FLOOD HAZARD ASSESSMENT OF GANDARA RIVER, PHILIPPINES

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Abstract

The flooding problem in San Jorge Samar, the Philippines can be effectively addressed using a holistic approach using factual information. This is the main purpose of the study, which is to understand the parameters contributory to the flood hazard specifically along the San Jorge channel of the Gandara River. The paper also evaluated flood control initiatives implemented by authorities. The evaluation is guided by the DPWH Flood Control Planning Manual, assessment and computation of the needed parameters in planning and design of flood control program was processed through HEC-HMS (Hydrological Engineering Center –Hydrologic Modeling System) software. Findings suggest San Jorge rurban areas, as well as portions of its adjacent barangays as depicted in topography, is surrounded by significant upland and rolling hills. San Jorge basin is considered a flood prone. Using the designed rain based on historical data, it was found out that the flood plain which is 431 hectares (which includes a big portion of mostly commercial, educational and agricultural area) adjacent to the river channel will be inundated; A. Peak discharge is 1,474 cubic meters per second, resulting in a flood depth up to about 7 meters is expected. This can go higher if sedimentation or siltation is not managed. There is no concrete strategy to control flood hazard. There is an immediate need to establish measures to prevent a catastrophe when the San Jorge channel of Gandara River in Samar capacity is exceeded.

Keywords: Hydrologic modeling, flood hazard, river swelling, HEC-HMS, flood simulation

I. INTRODUCTION

Flooding causes economic, social, and environmental damage and loss of lives. An estimated death of about 6.8 million in the 20th century was recorded, half of which is in Asia (Noji, 2000; Jonkman SN & Kelman I, 2005). The assets at risk from flooding can be enormous and include private housing, transport and public service infrastructure, commercial and industrial enterprises, and agricultural land. In addition to economic and social damage, floods can have severe consequences, where cultural sites of significant archaeological value are inundated, or protected wetland areas are destroyed (Pistrika, et.al., 2007). Climate change will potentially increase the factors that lead to unusual precipitation resulting to a higher frequency of extreme flood events (IPCC, 2001). Rivers and streams experience flooding as a natural result of large amount of rain that runs quickly to waterways such as rivers. The size of a flood is influenced by the volume of water entering into the natural drainage upstream-and how

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fast it is (EPA, 2016). This is mainly caused by surface runoff and locally poor drainage or inadequate catchment area. Historically, floods are and are repeatedly one of the most destructive and costly natural hazards faced by Filipinos. Very few areas in the Philippines, if not none, are completely free from the threat of floods. By nature and its geo-graphical location, the Philippines is prone to natural calamities like typhoons. Since this brings along floods, communities should have safety measures to minimize damage to lives and properties.

The flood problem has been the main constraint in the promotion of socio-economic development and improvement of the living condition of the people along San Jorge, Gandara and Pagsanghan, Samar, wherein Gandara River passes all through this three towns. It is in Pagsanghan channel where this river ends to the main channel or the ocean. Flooding becomes a serious dilemma of the people and a very disturbing phenomenon whenever there is an occurrence of continuous rain. Even light showers worry residents if it is nonstop especially those residents settling or those with farm lands along river banks. It became a condition that during this phenomenon the rise of water is fast but slowly subsides. For the three towns, flood affects 80% of the agricultural land thus affecting the 80-85% of the population who are farmers (LGU-San Jorge/Gandara, 2013-2014). Flooding resulted in low farm production, and this will become a permanent phenomenon yearly if there will be no mitigating measure that will be done.

There is a need for governments to invest in natural disaster prevention to reduce the number of victims and extent of the material damage. Globally, a more proactive intervention is necessary (Mata-lima, 2013).

This study was conducted to determine the characteristics of the river, specifically the vicinity where flood usually occur and identify proposed strategies for flood control.

II. METHODOLOGY

2.1. Research Design

This study employed the descriptive and developmental research design. Gathering and analyzing data related to floodplains profile and river basin characteristics were through actual field observations, engineering surveys, and hydrological analysis. Modern flood assessment techniques used today includes satellite remote sensing method covering single or multiple dates or events which permit digital or photo-optical analysis. This is very useful and is best when few data are available. For this study, images available through Google and Bing Maps were used and supplemented with digital topographic maps from NAMRIA. These images and information were inputted into an HEC-HMS software to determine potential peak flows at various scenarios.

