FLOOD RISK AT VARIOUS STAGES OF CATBALOGAN SKY CITY PROJECT DEVELOPMENT

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Abstract

The effects of climate change on low-lying communities discouraged cities to reclaim seas for urban expansion. The storm surge that has occurred during the onslaught of Typhoon Haiyan in some parts of the Visayas in the Philippines discouraged the City of Catbalogan from pursuing expansion through reclamation. Instead, the local government proposed a Sky City project which intends to develop the hills surrounding the city as the new growth area. However, the development will cause various problems, one of which is the increased runoff due to change in ground cover. The paper aimed to calculate the increased runoff at various stages of development which will lead to flooding in the old city. Data from 36 scenarios (9 rainfall intensity and 4 stages of the project) using Hydrologic Modeling System (HEC-HMS 4.1) of the US Corps of Engineers, reveals that areas along the river will swell at rains smaller than 10mm in 1 hour. While potential risk on other parts of the city remains almost the same. There is a need to implement mitigating measures against the expected increase in runoff volume before the Sky City project development starts.

Keywords: hydrologic modeling, runoff, erosion, landuse impact, urbanization

I. INTRODUCTION

Built-up urban areas will almost triple or increase by about 1.2 million square kilometers as urban population doubles in 30 years since the year 2000 (Worldbank,2014). As cities increase, their exposure to disaster risks also increases. There are about 40% of world population living within 100km from the sea or 10m elevation from the sea level, which is highly susceptible to storm surges and sea level rise. (www.columbia.edu). Aside from these risks, the changing climate has also increased the intensity of precipitation which has exceeded capacities of natural and manmade drainage systems (www.eoearth.org, 2014, www.apfm.info, 2012). The rapid increase in population and urbanization has forced communities to change land use. These changes in ground cover from vegetation to impervious layers like paved surfaces and buildings has reduced infiltration capacity and increased volume of run-off (www.epa.gov).

From 1995 to 2015 around 6,457 weather-related disasters were recorded claiming a total of 606,000 lives and affected more than 4 billion people around the world(UNISDR, 2015). About 43% of the said disasters were flooded affecting 2.3 billion people; most are from Asia and Africa (ibid, pp 13). In the same report, it says the Philippines is number 4 according to number of disasters which affected 130 million people in 20 years. Natural disasters in the Philippines has resulted into PhP 5B to PhP

15B direct damages which are about 9.5% of the country's Gross Domestic Product (Porcil, 2009). About 20 typhoons cross the Philippines yearly, 5 of which are destructive (ibid) carrying heavy precipitation that swells canals, streams, and rivers resulting into floods.

The Philippines has 64 of its 79 provinces, and 822 out of 1,502 municipalities are situated along the coast having an estimated inhabitants of about 2,467 inhabitants per kilometer coastline (www.worldbank.org, 2005). Catbalogan City is one of the coastal towns; it is the capital town of the province of Samar with 94,317 inhabitants in 57 barangays, 42 of which are along the coast including 21 baranggays in the Poblacion (NSCB, 2010). Total land area of the city is around 274 square kilometer (km^2) wherein 30.7 km^2 is urban with the Poblacion occupying around 1.3 km^2. Catbalogan is one of the communities in Eastern Visayas having the highest population density as inhabitants are concentrated at the 2% flat and gently sloping grounds of the city (Orale, 2006). Catbalogan remains to be the most competitive city in Samar Island (www.competitive.org.ph, 2015) which means an attractive investment hub in this part of the country. To accommodate the potential investors, new land for business must be created to reduce the cost of owning a land or renting it. In the past, Catbalogan proposed to expand by reclaiming around 40-hectare of the Maqueda Bay but abandoned due to some conflicts (USAID & NEDA, 2005).

In the year 2013, the strongest and deadliest typhoon hit the Philippines with maximum sustained winds of up to 315 kph with gusts up to 379 kph just before landfall (JWTC, 2013). The strength of the typhoon caused up to almost 6m storm surge (Lagmay, 2014) killing more than 6300 people with a total estimated damage of about $ 2.05 Trillion (NDRRMC, 2014). Scientists, engineers, and other experts have estimated that areas prone to floods, storm surge, and tsunamis are those low-lying communities (NOAA). Management of such risks usually is through the construction of levees, dams or walls which are often expensive and are providing a false sense of security as the biggest damages are when such systems fail(www.nature.org). At the aftermath of the TS Yolanda event, many local government units (LGUs) wished to transfer their people to safer grounds but such plan are expensive wherein many LGUS can't afford.

Since Catbalogan has been planning for expansion, they instead had chosen to develop the hills and dubbed it as the Catbalogan Skycity Mega Project. The said project will develop around 440 hectares of land located about 120 m above sea level (www.gib-foundation.org). Urban development has a direct effect on the frequency of floods if mitigation strategies are not in-placed. Changing ground cover will reduce infiltration or even suppressed it thereby increasing runoff to streams. As a result, the peak discharge, volume, and frequency of floods increase (Konrad, 2014). The said possible impact, especially to the old city, needs to be quantified so that mitigating strategies be identified and systematically implemented. This study was conducted to forecast river/drainage flow at various stages of the Sky City development.

