1905, but drainage improvements were only done in 1909. The drainage system was still insufficient as it experienced one of its worst floods in 1914 and continued to experience floods in the1920's[22].

In 1941, President Manuel Quezon approved the Frost Master Plan for the new capital, Quezon City, to decongest Manila while a separate drainage master plan for Manila, Quezon City, and other suburbs (Pasay, Mandaluyong, San Juan, and Makati) was completed in 1943. Unfortunately, relevant documents pertaining to the drainage plan were burned at the end of World War II in 1945[22].

In 1946, President Elpidio Quirino established the National Urban Planning Commission to recommend zoning ordinances and draw up city plans[23] to hasten reconstruction.

In 1948, he transferred the seat of government to Quezon City and ordered to revise the Frost Plan (later called Frost-Arellano Plan)[24] as Manila was under repair. The plan, however, provided no details about drainage lines or flood control structures. Another great flood swept Manila again the same year that prompted the Quirino Administration to make another drainage plan in 1952. Unfortunately, it was not fully implemented due to issues such as limited jurisdiction, lack of coordination between national and local governments, and insufficient funds[22]. In the same period, the flooding patterns have changed as the surrounding suburbs started to urbanize[16].

1970's

Floods brought by typhoons Meding and Yoling

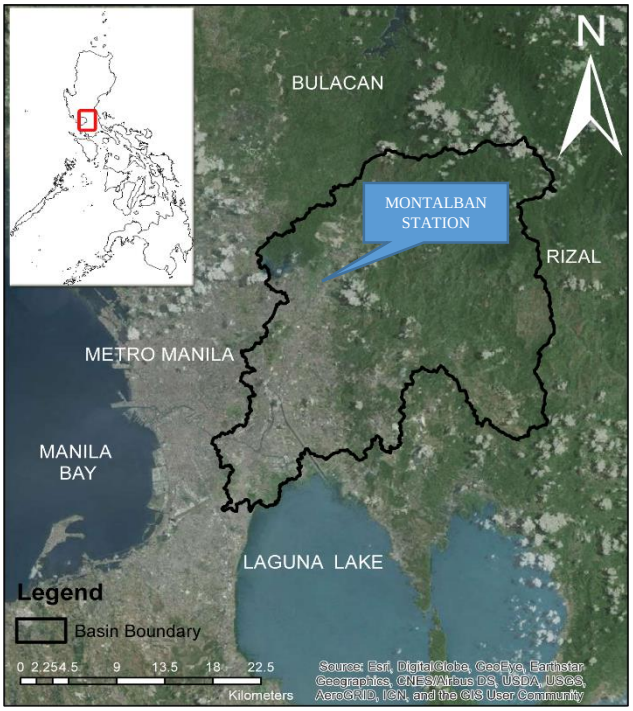


Fig.1 Map of Marikina River Basin and Metro Manila showing their relevant locations. (Inset) Map of the Philippines showing the location of Metro Manila and Marikina River Basin (red box).

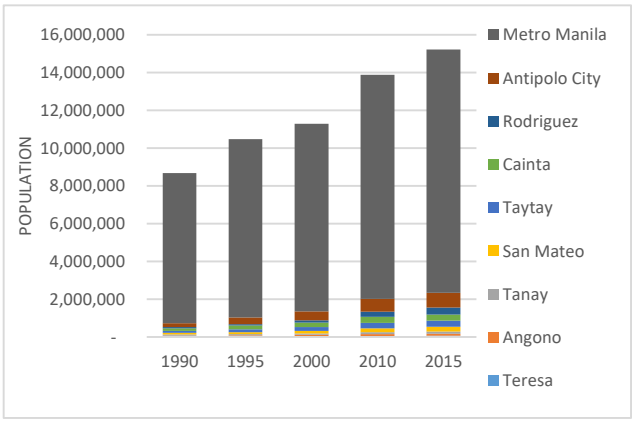


Fig.2 Population of municipalities of Rizal and Metro Manila (1990-2015). As the population of Metro Manila increase, the population of nearby municipalities of Rizal also increases its population. (Source: Philippine Statistical Authority)

caused havoc in Manila and Marikina River Basin in 1970[25] (see Fig. 3). In July 1970, President Marcos ordered a review of the 1952 master plan in response to the worsening flood situation in the metropolis. But in 1972, Typhoon Gloring struck the country and flooded Manila, its suburbs, and other nearby provinces. It was also in the same year that President Marcos declared Martial Law to suppress the communist insurrection[22], and enabled him to rule over the archipelago as a dictator.