2.2. Locale of the Study

The study was conducted in the Municipality of San Jorge, Samar. San Jorge has located 125°49’00” north latitude and 12°01'11" East longitude along the national highway and 32 kilometers away from Samar capital town, Catbalogan and approximately 36 kilometers from the city of Calbayog. It is bounded on the north by the municipality of Gandara with a distance of 6 kilometers, on the southwest by the municipalities of Catbalogan and Tarangnan, on the east by San Jose de Buan and on the west by the municipality of Pagsanghan.

2.3. Research Procedure

In this study historical data of flood events were collected from the main town subject, the Municipality of San Jorge as well as relevant and contributory data from neighboring Municipalities from which the

Gandara River is traversing. Actual Engineering Survey was also conducted. To support and validate the data and information gathered from the survey, historical and research results from a farm and non-farm sources from private and government agencies, institutions and entities were collected and collated. Current and past government plans and programs in the area, including the findings from research, demonstrations and experimental stations deemed useful to the study were also considered.

Analysis of data was chiefly Hydrologic and Hydraulic Analyses; rainfall distribution and rainfall depth-duration-frequency were based on secondary data. The Gandara River basin rainfall was estimated from Catbalogan and Catarman rainfall stations using the distance square as a weighting factor, Catbalogan and Catarman PAG-ASA stations are the nearest rainfall data to the study site. In establishing the floodplain, a topographic map from US Army Corps of Engineers which was digitized by DENR-NAMRIA was used. The extent of flood range of inundated areas and its impact, flood records were taken from various local government offices like Municipal Planning Office. Information gathered were validated through interviews and actual site observations and was delineated on the topographic map plotted in AutoCAD environment to calculate inundation area.

The analysis of flood flow particularly peak discharges was obtained through Hydrologic Engineering Center-Hydrology Modeling System (HEC-HMS v. 4) software, developed by US Army Corps of Engineers as suggested in the Manual of Flood Control Planning of DPWH considering the profile of catchment area. Estimation of river system flow at normal condition and the river profiling was obtained by actual engineering survey. Existing data National Irrigation Administration-Samar were helpful like the derivation of rainfall for Gandara River basin. HEC-HMS approach included watershed profiling, soil characterization and characterization of precipitation; then a simulation was performed to analyze the runoff and discharge characteristics. In watershed profiling, the profile of all watersheds that may have contributed to the flood water that goes to the San Jorge portion of the Gandara River was determined with the aid of topographic maps and rasterized map from satellite images. The said maps were used to identify the boundaries of the watershed including the tributaries supplying water to the river.

Soil classification was derived from the Bureau of Soils and Water Management (BSWM) geological and soil maps. Also, the determination of ground cover of the San Jorge Watershed was estimated using rasterized satellite images from www.bing.com and simulation run using the HEC-HMS software for run off and discharge analysis was performed using daily rainfall data on selected months with extreme precipitation events. The simulation run is capable of estimating flow behavior of the modeled watershed given hydrologic information and the bases of the formulation of the proposed flood control program were the findings of the data analysis guided primarily by the Manual on Flood Control Planning of Department of Public Works and Highways.

III. RESULTS AND DISCUSSIONS

The forgoing are based on actual survey data, secondary data from various authorities and the hydrologic simulation results.

3.1 Topography

As reflected in Figure 1, the river is located in mountainous areas characterized by moderate to steep slopes with on the eastern and northern edges of the Gandara River basin at San Jorge with an average slope of 50 meters guided by the contour lines. Topographic profile of Gandara River