II. METHODOLOGY

The methods used to answer the research question includes watershed profiling considering the different stages of development of the SkyCity project, runoff and river discharge analysis from a simulated rain.

2.1 Watershed Profiling

There are several watersheds in Catbalogan, but the largest is the Antiao watershed draining its water to the Antiao River. Other smaller watershed drains its water to small intermittent streams, only with flowing water when it's raining. The profile of Catbalogan watersheds was determined with the aid of National Mapping and Resource Information Authority (NAMRIA) topographic maps. The said map was used to identify the boundaries of the watershed including the tributaries supplying water to the natural and other manmade drainage systems. Soil classification was derived from the Bureau of Soils and Water Management (BSWM) geological and soil maps. The determination of ground cover of the Antiao Watershed was estimated using rasterized satellite images from www.bing.com. As well as those in Google Maps. These maps were analyzed by overlaying it with the NAMRIA maps in AutoCAD environment.

2.2 Precipitation Characteristics and Cases

Information about the characteristics of Catbalogan precipitation was from the Department of Science and Technology (DOST)-Philippine Atmospheric, Geographical and Astronomical Services Administration (PAGASA). The data from PAGASA was used to determine what scenarios will be analyzed. Also, the highest observed precipitation from 2010 to 2014 was used as one case.

There were 36 cases that were simulated to determine the volume of runoff water, discharge, and velocity. Four stages of SkyCity development and nine precipitation scenarios. The four stages of Skycity development are; current condition (0% Skycity development), at 10%, 50% and full completion. The nine precipitation cases are; 10mm in 30min, 10mm in 1 hr., 50mm in 1 hr, 50mm in 6 hrs, 100mm in 1hr, 100mm in 6hrs, 400mm in 6hrs and 400mm in 12 hrs; and one month (December 2014) actual precipitation intensity.

2.3 Runoff and Discharge Analysis

The runoff and discharge analysis made use of the Hydrologic Modeling System (HEC-HMS) Version 4.1, developed by the US Army Corps of Engineers-Institute for Water Resources Hydrologic Engineering Center. Variables used are based on runoff curve number (CN) method proposed by the United States Department of Agriculture (USDA) Technical Release 55 (TR55) published in June 1986.

Simulation run using the HEC-HMS software was performed using daily rainfall data on selected month with extreme precipitation events as several designed precipitation. The simulation run is capable of estimating the behavior of the modeled watershed given hydrologic information.

2.4 Flood Risk Estimation

The run-off volume running towards the drainage systems were compared to the capacities of the same systems. This is performed to determine when the drainage systems will swell and eventually cause a flood. Regression curves were developed from the data simulation and were used to estimate what rainfall intensity is needed to swell the river. Anything more than the calculated value will mean flood within the immediate vicinity of the waterway analyzed.

III. RESULTS AND DISCUSSIONS

3.1 The Catbalogan Watershed

This study only focuses on two watersheds of Catbalogan that will be most affected by the proposed Catbalogan Skycity Mega Project. These watersheds are the Antiao Watershed and the Catbalogan Southwest Watershed (WS). Antiao watershed covers about 1,942 hectares and is draining water from three sub-watershed denoted as Antiao Watershed–North (WN), the Antiao Watershed-East (WE) and Antiao Watershed-West (WW). The WN and WE watershed have a total area of 1206 and 443 hectares respectively wherein tributaries drop its water to Barangay San Andres section of the Antiao River. The WW drains

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Table 1. Current Watershed Profile of Catbalogan City

Ground Cover	Area in Hectares							
	Antiao Watershed (Orale, 2015)						Others	
	WN	%	WE	%	WW	%	WS	%
Woods	244.9	20.3	36.4	8.2	57.6	19.6	12.8	5.1
Woods-grass (Coconuts)	351.2	29.1	79.0	17.8	53.7	18.3	142.5	57.1
Bare soil	102.9	8.5	54.9	12.4	3.8	1.3	7.1	2.8
Meadow-grass	491.6	40.8	234.1	52.8	32.8	11.2	34.6	13.9
Urban District	0.0	0.0	0.0	0.0	46.5	15.9	0.0	0.0
Residential Districts	14.6	1.2	38.6	8.7	89.2	30.5	52.6	21.1
Antiao River	0.8	0.1	0.6	0.1	9.3	3.2	0.0	0.0
Total	1,206.0	100.0	443.5	100.0	292.9	100.0	249.6	100.0
Grand Total	1942.4						249.6	

water through two of three major canals and ends along the remaining 2.5 km stretch of the river. The WS drains directly to the sea, through natural streams and manmade canals. The WS covers areas of Brgy Lagundi down to some parts of Barangays Ubanon, Guinsorongan, Bunuanan, Ibol, and Pangdan.