President Ferdinand Marcos was able to implement projects and policies with less political opposition. His policies were both technocratic and highly-modernistic; believing that nature is "tamable",

floodwaters are “containable”, and typhoons are “modifiable” and “moderated”[22].

In 1975, he established the Metropolitan Manila Commission to centralize coordination between the national government and local governments of Manila and surrounding municipalities[22,26]. The MMC concentrated more on floods, transportation and traffic, and waste disposal while other related problems such as housing, health, and jobs were treated with less priority[22].

Marcos implemented large infrastructure projects for flood control consisted of the Mangahan Floodway and Rosario Weir, Napindan Hydraulic Control Structure, the Parañaque Spillway, and several pumping stations in the core area of the metropolis[22,27]. The Mangahan Floodway diverts floodwater from the upstream of Marikina River towards the Laguna Lake, while the Rosario Weir regulates the discharge flowing to the lake, and the Parañaque Spillway serves as the direct outfall of floodwater from Laguna Lake to Manila Bay. The Napindan Hydraulic Control Structure serves as the passageway of excess water from Laguna Lake towards the Pasig River and can prevent saline water from Manila Bay during tidal flux[27,28,29,30].

His administration conducted several studies for transportation and urban planning. One of those was the Metropolitan Manila Transport, Land Use, and Development Planning Project (MMETROPLAN) which tackled both transportation and urban development planning for Metro Manila[31]. The study cited the Marikina Floodplain as one of the areas where development should be restricted[9] (see Fig.4). He also enacted the Urban Land Reform Program that would have given the government the control over the urban development of the metropolis, but it was strongly contested by private owners and real estate developers in Manila. The law only became applicable to depressed areas or lands occupied by informal settlers[20].

However, such plans and studies were outpaced by the rapid population increase in the metropolis[32]. People from the rural areas continued to migrate towards the metropolis to seek for job opportunities, but with no adequate housing to accommodate such influx, it resulted to the proliferation of informal settlements, with some already encroached the waterways[25] and caused other problems such as improper waste disposal[33]. Private businesses and establishments also encroached the existing waterways[22].

Another problem was the large amount of capital

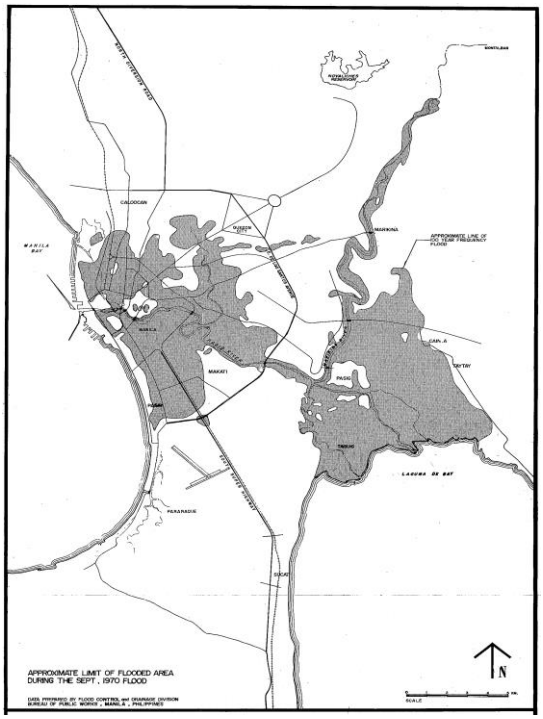


Fig.3 Inundation area during the 1970 flood. Manila’s coastal flats and the Marikina Alluvial Plain were the most flooded areas at the time. (Source: Dept. of Public Works and Highways)