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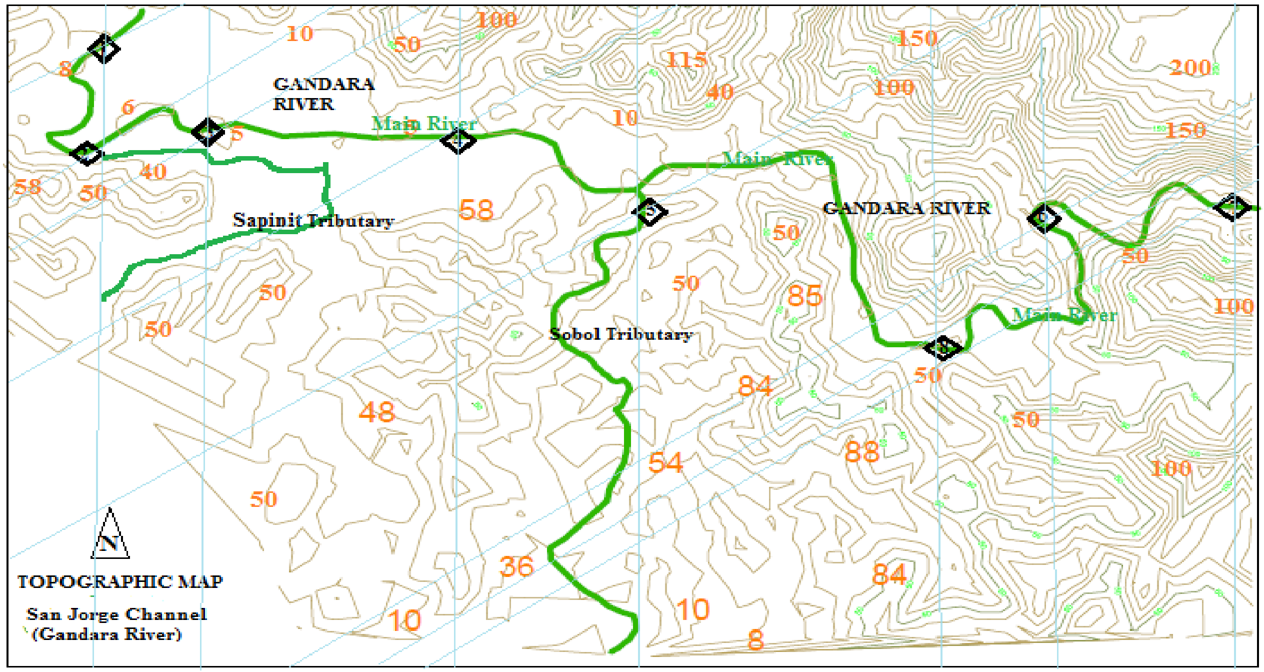

Figure 1. Topographic Map of San Jorge Samar

Table 1. Topographic Profile of Gandara River along San Jorge

Station	Lowest Elevation (m)	Area Covered (km^2)	Average Elevation of the Area (m)	Average Depth of Water (m) from Survey
1-2	8	0.45	8.00	1.20
2-3	6	1.35	7.25	3.35
3-4	5	1.78	7.00	5.50
4-5	10	0.98	37.00	3.30
5-6	46	3.35	46.70	2.38
6-7	32	2.44	36.70	2.40
7-8	128	2.77	128.00	2.40

along San Jorge was examined through stations marked from Station 1 to Station 8. As shown, station 1 has a flat slope of contour lines 5 to 10 meters; stations 2, 3, and 4 have a relatively similar elevation of 6 meters to 10 meters. While stations 6, 7, & 8, the elevation increased to 50 meters on the average. Stations 6 to 8 are upstream of the river. This data is supplemented by Table 1, the topographic profile of Gandara river along San Jorge.

By inspection through the topographic map, lowest elevation along a portion of the Gandara River at San Jorge is 5 meters, as designated by stations which are found out to be the Poblacion area (Station 3-4), elevation ranges from 5 meters to 10 meters along Poblacion and its adjacent urban and rural barangays. As validated through an actual hydrographic survey, it was observed that station 2-3 and 3-4 is deep as to water elevation as compared to other stations. It was found out that this area has the lowest elevation, the

Table 2. Rainfall depth frequency-duration by return period

T years	Rainfall depth, mm /frequency duration								
	10min	20min	30min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
5	20.8	31.0	38.7	51.5	70.6	82.7	106.3	132.1	159.2
10	27.7	41.8	52.4	71.2	100.6	119.9	156.1	195.2	230.9
15	34.9	53.0	66.4	91.7	131.8	158.2	207.7	260.6	305.1
20	36.7	55.8	70.0	96.8	139.7	168.0	220.7	277.1	323.8
25	38.1	58.0	72.7	100.8	145.8	175.5	230.7	288.2	323.8
50	42.5	64.7	81.3	113.0	164.5	198.5	261.6	329.0	382.7
100	46.7	71.3	89.6	125.2	183.0	221.3	292.3	367.9	426.8

Source: NIA-Samar

flood water is greater in this areas which may result to a wider flood plain. As to its topography, the area is a basin-like plain as surrounded by the upland and rolling hills.