The portion of watershed denoted as WN, and WE are primarily covered by non-graze grasslands which sometimes are cultivated, and grass covers are often removed, sometimes through slash and burn or locally known as kaingin. Coconut trees dominate and woods or forest trees are few. On the other hand, the WW are mostly built up zones. The Catbalogan Skycity Mega Project will be situated along the WE, WW and the WS portion of Catbalogan Watershed. Most of the built-up zone for the Skycity is found on the WE portion of the watershed.

The watershed groundcover is going to change ones the development of the Skycity commences. The WE, WW and the WS portion of the watershed are going to change heavily. Most of the infrastructure will be on WE portion of the watershed. These changes in ground cover will alter the ability of the soil to absorb rainwater. During the development stages, soil erosion is expected to increase significantly which will choke streams and other drainage systems.

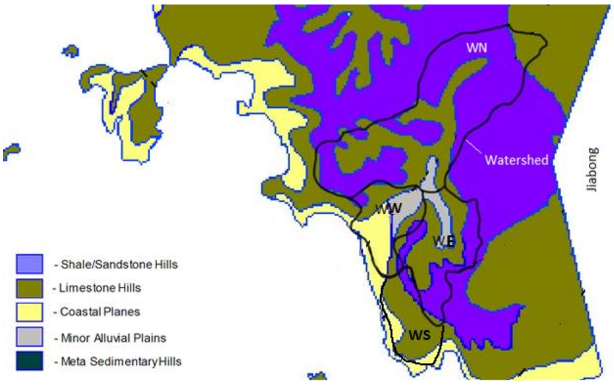

Figure 1.Geologic Profile in the Catbalogan Watershed

The weathered limestone and shale are of clay type (Caroll and Hathaway, undated; Zagorzki, 2010) on the other hand shale and sandstone rocks when weathered produces clay loam (www.claysandminerals.com). Clay and clay loam has the very low permeability (www.usgs.gov, JS Dagdu & Nimbalkar P., 2012) with infiltration rate for clay range from 1 to 5 mm/hr and 5 to 10 mm/hr for clay loam (www.fao.org). This means that surface runoff is heavier because infiltration is low. Infiltration rates of soils are affected by subsurface permeability including surface intake rates. Soils are classified into four Hydrologic Soil Groups (HSGs) according to their minimum infiltration rate which is obtained for bare soil after prolonged

Table 2. Geologic Soil Types of Catbalogan City

Geologic Type	Top Soil Type	HSG*	WN	WE	WW	WS	Sub Total
Shale/Sandstone	Clay Loam	C	740.2	193.2	18.3	32.5	984.2
Limestone Hills	Faraon Clay	D	442.9	191.3	101.9	178.9	915.0
Coastal Planes	Sand	A	0.0	0.0	104.4	38.2	142.6
Minor Alluvial Plains	Fine Sand	B	22.9	59.0	68.3	0.0	150.2
Sub Basin HSG	-	-	C	C	B	D	C
Total			1206.0	443.5	292.9	249.6	2192.1

Legend: *Hydrologic Soil Group(HSG)
A -Sand, loamy sand, or sandy loam
B -Silt loam or loam
C -Sandy clay loam
D -Clay loam, silty clay loam, sandy clay, silty clay, or clay

saturation (www.usda.gov). Figure 1 and Table 2 illustrates soil and bed rock characteristics of the watershed. The soil type in the watershed is of clay type while soil surrounding most of the stretch of the river are of the sand type.

The type of soil has significant influence to the volume of runoff. The finer the soil type like clay, silt and especially those with high plasticity and well compacted has a lower permeability (www.geotechdata.info) therefore infiltration is also low and runoff increases. Vegetation, specifically trees enhances soils permeability through its roots (Shanstrom, 2015).

3.2 Precipitation Characteristics in Catbalogan

Most of Samar Island weather is of type II but Catbalogan is more of type IV, meaning that rainfall is evenly distributed over the year (PAGASA, nd). Rainfall intensity from 2010 to 2014 and compared to 30-year normalized rainfall intensity. Months of January, March and May 2011 exhibited more than 600mm of rain while December 2014 has the highest monthly rainfall totaling to about 1140mm of rain, 72% higher than normal. January and March heavy precipitation occurred even when there was no typhoon. It is also very notable that more than half of the months have total rain more than the 30-year average. The profile shows that it is highly probable that rain in Catbalogan could go to worse causing streams, rivers and canals to overflow and eventually resulting into floods.

3.3 The Catbalogan Skycity Mega Project

The Global Infrastructure-Basel website revealed that the City Government of Catbalogan envisioned to develop a new urban area adjacent to where the current city center is located. This is an answer to the fast becoming congested city and as a response to threats of climate change risks. The Catbalogan Skycity will be constructed on 440 hectares of land, situated on the adjacent hills, highest elevation of which is 120 meters above sea level. The selected location includes flat land and hills and is surrounded by picturesque scenery such as a mountain range, a beautiful coastline, a river, and a man-made lagoon.

