Alternative River Control Design for Antiao River Catbalogan City, Philippines

Joseph R. Dalemit, Joseph M. Baylon, Anton Mark C. Cabanacan, Kiven R. Gulane, Alvin L. Jabinal, Jude V. Malinao and Hanzen C. Raytos
College of Engineering, Samar State University, Philippines
Joseph.dalemit@ssu.edu.ph

Abstract: Flooding due to swelling of the river in Catbalogan City, Samar Philippines is persistent. To manage river swelling, the government implemented a river control project in 2014, but flooding persists. This paper explored other designs and impact was estimated using Hydrologic Engineering Center – River Analysis System (HEC-RAS) software. The identified designs which include four different cross section and two river sinuosity were examined regarding river carrying capacity during an extreme precipitation event. Analyses have shown that either straight or meandering channel having a rectangular cross-section resulted into significant improvement compared to the current condition. A straightened river has 36% improvement than the current meandering situation. Reducing sinuosity from 1.6 to 1.03 will require right of way of about 49 hectares and reclaim 75 hectares.

Keywords: river flow, river channel design, flood control, optimal design, river swelling, meandering channel

1. Introduction

A river flood or river swelling is typically caused by sudden, excessive rainfall that sends a river, stream or another body of water rapidly out of its banks. Often, this occurs in a short amount of time, only several hours or even less. This increases the probability of property damage and loss of life from a flash flood's quick moving, often unexpected, a wall of water or the slower inundation of a flood. For example, in Australia, the most expensive natural hazard is flooding with annual average damages estimated at $377 million Australian dollars or PHP 15.8 billion (Geoscience Australia, 2010).

In 2012, an estimated 372,000 people died from drowning during the flood, making drowning from a flood a major public health problem worldwide. Injuries account for every 9% of total global mortality. Drowning during flood disaster is the 3rd leading cause of unintentional injury death, accounting for 7% of all injury-related deaths. Drowning accounts for 75% of deaths in flood disasters and these are becoming more frequent, and this trend is expected to continue. Drowning risks increase with floods particularly in low-and-middle-income countries where people live in flood-prone areas and the ability to warn, evacuate, or protect communities from floods is weak or only just developing. (WHO, 2014).

The Philippines is considered one of the most disaster-prone countries in the world with almost 20 tropical cyclones a year, most of it passes by Eastern Visayas where Catbalogan City is found. From 1980 to 2001, a total of 23,942 human lives were claimed or an annual average of 1,088 due to typhoon and flood with a total damage value of PHP 183 billion according to the Office of the Civil Defence (DPWH & JICA, 2003). River swelling in the Philippines is common resulting into families being evacuated and properties damaged. The most tragic example was the flash flood in Ormoc City due to Typhoon Uring resulting into a peak flow between 70,000 to 80,000 cuft/second compared to the carrying capacity of the river at 30,000 cuft/sec (Pearson & Oliver, 1992). This flood resulted into killing about 4,000 residents, more than 3,000 people injured and some 2,500 missing (ESSC, 2000).

Catbalogan City is a coastal community located in the province of Samar, Philippines. It has a river traversing the center of the city and exits to the Maqueda Bay. The northern part of the Antiao Watershed draining its runoff water northernmost portion of the 4.08km river is about 1649.5 hectares (Orale, 2015). The river on the downstream side has an average width of 37.55m and depth of 1.25m. This river serves as the primary outlet or artery for freshwater and transport network in the past. Water in the river is heavily dependent on precipitation with little contribution from the aquifer system. During prolonged dry spell, many of the headwaters relatively stop supplying the river. One of the major sources of river water aside from rain is the Masacpasac sub-surface channel. However, almost all of its discharge is for Catbalogan water supply use (Gomba, et. al., 2007) except when there is massive rain.