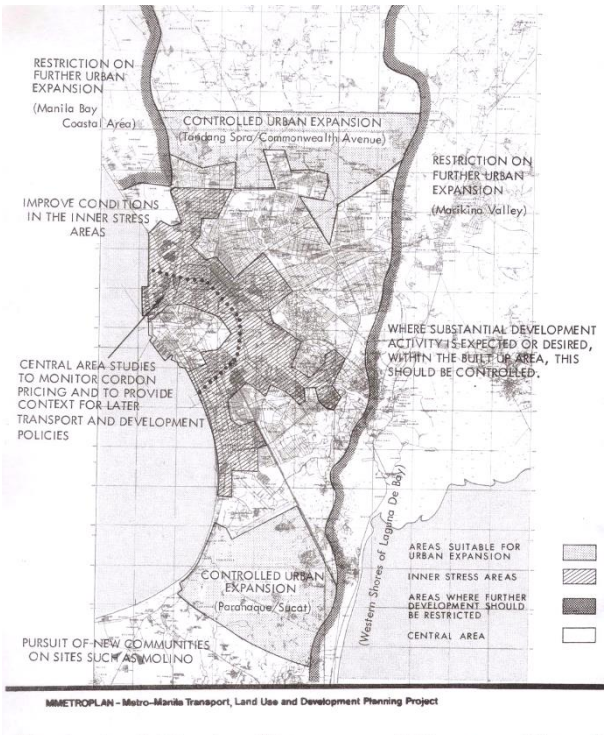


Fig.4 Urban Development Plan as recommended by the MMETROPLAN. (Source: Freeman Fox and Associates)

needed for the completion of flood control projects of Metro Manila. The construction costs for the Mangahan Floodway, Napindan Hydraulic Control Structure, and the Parañaque Spillway reached a total of Php 962.9 million (equivalent to Php 4.92 Trillion in 2010). Marcos had to resort to foreign loans to sustain the construction of the projects[22].

Unfortunately, issues such as cronyism, corruption, and economic instability[34] led to the downfall of the Marcos regime in 1986. At the time he was ousted, there were at least nine working pumping stations, thirteen floodgates, one revetment, eleven kilometers of gravity wall along the Pasig River, and twenty-one improved esteros. However, out of the three big flood control infrastructure projects proposed, only the Parañaque Spillway did not materialize due to financial constraints[22].

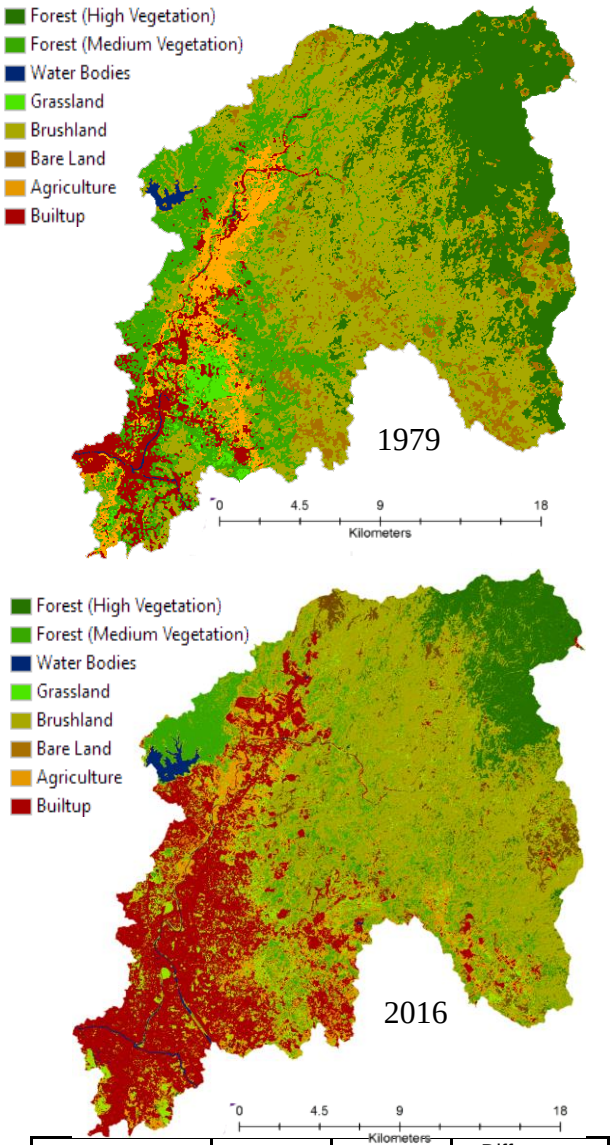
After 1970's

The failure of Marcos' technocratic approach to flood control, as well as other unresolved problems such as uncontrolled population growth and urbanization, has a long lasting impact in the years after his rule as floods became much worse. The presidents after Marcos also have committed their own shortcomings to solve the flooding situation in Metro Manila and Marikina River Basin. Worse, the urbanization has spread rapidly at the downstream of Marikina River Basin and exposed more people to floods.