Source: City LGU of Catbalogan

Figure 2. Photo Illustration of the Catbalogan Skycity Mega Project

As shown in figure 2 and 3, the proposed land use of the SkyCity includes local and regional government centers, a

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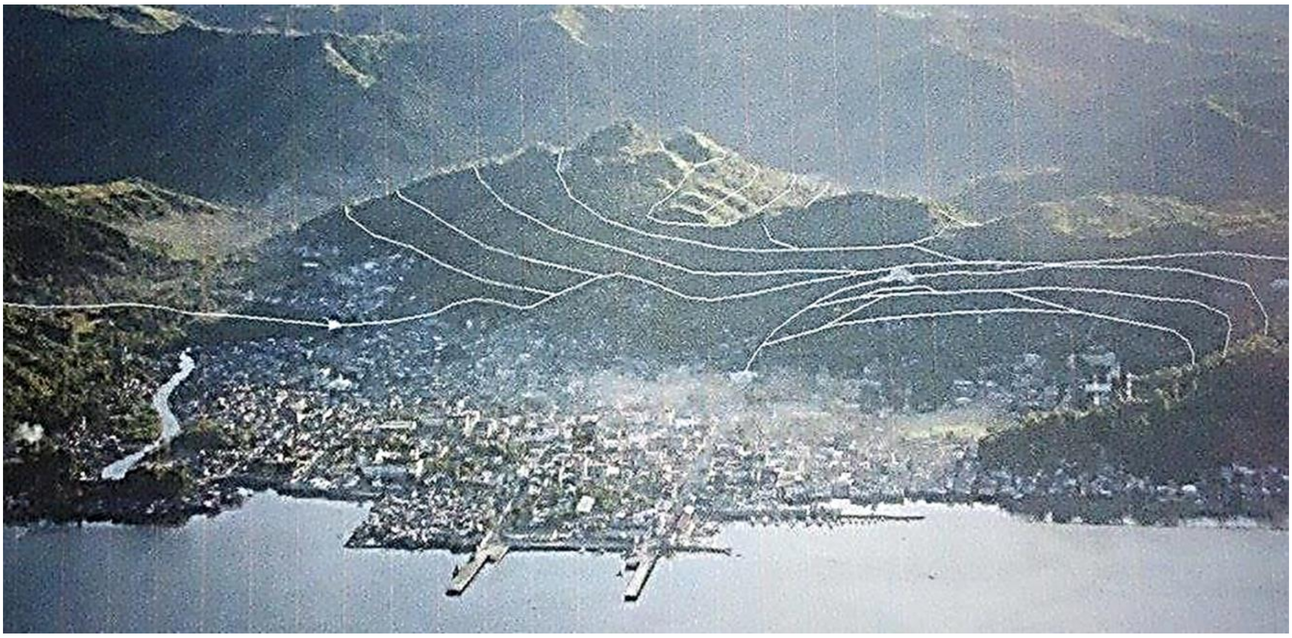
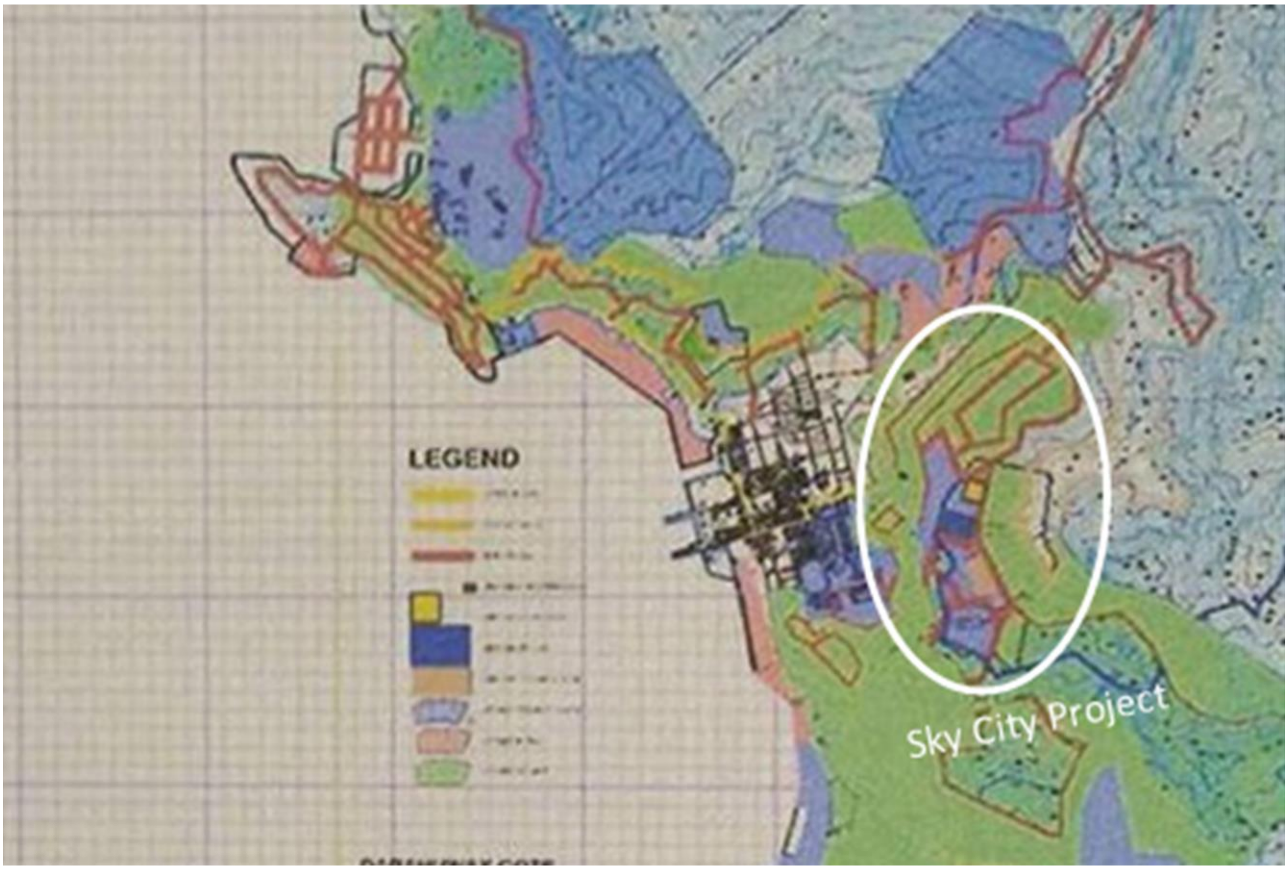