Having a type IV climate, the rainfall in Catbalogan City and nearby towns is evenly distributed all year long (PAGASA, nd.), swelling of the river is inevitable. The river has been a source of flooding recently. In 2014, the storms Ruby (Hagupit) and Seniang (Jangmi) brought with it the significant volume of rain causing floods in Catbalogan City. The month of December 2014 brought with it a significant volume of rain totaling to about 1140mm or 72% higher than 30 years average (Orale, 2015). The flooding was believed to be worse even if the first phase of the Antiao River control project is almost complete that time.

Theoretically, river flow is fast in the upstream part as the river relief changes fast and it decreases as it nears the mouth. In most cases, River near mouth often swell and causes flooding. Meandering also has an effect on the velocity of water flow in the river. Can straitening improve river flow and minimize river swelling?

2. Objective

Will the river control project worth hundreds of millions of pesos serve its purpose? This is what the study is all about. It evaluated the capacity of the river in a designed storm and compared it to alternative river control design.

3. Methodology

The study evaluated eight(8) river control design for the Antiao River in Catbalogan City, Philippines using the Hydrologic Engineering Center – River Flood Control Analysis System (HEC-RAS). Of the eight(8), seven(7) were alternative design, and the other simulates the current design.

The HEC-RAS software was fed with values taken from the field and some assumptions based on the profile of watershed, the river and the precipitation behavior in the study area.

River profile was generated from topographic and hydrographical surveys.

Figure 1. Evaluation stations along Antiao River

River flow was based on the simulated flow during December 2014 rains which was reported in the study of Orale (2015).

Table 1 summarizes the different design subjected to HEC-RAS analysis.

Table 1. River Control Design Assessed

Cross-sectional	Maintaining configuration	Straightening river channel
Trapezoid	X	X
Rectangle	X	X
Semi-circle	X	X
Triangle		X
Control	X	

The river was cut into 35 segments of 100m long each from the river mouth (Sta. 0+000) to Sta. 3+400 somewhere in the area of Barangay San Andres as shown in figure 1. For this simulation, performance along stations 0+000, 1+100, 2+300 and 3+400 was examined.

4. Results and Discussion

4.1 The current river configuration

The current river configuration as shown on figure 1 was inputted to HEC-RAS environment as shown on figure 2. The physical characteristics of the four observed stations are shown on figure 3 and table 2. The capacity of the river at Station 0+000 is about 289.29 cu.m/s and it decreases as it recesses to upstream with stations 1+100, 2+300 and 3+400 having 80.09%, 91.8%, and 98.5% lower than the river mouth capacity respectively. The river is silted more heavily upstream than downstream primarily because it was recently disilted due to the implementation of the river control project. On the other hand, the groundcover condition in the upstream part

Table 2. Physical Characteristics of Antiao River observation stations

Stations	Cross-sectional Area (m2)	Elevation (m)	Maximum Discharge Capacity (cu.m/s)	Physical Condition
3+400	3.85	0.35	4.27	Heavily silted
2+300	25.76	1.37	23.70	Slightly silted
1+100	61.25	2.48	57.58	Slightly silted
0+000	106.75	3.50	289.29	Fairly silted