During the presidency of Corazon Aquino, the responsibility and funds for flood control were transferred from the Department of Public Works and Highways to the Metropolitan Manila Authority[22]. President Aquino also made the Metropolitan Manila Authority more democratic as the 17 mayors would choose among themselves the chairman. Furthermore, the enactments of the Local Government Code of 1991, Urban Development and Housing Act of 1992, and the Comprehensive Agrarian Reform Program of 1988 had influenced the spread of urban development in the metropolis and the river basin.

The Local Government Code of 1991 made urban planning more decentralized as the national government gave the local governments more freedom to make their own land use plans. The Urban Development and Housing Act of 1992 mandated developers to allocate 20% of the land or project cost for socialized housing. Lastly, the Comprehensive Agrarian Reform Program provided means to control land use and development by restricting the ownership of agricultural lands from landlords and controlling the conversion of agricultural lands to non-agricultural use. The agrarian law might not be applicable to Metro Manila as it was already urban at that time, but the law still has influence on other municipalities[20], particularly in the Marikina River Basin.

The decentralization of land use planning, as well as the laws mentioned, were carried over in the next three administrations (Ramos, Estrada, and Arroyo),



Land Use	1979 Area (sqm)	2016 Area (sqm)	Difference (sqm)
Forest (High Vegetation)	159.61	71.25	-88.36
Forest (Medium Vegetation)	117.036	52.768	-64.268
Water Bodies	3.607	6.52	2.913
Bare Land	9.817	24.876	15.059
Brushland	277.261	259.444	-17.817
Grassland	42.25	64.589	22.339
Agriculture	41.184	53.819	12.635
Builtup	43.769	164.254	120.485

Fig.5 and Tab.1 Preliminary Land classification images of Marikina River Basin in 1979 and 2016 (top) using Landsat images. Tab.1 (below) shows the area of each classification at different 1979 and 2016. (Source: USGS Landsat/EarthExplorer)

as the national government did less for urban planning and more on the issuance of permits and licenses[23]. The lack of a national land use policy became the catalyst for rapid urbanization and population increase as the cities and municipalities within the river basin continued to develop while disregarding zoning laws and regulations[17,20]. As a result, Metro Manila and the downstream of Marikina

River Basin became too congested that urbanization has started to crawl towards the upstream municipalities of San Mateo and Rodriguez[35] (see Fig.5). Along with forest degradation caused by excessive logging and kaingin[9,17], it would become the perfect recipe for a disaster.

After TS Ondoy

The floods caused by Tropical Storm Ondoy served as a wake-up call for a comprehensive disaster management, flood control, and land use plans. Two laws were immediately passed in the Congress to respond to the impacts of the disaster. These were the Republic Act 9729 or the Climate Change Act of 2009 and the Republic Act 10121 or the National Disaster Risk Reduction and Management Framework of 2010. The Climate Change Act of 2009 established the Climate Change Commission that will formulate the country's framework strategy and program for climate change. The National Disaster Risk Reduction and Management Framework meanwhile, aims to strengthen the coordination between national agencies and local governments for disaster preparedness, and mandates local governments to include hazard mapping in their respective comprehensive land use plans[36,37].

However, the process for approving land use plans remained decentralized, while eleven out of seventeen local governments in Metro Manila and ten out of fourteen local governments in Rizal Province have outdated comprehensive land use plans based on the 4th quarter 2016 data of the Housing and Land Use Regulatory Board[38].