Source: City LGU of Catbalogan *White lines are the proposed road network in the Sky city*

Figure 3. Aerial View showing location of the Catbalogan Skycity Mega Project



Source: City LGU of Catbalogan

Figure 4. Proposed Catbalogan City Urban Development Project - Map

corporate center, an educational center, a regional health & wellness zone, a Disaster and Risk Reduction Management Command & Evacuation Centre, an Information and Communication Technology Hub, a twenty hectare viewing deck, as well as a theme park, a sports complex, hotels and an intermodal terminal. The urbanization of the said land will result in an increased runoff and more erosion. The said impact is expected to endanger more the low-lying communities from floods.

As shown on figure 2 and 3, the proposed land use of the skycity includes local and regional government centers, a corporate center, an educational center, a regional health & wellness zone, a Disaster and Risk Reduction Management Command & Evacuation Centre, an Information and Communication Technology Hub, a twenty hectare viewing deck, as well as a theme park, a sports complex, hotels and an intermodal terminal. The urbanization of the said land will result into an increased runoff and more erosion. The said impact is expected to endanger more the low lying communities from floods.

3.4 Rainfall Runoff Simulation

In Catbalogan, there is a 16%, 0.3%, 0.1% and 0.05% chances of at least 10mm, 50mm, 100mm and about 400mm rain respectively with varying duration. To generalize the rainfall scenarios, simulation runs assumed rain from 10mm to 400mm on at least two duration and the December 2014 real rainfall data. The simulated rainfall runoff was calculated at four stages of the Skycity development. The current state (0%), at 10%, 50% and 100% development. The changes in land cover/use at different stages of development was all assumed. Roads are expected to be built first, followed by prominent structures such as the new Cityhall and the proposed wind tower by the ODIN Energy of Korea. Drainage capacity has not considered clogging or reducing cross-sectional area from eroded soil and solid waste that may flow together with the runoff water.

Table 3 to 7 are the results of the simulations using the HEC-HMS. Runoff volume (RV) and peak discharge (PQ) was based on eight (8) designed precipitations and one real event, the December 2014 precipitation scenario. The curve number was based on several Sky City development scenarios.

Table 3 shows the volume of runoff water and the discharge rate along the Antiao River in the vicinity of Brgy San Andres. The said portion of the river is the junction where the water coming from the WE and WN converges. At the current land

Table 3. Simulated Peak Discharge along Antiao River (San Andres Area)

Percent Skycity Development	0%		10%		50%		100%	
Rainfall and Duration	Peak Q	RV	Peak Q	RV	Peak Q	RV	Peak Q	RV
Simulated (10mm in ½ hr)	0.0	0.0	1.8	0.3	7.6	1.0	20.4	2.3
Simulated (10mm in 1 hr)	0.0	0.0	1.4	0.3	5.6	1.0	14.4	2.3
Simulated (50mm in 1 hr)	57.0	9.9	65.6	12.3	78.8	15.6	90.9	19.1
Simulated (50mm in 6 hrs)	16.5	9.9	18.8	12.3	21.1	15.7	22.8	19.1
Simulated (100mm in 1 hr)	242.7	42.2	256.6	46.1	258.5	50.7	249.8	54.9
Simulated (100mm in 6 hrs)	94.3	42.4	99.8	46.2	104.5	50.9	104.2	55.1
Simulated (400mm in 6hrs)	440.7	315.9	444.5	322.1	446.2	328.4	443.9	333.4
Simulated (400mm in 12 hrs)	339.2	316.0	342.8	322.1	342.8	328.5	339.2	333.5
December 2014 Rain	45.4	1041.7	45.5	1048.7	45.5	1055.5	45.5	1060.7

RV-runoff volume   Peak Q – peak discharge   River capacity – 2 cum/sec

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use (0% SkyCity development), a rain of about 22mm in 1-hour duration is enough to swell the river, anything more than that means flood in the area. The said behavior changes when the Skycity development commences. At 10%, 50%, and 100% development stages, the same portion of the river is to swell at about 11, 8 and 3 mm of rain poured in 1 hr. December 2014 rains have flooded the area twice, during the typhoon Rubi and Seniang where rain was more than 300mm on each event.