Examining the contours, the study area serves as a drainage channel to the Samar Sea. The mountainous areas are considered steep slopes with 100 meters to 500 meters, which were found on the eastern and northern edges of the basin. Gandara River Basin at San Jorge channel is considered a flood prone as situated at a much lower elevation at an average of 5 meters to 10 meters elevation through its reach, identified through designated stations.

3.2. Rainfall Depth-Frequency-Duration

The rainfall depth-frequency duration is shown in Table 2 about extreme precipitation in 5 to 100 years return period, the rainfall depth in millimeters occurred in a particular period regarding minutes and hour for over a 24-hour rain duration during the specific return periods by year. This implies that there is a rainfall depth of 20.8 millimeters that has a duration of 10 minutes and may return after five years. Similarly, the 159.2 millimeters a 24-hour rainfall may recur in 5 years. These values show the behavior of rain regarding depth and duration.

3.3. Flood Plain

Table 3 shows the flood plain profile of the land along Gandara River at San Jorge channel. It is at station 2-3 and 3-4 that flood plain is wider, with 1.09 square kilometers and 1.78 square kilometers flood covered area, as such because it is in this station that elevation is lowest. This was also validated through actual interview among the residents as to highest flood depth they experience in the area. Figure 5 shows the delineated flood plain.

3.4. Flood Flow

Stream flow at normal or no inundation condition were gathered from all identified stations by engineering survey procedure then discharge of water or stream flow was computed based on actual river profile.

As shown in Table 4, it is at station 2-3 and 3-4 that average streamflow is greater, 459.80 cubic meters per second and 982.7 cubic meters per second at normal or no inundation condition. It is also noted that it is

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Table 3. Flood Plain-Profile of Gandara River at San Jorge Channel

Station	Lowest Elevation (m)	Area Covered (km^2)	Average Elevation of the area (m)	Flood Depth (m)	Flood Area (km^2)
1-2	8	0.45	8.00	3.0	0.45
2-3	6	1.35	7.25	3.0	1.09
3-4	5	1.78	7.00	5.0	1.78
4-5	10	0.98	37.00	7.0	0.98
5-6	46	3.35	46.70	0.5	0.30
6-7	32	2.44	36.70	0.0	0.00
7-8	128	2.77	128.00	0.0	0.00
Total inundation area along San Jorge Channel of Gandara River					4.603

Table 4. Average streamflow of San Jorge River at Normal Condition

Station	Width (m)	Depth (m)	Area (m^2)	Stream Flow (m^3/s)
1-2	65.00	1.20	78.00	114.64
2-3	50.00	3.35	167.5	459.81
3-4	49.20	5.50	270.60	982.7
4-5	43.45	3.30	143.39	363.48
5-6	65.85	2.38	156.72	355.55
6-7	34.88	2.40	83.71	183.59
7-8	24.88	3.75	93.30	251.90

Note: Discharge from Open Water Flow Rate Calculator (Manning's Formula). Used Coefficient of Roughness, n = 0.075 for meandering flows/uneven bottoms and banks.

because in this stations that the river has the larger cross-sectional area. While the volume of probable flood water and the behavior of it flow was obtained and analyzed through Hydrology Engineering Center - Hydrologic Modelling System (HEC-HMS) Version 4 software. As simulation were performed using extreme precipitation events, December 2014 rainfall data (the highest recorded precipitation /during typhoon Ruby) was used in the analysis of behavior of flow , volume and flow behavior was obtained considering the identified Gandara River basin watershed as shown in Figure 3 contributory to the flood water that passes through Gandara River at San Jorge channel.