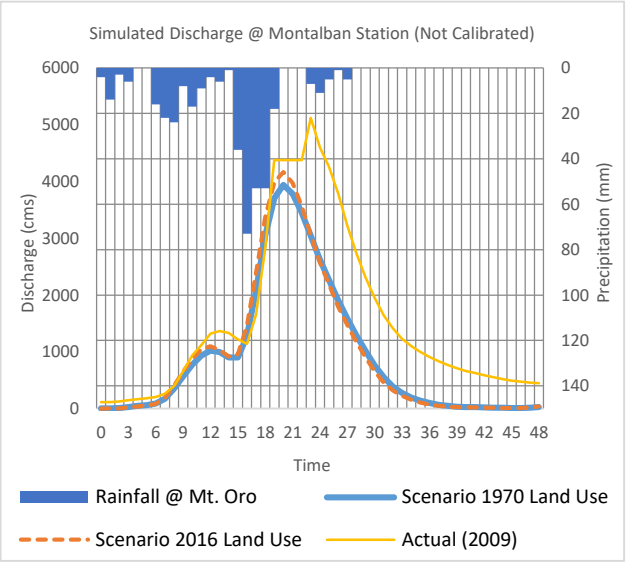
Technocratic approach to floods was still the prevalent solution for floods in Metro Manila and Marikina River Basin, but recently, non-structural technological approach such as flood modeling (Project NOAH) and flood monitoring (MMDA-EFCOS) have emerged to compliment the structural approach.

A new master plan for flood control has been approved during President Benigno Aquino III's term which includes dam construction at the upstream of Marikina River, new land use ordinances, and other structural and non-structural methods[39].

(2) Analysis of the impact of urbanization to flood

We determine the impact of urbanization to the river basin in terms of its effects on the peak time and discharge.

We applied the methodologies similar to Abino, et al., (2015), Ali, et al., (2011) and Santillan, et al., (2013) for land use classification and hydrological modeling using HEC-HMS.



Scenario	Peak Discharge (cms)	Peak Time (hrs)
1979 Land Use	3939.3	20
2016 Land Use	4165	20
Actual 2009	5122.8	23

Fig.6 and Tab.2 Preliminary (not calibrated) results of the simulation run for the peak discharge and time using the 1972 and 2016 land use scenarios of Marikina River Basin.

Figure 5 and Table 1 shows the preliminary land classification results for the Marikina River Basin and how much has changed in a span of 37 years. As shown, the extent of urbanization (builtup areas) has already reached the upper municipalities. Major changes can also be seen for other classifications such as, forests (high and medium vegetation), agriculture, and brushlands (land covered both by bushes and shrubs). However, accuracy (Kappa Statistics) and the significant differences between Landsat 2 and Landsat 8 (instrument technology,

Figure 6 and Table 2 show the preliminary (not calibrated) results for the discharge simulation using the
1979 and 2016 land use classification. Rainfall data reading from 25Sept-27Sept 2009 was used to simulate the discharges and peak times from the two land use scenarios. An observed discharge data at Montalban Station was also used for comparative purposes. The preliminary results show that the 2016 Land Use Scenario is just 225.7cu.m/s higher than the 1972 Land Use Scenario, while the peak time for both of the simulations were the same. The simulated results were also underestimated compared to the observed flow. Further calibration is needed to confirm the how much is the impact of urbanization to floods in Marikina River Basin.

4. CONCLUSION AND RECOMMENDATION

A review of the interaction between Metro Manila and Marikina River Basin has been made based on existing records, plans and previous studies. Hydrological simulations were also done to quantify the impact of urbanization in the river basin.

Based on historical accounts and previous studies, the causes of urbanization in Metro Manila has been multifaceted – a complicated interaction of land use, population growth, and existing political landscape. These causes have shaped the current flooding scenario in the metropolis and river basin.

Urban plans and flood mitigation plans were treated as separate endeavors in the past. The non-integration of drainage plans to the urban plans could have been the major drawback in flood mitigation measures for Metro Manila and Marikina River Basin.

Issues such as inconsistent and weak implementation resulting to discontinued projects, too much decentralization, and lack of unified land use policy were the problems the past administrations have tried to address, yet their efforts were not enough as urbanization has continued to spread towards the river basin, exposing more people to the dangers of flooding.

It was only after the onslaught of TS Ondoy that the people realized the grave impacts of urbanization to floods in Metro Manila and Marikina River Basin. Since then, people became more aware and decision-makers became more critical in their policies regarding land use and disaster risk management. However, greater effort must be done to ensure that floods in Marikina River Basin and Metro Manila become manageable in spite of the impacts of the rapid urbanization experienced in the river basin.

A hydrological modeling of the river basin was also done to determine how much the impact of urbanization to the floods in Marikina River Basin is. Further improvements to the land classification and discharge simulation should also be done to determine whether urbanization has significant impact to the floods in Marikina River Basin.

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