Table 4 shows the peak discharge and the runoff volume along Bliss Community, a part of Brgy Sto. Nino in Catbalogan City. This village is one of the communities easily flooded from high precipitation. The low river capacity, the meandering channel and almost flat channel slope increase flood risk in the area. Even without the Skycity, a 10mm rain poured within 1 hour period will swell the river. Noticeably, the calculated discharge along San Andres and Bliss Community when the sky city is completed is at most increased 2000 times as shown in Table 3 and 4. For example, a rain of 10mm in 30 minutes will not be felt at the current land use but will become 20.4 cum/s when the project is completed.

Table 4: Simulated Peak Discharge along Antiao River (Bliss Community)

Percent Skycity Development	0%		10%		50%		100%	
Rainfall and Duration	Peak Q	RV	Peak Q	RV	Peak Q	RV	Peak Q	RV
Simulated (10mm in ½ hr)	0	0	1.8	0.26	7.6	0.95	20.4	2.08
Simulated (10mm in 1 hr)	0	0	1.4	0.26	5.6	0.95	14.5	2.08
Simulated (50mm in 1 hr)	57.1	9.8	65.6	11.98	79	15.05	93.5	18.32
Simulated (50mm in 6 hrs)	18	9.87	20.4	12.05	22.9	15.11	24.8	18.37
Simulated (100mm in 1 hr)	242.9	41.92	256.8	45.46	259.5	49.76	250.8	53.84
Simulated (100mm in 6 hrs)	99.9	42.24	105.5	45.78	110.9	50.04	110.8	54.12
Simulated (400mm in 6hrs)	482.4	315.61	486.7	321.27	488.6	327.08	486.6	332.13
Simulated (400mm in 12 hrs)	361.4	315.75	366	321.4	370	327.2	368.8	332.25
December 2014 Rain	50.1	1041.39	50.1	1047.76	50.1	1054.03	50.2	1059.36

RV-runoff volume *Peak Q – peak discharge* *River capacity – 27 cum/sec*

Table 5. Simulated Peak Discharge along Antiao Creek

Percent Skycity Development	0%		10%		50%		100%	
Rainfall and Duration	Peak Q	RV	Peak Q	RV	Peak Q	RV	Peak Q	RV
Simulated (10mm in ½ hr)	1	6.89	1	6.89	1.1	7.03	1.1	7.41
Simulated (10mm in 1 hr)	0.8	6.89	0.8	6.89	0.8	7.02	0.8	7.4
Simulated (50mm in 1 hr)	5.4	43.23	5.4	43.23	5.5	43.91	5.7	45.4
Simulated (50mm in 6 hrs)	1.6	43.24	1.6	43.24	1.6	43.93	1.7	45.41
Simulated (100mm in 1 hr)	12	92.11	12	92.11	12.1	93.02	12.4	94.89
Simulated (100mm in 6 hrs)	4.3	92.17	4.3	92.17	4.3	93.08	4.4	94.95
Simulated (400mm in 6hrs)	12.1	391.11	12.1	391.11	12.1	392.26	12.1	394.52
Simulated (400mm in 12 hrs)	9.4	391.13	9.4	391.13	9.4	392.28	9.4	394.54
December 2014 Rain	1.2	1126.01	1.2	1126.01	1.2	1127.22	1.2	1129.58

RV-runoff volume *Peak Q – peak discharge* *River capacity – 9.8 cum/sec*

Table 6: Simulated Peak Discharge of the Main Canal

Percent Skycity Development	0%		10%		50%		100%	
Rainfall and Duration	Peak Q	RV	Peak Q	RV	Peak Q	RV	Peak Q	RV
Simulated (10mm in ½ hr)	0.7	4.01	0.7	4.04	0.7	4.15	1	5.56
Simulated (10mm in 1 hr)	0.5	4.01	0.5	4.04	0.5	4.15	0.8	5.56
Simulated (50mm in 1 hr)	4.8	31.77	4.9	32.58	5.2	34.32	6.4	42.14
Simulated (50mm in 6 hrs)	1.3	31.77	1.3	32.58	1.4	34.32	1.8	42.14
Simulated (100mm in 1 hr)	11.9	76.6	12.1	77.94	12.5	80.7	14.1	91.34
Simulated (100mm in 6 hrs)	4.2	76.6	4.3	77.94	4.4	80.7	4.9	91.34
Simulated (400mm in 6hrs)	13.1	370.49	13.1	372.6	13.2	376.74	13.4	390.64
Simulated (400mm in 12 hrs)	10.2	370.49	10.2	372.6	10.3	376.74	10.5	390.64
December 2014 Rain	1.3	1103.95	1.3	1106.3	1.3	1110.87	1.4	1125.66