As identified Gandara River basin watershed, considering contours and boundaries contributory to the discharge of the entire 80 km approximate reach of Gandara River are the Gandara (G) watershed, portions Matuguinao (M) watershed, portions of San Jose de Buan watershed called San Jorge North watershed (SJN), portions of Catbalogan watershed called San Jorge South (SJS) and San Jorge watershed called San Jorge West (SW). The potential runoff and river discharge flow are shown in Figure 2. As automatically designated in HEC-HMS simulation model, S7 reflects the portion of the Gandara River at San Jorge.

From the identified runoff and river discharge directions that go through Gandara River Basin, it was observed that the flow that upstream to downstream behaves in a down right direction as seen in

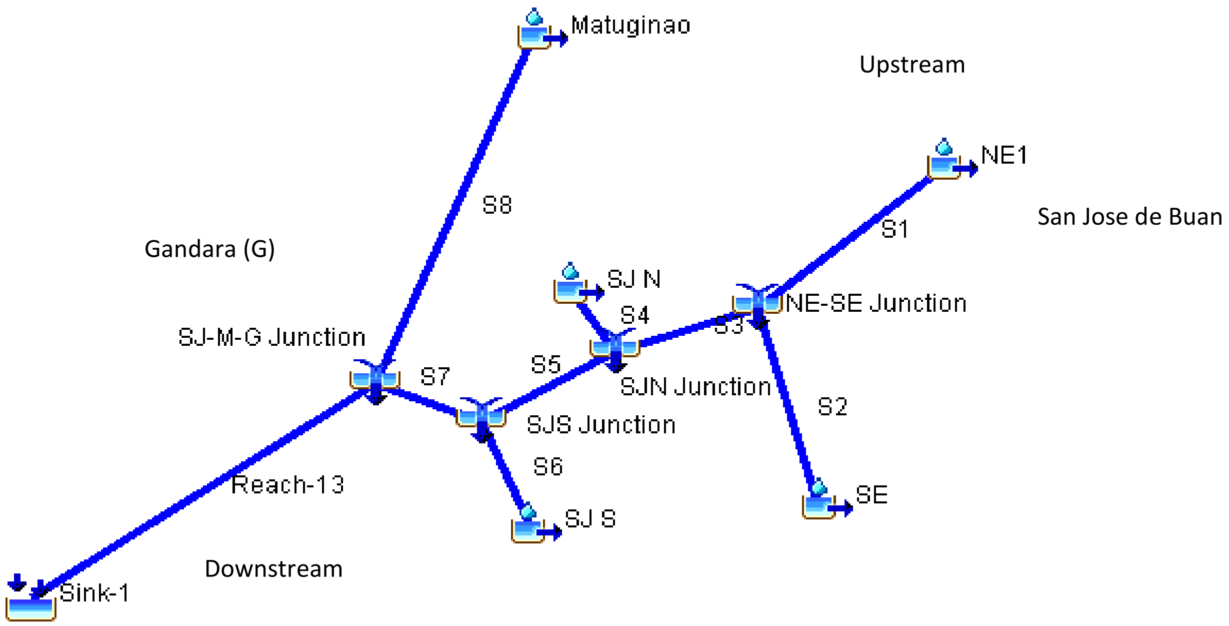

Figure 2. Flow in Gandara River Basin HEC-HMS Model

Table 5. Flood Flow Characteristic

Hydrologic Element	Drainage Area (Km2)	Peak Discharge (m3/s)
NE 1	341.2	965.5
S1	341.2	947.2
SE	134.2	379.7
S2	134.2	373.5
NE-SE Junction	475.5	1320.7
S3	475.4	1312.9
SJN	38.0	107.5
S4	38.0	106.9
SJN Junction	513.4	1419.8
S5	513.4	1411.4
SJS	25.4	73.4
S6	25.4	72.9
SJS Junction	538.8	1483.0
S7	538.8	1474.2
Matuginao	280.6	794.0
S8	280.6	754.1
SJ-M-G Junction	819.4	2228.3
Reach -13	819.4	2228.3
Sink-1	819.4	2228.3

Figure 2, the flow was also modeled in HEC-HMS environment shown in Figure 2. As observed Gandara watershed (G) do not contributes to the discharge of Gandara River at San Jorge so it was excluded in the simulation of flow. The result of simulation run is in presented in Table 5

From the result of the simulation run through HEC-HMS software, it is shown that flow S7 has the highest value as to peak discharge among other flood paths in the area. S7 occurs at Gandara River along San Jorge predominantly along Poblacion and other adjacent urban areas. The area, therefore, most potential for a flood control mitigation measures since this area is the educational, commercial, partly residential and partly agricultural area of the municipality.