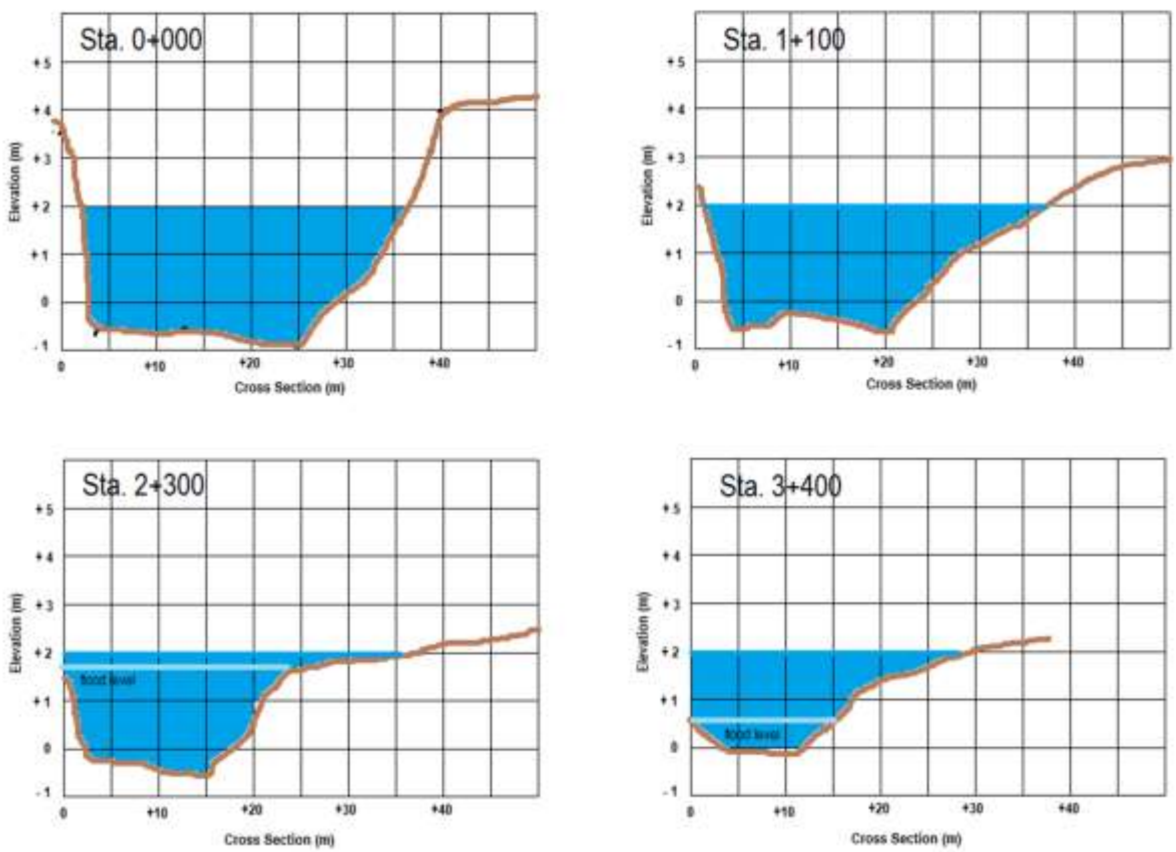


Figure 2. Cross-sectional profile of observation stations

of the river plus the fact that the river banks are not protected is one probable factor of heavy siltation condition. From the river mouth, the last observation station upstream is about 3.15m.

4.2 Antiao River flow during December 2014

December 2014 was a very wet month. Aside from the almost daily rain, this was also the month with peak rainfall in the last five years primarily due to two storms that have affected severely the city of Catbalogan. This precipitation resulted in a maximum flow of about 50 cu.m/sec on two occasions with typhoon. This resulted into overflowing of river water specifically along Brgy. San Andres (Sta. 3+000 to 2+800) down to Sta. 1+500. Table 3 shows the simulated discharge in the river at five stations with varying peak flow from 50 to 10 cu.m./sec using HEC-RAS software.

Table 3. Flood risk of Antiao River (current condition)

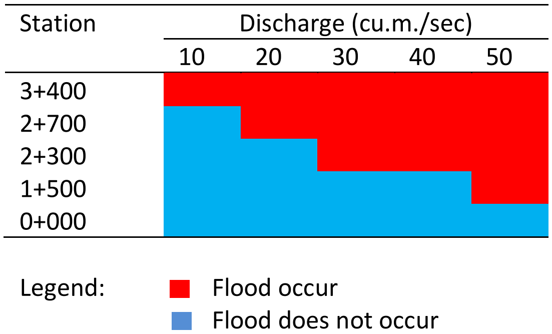


Table 3 suggests that considering the current profile, the river (specifically the upstream portion will swell at rain about between 20 to 30 mm of rain in an hour period