RV-runoff volume *Peak Q – peak discharge* *River capacity – 12.4 cum/sec*

Table 7. Simulated Peak Discharge along Antiao Creek

Percent Skycity Development	0%		10%		50%		100%	
Rainfall and Duration	Peak Q	RV	Peak Q	RV	Peak Q	RV	Peak Q	RV
Simulated (10mm in ½ hr)	1.6	0.24	2.2	0.48	7.7	1.16	18.1	2.28
Simulated (10mm in 1 hr)	1.3	0.24	2.1	0.48	6	1.15	14.3	2.28
Simulated (50mm in 1 hr)	54	10.95	64.5	13.05	77.3	16.05	97	19.39
Simulated (50mm in 6 hrs)	19.5	11.06	22	13.17	24.8	16.15	27.1	19.48
Simulated (100mm in 1 hr)	229.2	43.48	241.9	46.9	255.7	51.13	249.8	55.33
Simulated (100mm in 6 hrs)	101.7	44.07	108.1	47.48	113.6	51.64	114.1	55.82
Simulated (400mm in 6hrs)	502.4	318.33	507.1	323.79	509.2	329.48	508	334.67
Simulated (400mm in 12 hrs)	373.6	318.59	378.1	324.04	381.3	329.71	380.1	334.9
December 2014 Rain	52.2	1044.5	52.3	1050.65	52.3	1056.77	52.3	1062.26

RV-runoff volume *Peak Q – peak discharge* *River capacity – 227 cum/sec*

Table 5 shows one of the major creek flowing across the city center. The Antiao Creek is a concrete lined canal of varying size; the shallow part has an approximate discharge capacity of 9.8 cu.m/s. The effect of sky city development on all stages of development to the Antiao Creek is not significant. Mostly affected section of the watershed is the WE while the creek drains water from a small portion of the WW watershed. The rain needed to swell the said drainage canal ranges from 84mm to 73mm in an hour of precipitation duration. A 10mm rain in 30min at the current state of land use will result into 1 cum/s discharge rate and is increased by 10% when the whole sky city project is completed.

There is three major drainage canal namely; Antiao Creek and two covered canals draining water mostly from WW portion of the watershed. The main canal is one of the covered drainage systems of Catbalogan. This canal is slightly more affected than the Antiao Creek even if both are serving the WW portion of the watershed. As shown in Table 6, the needed precipitation to cause swelling is higher as it has higher capacity. It needs close to 100mm of rain poured in 1 hour to swell. Sown on table 7, a 10mm rain poured in 30 minutes resulted into 0.3cum/s discharge rate from 0.7cum/s or about 43% increase.

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The river absorbs most of the runoff waters from the Antiao watershed, the mostly affected portion of Catbalogan watersheds from the proposed SkyCity. Based on the data presented in Table 7, the Skycity development on all stages has a very small impact regarding the volume of water it will carry. At the current state of land use (0% Skycity development stage), around 100mm rain poured in 1 hour will swell the river. On a post-development stage, around 93 mm of precipitation is needed to swell the river. However, there is an estimated increase of about 1000 times more discharge (from 1.6 to 18.1 cu.m/s) when pre-development (0%) and post development (100%) sky city cases are compared.

Figure 4 is a typical situation after a very heavy precipitation. Smaller precipitations also carry sediments which eventually clogged waterways. Solid waste also goes with the water runoff. Sediments and wastes reduce carrying capacity of the drainage systems further increasing the risk.

Figure 4: Massive sand bars after December 2014 Storms

3.5 Flood Susceptibility

A major cause of flood in Catbalogan will be the swelling of the waterways draining water after a heavy precipitation. Based on the flood susceptibility map of Catbalogan City, the low-lying areas along the river bank will be flooded. The dark pink color in the map are the flood plains many of which are already occupied. The Bliss Community is the first subdivision in Catbalogan is also located in a floodplain. It is bounded on three sides by the river and one side a hill making it prone to flooding.

Flood risk assessment focused on five zones near a major waterway and is shown in figure 9, namely; Brgy San Andres, Bliss Community, Antiao River mouth, Antiao Creek and one of the main canal.

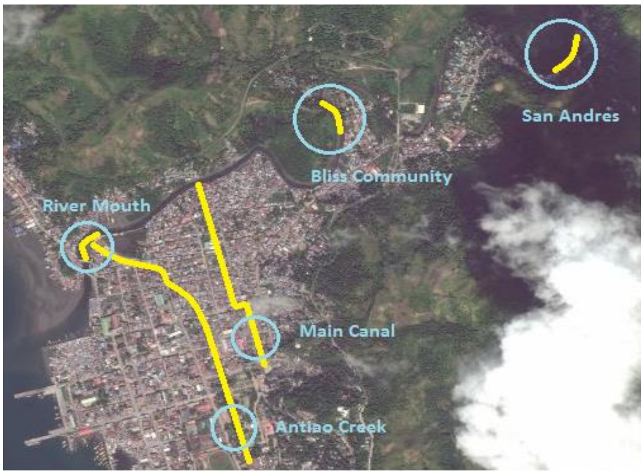


Figure 5: Flood Risk Assessment Zones

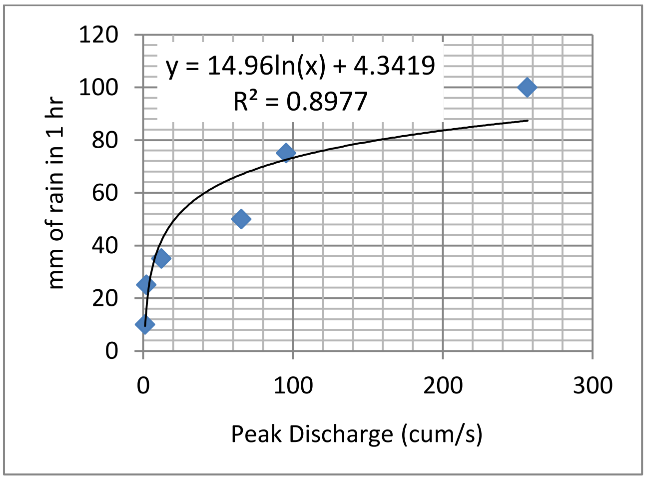
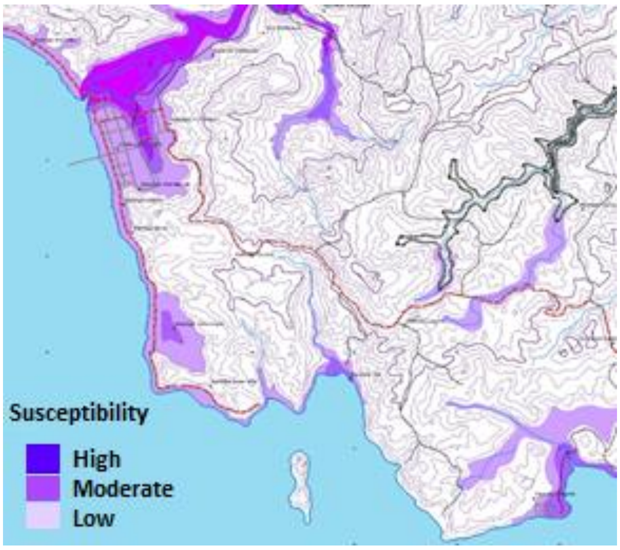


Figure 6: Peak discharge at varying intensity of rain for San Andres portion of Antiao River (10% Sky City Development Stage)

Figure 6 is an example of the regression curves developed to predict peak discharge of river/canal/drainage at different rainfall intensity. Figure 6 is a state where Sky City development is at 10%. The regression curve suggests that at about 15mm rain, the Antiao River along Brgy. San Andres will start to swell. As development increases, it needs lower intensity to cause swelling of this part of the river. Based on the study of Orale(2015), there are about 11% days where rain is about 10-20mm, not necessarily of 1-hour duration. At current condition, the river is expected to swell at less than 20mm rain in an hour. The swelling river is just the start of the flood, if the amount of rain is not sustained, then the flood will not occur.



Source: Mines and Geosciences Bureau

Figure 7: Catbalogan Flood Susceptibility Map

It is, however, interesting to note that the river mouth can carry the large volume of water and will not swell easily. It requires between 90-100mm of rainwater in 1 hour to start the river to swell. The percent change between the three stages of Skycity development (0%, 50%, and 100%) are not too far from each other which means the project has minimal flood risk contribution. However, this estimate has not taken into account the possibility of reduced river capacity primarily due to siltation or due to changes in ground cover from the other watershed (i.e., AWN and AWE).

Figure 7 shows flood risk susceptibility map developed by Department of Science and Technology-Mines and Geosciences Bureau. This map has not taken into consideration the changes in land use specifically in the WW portion of the watershed. Flood susceptible areas identified were low-lying zones and adjacent to the Antiao River.

IV. CONCLUSIONS

Catbalogan City needs to expand to accommodate growth, however, due to recent climate-related risks have forced communities to look for out-of-the-box ideas for expansion, such as the Catbalogan Skycity Mega Project. However, as the project responds to current and future problems like decongestion, storm surge, and the likes, it is also expected to develop new problems. The change of land use poses flooding risks on low-lying communities like the current city center.

Data have shown that if current state of waterways is not enhanced to drain increased runoff water, flooding in Catbalogan will worsen. Brgy. San Andres, for example, has only 2cum/s capacity and can be overcome by 11mm rain poured in 1 hr. On post-Skycity development and assuming that the Antiao River capacity in San Andress is not enhanced, it will only need 3mm of rain to start the river to swell. There is more than 70% probability that a rain of up to 10mm anytime of the day making it highly susceptible to river swelling.

To come-up a more accurate estimate, there is a need to complete the Skycity development plan to identify different stages of development. The inclusion of the effect of siltation is also incorporated in the stream capacity analysis. A comprehensive plan to mitigate the calculated flood risks be developed and implemented strategically.

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