4.3 Design and evaluation of an alternative flood control system for Antiao River at original sinuosity level.

The alternative river control design focuses on two major areas; the cross-sectional properties and the sinuosity of the river. Sinuosity is a measure of how meandering the river is, a straight river has a sinuosity value of 1 and Antiao River is 1.6. Table 4 shows discharge capacity of the river having a different cross section from station 0+000 to station 0+3400. The current river wall is only up to Sta. 0+554 while the proposed new walls in the Antiao River Control Project will cover the river from the river mouth to area near Brgy. San Andres. For the simulation, the cross-section was maintained for the entire stretch of the river having a width of 15 and river height of 4m.

As shown in Table 2 and compared to table 4, the river cross sectional area at station 3+400 has improved from 3.85 sq.m. to 60.00 sq.m. (1458%). This size can accommodate up to about 65.4 cu.m./sec based on HEC-RAS simulation. If the size of the river is reduced from 15 x 4m to 10x 2m (width x height), the river at Sta. 3+400 can accommodate about 54.82 cu.m./sec with the assumption that the river walls upstream has been completed with a regular

Table 4. River capacity at various cross section and sinuosity of 1.6

Station	Cross-section (sq.m.)				Flow (m/s)				Discharge (cu.m./s)			
	A	B	C	D	A	B	C	D	A	B	C	D
3+400	60.0	52.0	38.8	30.0	1.1	1.2	1.2	1.1	65.4	61.4	46.5	34.2
2+700	80.6	70.9	50.4	40.3	0.9	1.0	1.0	1.0	74.9	71.6	51.9	39.5
2+300	98.2	87.2	61.7	49.1	0.9	0.9	1.0	0.9	83.5	80.2	58.6	44.7
1+500	115.9	103.4	80.2	57.9	0.8	0.8	0.9	0.9	93.9	91.0	73.0	51.6
0+000	160.0	144.0	114.0	80.0	2.3	2.5	2.6	3.0	369.6	354.2	296.4	241.6

Legend: A – Rectangular section B-Trapezoidal section C-Semi-Circular section D- Triangular section

Table 5. Flood risk of Antiao River (sinuosity: 1.6) for peak flow of 50 cu.m/sec

Station	Current River	Trapezoidal Section	Rectangular Section	Semi-circular Section	Triangular Section
3+400	4.27	61.36	65.4	46.54	34.20
2+700	18.60	71.65	74.95	51.90	39.48
2+300	27.26	80.21	83.50	58.58	44.70
1+500	43.47	91.00	93.86	72.97	51.57
0+000	289.3	354.24	369.60	296.40	241.60

Legend: Flood occurs No flood occurs

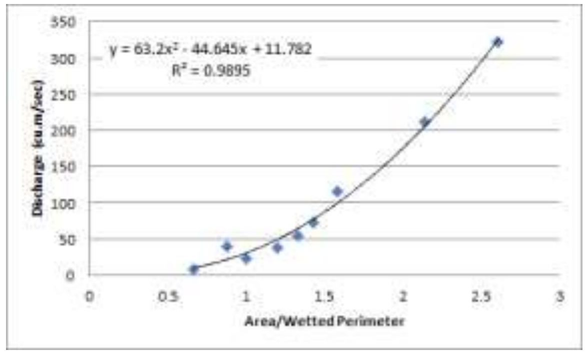
cross section. For other rectangular dimensions, the river discharge capacity (using Manning's formula with a slope of 0.02 and coefficient of a roughness of 0.05) versus area/perimeter ratio (of a rectangular section) is shown in figure 3. Using the equation

$$y = 63.2\,x^2 - 44.645x - 43.04 \quad (1)$$

where x stands for the ratio of the cross-sectional area and witted perimeter of a rectangular river. For a river discharge of 45.4 cu.m./sec (estimated peak discharge near Sta. 3+400 during December 2014 rains) needs area/witted perimeter ratio of 1.25. This ratio is described using formula (2).

$$h = 0.0051w^2 - 0.1603w + 2.774 \quad (2)$$

where h is the height and w is the width of a rectangular river will provide the depth requirement given the river width at station 3+400 with area/witted perimeter of 1.25. Using equation 2, a river width of 12m needs 1.58m depth to maintain 1.25 ratio. This river dimension is just enough to accommodate the peak discharge during the December 2014 rains.



Parameters used: slope of 0.02, Roughness coef. of 0.05

Figure 3. The discharge capacity of Sta. 4+000 for a rectangular section

Table 6. River capacity at various cross section and sinuosity of 1.03

Station (new config.)*	Cross-section (sq.m.)				Flow (m/s)				Discharge (cu.m./s)			
	A	B	C	D	A	B	C	D	A	B	C	D
2+000*	160.0	144.0	114.0	80.0	0.59	0.63	0.64	0.65	94.40	90.72	72.96	52.00
1+500*	160.0	144.0	114.0	80.0	0.63	0.68	0.68	0.71	100.80	97.92	77.52	56.80
1+000*	160.0	144.0	114.0	80.0	0.69	0.74	0.75	0.80	110.40	106.56	85.50	64.00
0+500	160.0	144.0	114.0	80.0	0.80	0.87	0.88	0.96	128.00	125.28	100.32	76.80
0+000	160.0	144.0	114.0	80.0	2.31	2.46	2.60	3.02	369.60	354.24	296.40	330.50

Legend: A – Rectangular section B-Trapezoidal section C-Semi-Circular section D- Triangular section

Table 7. Flood risk of Antiao River (sinuosity: 1.6) for peak flow of 50 cu.m/sec

Current Condition		Straightened River (Sinuosity: 1.03)				
Station	River Capacity	Approx. Station	Trapezoidal Section	Rectangular Section	Semi-circular Section	Triangular Section
3+400	4.27	2+000	90.72	94.40	72.96	52.00
2+700	18.60					
2+300	27.26	1+500	97.92	100.80	77.52	56.80
1+500	43.47	1+000	106.56	110.40	85.50	64.00
0+000	289.3	0+000	354.24	369.60	296.40	241.60

Legend: Flood occurs (red) No flood occurs (blue)

4.3 Design and evaluation of an alternative flood control system for straightened Antiao River

Sinuosity of the river causes turbulent flow as well as reduction of its flow rate. This will result in faster rate of water rise causing the river to swell and eventually flood. One probable option is to improve sinuosity close to one. This means removing the curves by straitening the entire stretch of the river.

The other alternative way of managing flood risk is through straightening of a portion of the river. This will change the sinuosity from 1.6 to 1.03. The said straightening will require massive ground excavation and lot acquisition of about 49 hectares but will reclaim about 75 hectares. Shown in figure 4 is the portion of the Antiao River which will be straightened. The original segment under consideration has a total length of 3.4km and due to straightening will reduce the total length to 2.11 km. The effect of this reduction to different river cross section is shown in Table 8. The new river capacity has improved specifically the upstream portion with improvement as high as 36.2%. For a rectangular rive, around 32.36% projected improvement along station 3+400 or station 2+000 considering new configuration.

The rectangular section appears to have the best performance where a 70-80% water level height was estimated to have been reduced. This estimate, however, is based on uniform river dimension from station 0+000 to station 2+000 (3+400). The effect on water height for river having sinuosity of 1.6 versus sinuosity of 1.03 is for the first 700m of the river is only about 5.2%, 7.5% and 35% for rectangular, trapezoidal and semi-circular respectively.

Figure 4. Reduced river sinuosity (1.6 to 1.03)

Table 8. Percent improvement in river capacity (1.6 VS 1.03 river sinuosity)

Orig. Station	New Station Approx.	A	B	C	D
3+400	2+000	32.36	30.72	36.21	34.23
2+300	1+500	18.09	17.16	24.43	21.30
1+500	1+000	14.60	14.98	14.65	19.42
0+000	0+000	0.00	0.00	0.00	0.00

Legend: A – Rectangular B-Trapezoidal section
C-Semi-Circular D- Triangular section

This is however not true to the upstream portion of the river where the

Table 9. Percent difference of depth of water using December 2014 rainfall data

Station	Alternative Flood Control Design (Sinousity:1.60)			Alternative Flood Control Design (Sinousity:1.03)		
	Trapezoidal	Rectangular	Semi-Circular	Trapezoidal	Rectangular	Semi-Circular
0+700	61.07	73.28	1.53	65.65	77.10	6.87
0+300	17.31	23.56	-19.71	17.79	24.52	-18.75
0+000	-1.74	0.58	-22.67	-1.74	0.58	-22.67

difference was estimated to be high.

Flood events in recent years have caused huge losses in life and properties and management requires more than just increasing dimensions as this will eventually be out-dated therefore solutions must keep on improving. An integrated approach covering all relevant aspects of water management, physical planning, land use, agriculture, transport and urban development, nature conservation at all levels needs to be implemented. All stakeholders and civil society should be involved in developing strategies to manage flood (ASFM, 2004).

5. Conclusion and Recommendation

The current river condition still has high flood risk specifically in the upstream part. This is primarily attributed to the high volume of siltation and narrow river width resulting to poor drainage capacity. When completed, the Antiao River Control Project will reduce the flood risk dependent on the final cross-section and the slope of the river.

Straightening of the river will improve its carrying capacity up to 32-36% in the upstream portion and up to 14-21% in the midstream.

All-in-all, the river having a rectangular section and straightened river is the best alternative to the current river control design project. If straightening is difficult due to concerns such as the right of way, and cost of excavation, an alternative river control project with a rectangular cross-section with the current sinuosity is still effective.

A similar study determining the most appropriate dimensions at various stations using a designed 100-year storm needs to be performed.

6. Bibliography

DPWH & JICA (2003). Manual on Flood Control Planning. Department of Public Works and Highways and Japan International Cooperation Agency. https://www.jica.go.jp/project/philippines/0600933/04/pdf/Manual_on_FC_Planning.pdf Accessed 1/12/2016

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). nd. Climate of the Philippines. http://www1.pagasa.dost.gov.ph/index.php/climate-of-the-philippines Accessed 8/12/16

Geoscience, Australia (2010). What Causes Floods? http://www.ga.gov.au/scientific-topics/hazards/flood/basics/causes Accessed 1/16/16

Orale, RL. (2015). Flood Risk Assessment in Post Antiao River Control Project in Catbalogan City, Philippines. Countryside Development Research Journal 3(2)

Gomba, FE., Orale, RL., & Uy, RS (2007). 10th National Convention on Statistics (NCS). http://nap.psa.gov.ph/ncs/10thNCS/papers/invited%20papers/ips-13/ips13-01.pdf Accessed 1/3/2016

Association of State Floodplain Managers (2004). Floods Best Practices on Flood Prevention, Protection, and Mitigation. http://www.floods.org/PDF/Intl_BestPractices_EU_2004.pdf Accessed 2/3/2016

World Health Organization, (2014). Drowning. http://www.who.int/mediacentre/factsheets/fs347/en/ Accessed 12/2/2015

US Army Corps of Engineers. Hydrologic Engineering Center – River Analysis System.

http://www.hec.usace.army.mil/software/hec-ras/

Pearson, ML. and Oliver, JG., 1992. Reconnaisance Report: Flooding Resulting from Typhoon Uring in Ormoc City, Leyte Province, The Philippines. Department of the Army, US Army Corps of Engineers, Washington DC. http://www.dtic.mil/dtic/tr/fulltext/u2/a269264.pdf Accessed 1/3/2016

Environmental Science for Social Change, 2000. The Ormoc Tragedy. http://essc.org.ph/content/wp-content/uploads/2010/01/chapter%201%20the%20ormoc%20city%20tragedy.pdf Accessed 1/3/2016