3.5 Siltation

Another parameter contributory to flooding occurrence used in this study was sedimentation. A study on Watershed Hydrology Assessment was conducted for Samar Island by Cruz (2000) and the bulk density sedimentation was taken at 1.65 tons/cu.m. In the study of Orale (2015),

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siltation was given an emphasis to have caused the flooding in the Catbalogan City, Philippines. The newly disilted Antiao River was full of silt after the December 2014 storms that have hit Samar Province, including San Jorge Samar. The study of Mercado (2012) has shown that siltation is a major concern in Borongan City, Eastern Samar Philippines. Siltation is also true to man-made drainage systems which like that of rivers resulted in reduced carrying capacity which swells at a small amount of rain (Cuna, 2010).

3.6 Existing Practice of Flood Control Initiatives

DPWH web-site has listed several flood control projects, many of which are river control projects consisting mainly of river walls and disiltation of river. A good example was the Antiao River Control Project in Catbalogan City which was tested during the December 2014 to be inadequate to address flooding in the City.

Table 6. Flood Control Initiatives

Sponsoring Agency	Flood Control Efforts	Status
LGU- San Jorge	Flood Wall Proposal	Part of Comprehensive Development Plan 2010-2020
DPWH	Construction of Concrete Revetment for Erosion control along San Jorge Urban Barangays	On-going
CENRO/ DENR	Implementation of National Greening Program at Gandara Watershed	On-going
DOST-ASTI	Installation of Water Level Monitoring Device and Flood Warning Signages	Operational/Functional

Table 6 shows some of the current flood control initiatives. As shown, At present, no concrete strategy on the prevention and mitigation, has been yet materialized and implemented effectively though there are initiatives by various government agencies, thus a flood control program is an imperative measure deemed urgently necessary.

A study about the trend of floods in Asia and flood risk management concluded that it is worsening. It showed the importance of flood risk management emphasizing the need for an integrated basin-wide flood management approach (Dutta, 2004). Using technology in analyzing flood risk and impact of proposed intervention could be simulated first before implementation to improve chances of success.

3.7 Proposed Flood Control Program

3.7.1 Design Concept Basis

This proposal is anchored on an integrated approach to urban flood control (Miquez, et al, 2013). This concept provides a better understanding of urbanization and its consequences or impact to societal problems like flooding. Urbanization changes landscape patterns, aggravating floods by increasing surface runoff flows. Wherein, flood control measures work through integrated approach.The study found out that along the river banks were utilized as residential areas and business establishments. The natural vegetation removal and inundation were heavily observed in the area. Therefore, integrated approach concept will be utilized in this proposal. Specifically, the storm water management and urban flood control concepts will be utilized as an integrative approach in the flood control measures for Gandara River at San Jorge Samar. Based on the results of this study, the flood control design basis is: 1) maximum flood depth is 3-7 meters; 2) flood area and flood plain is

460.3 hectares; 3) maximum flood flow rate is 982 cubic meters per seconds.

3.7.2. Program Components

The proposed program has the following program components: Engineering and structural program; and Non-engineering or non–structural. Structural flood control measures are further classified as intensive and extensive measures. Intensive measures for Gandara River will include main drainage net modification through canalization and dredging due to increase in siltation as described in this study, construction of impounding dam, protection walls, and detention ponds. The extensive measures will include watershed management to control heavy rain runoff. The non-structural measures will be proposed to reduce lives and properties to flooding. This includes flood plain management and regulation through the development of the flood management master plan (FMMP) for Gandara River and the municipality of San Jorge in general. The FMMP will consist of a set of strategies, measures and policies will be arranged together to management flood risk and guide the development of drainage system. Another component in non-structural is flood forecasting and warning and flood proofing. Reforestation is another non-structural measures to improve the vegetation cover of the place.

3.7.3. Implementation Strategies

The following are the proposed implementation strategies of the proposed flood control program:

1. Presentation of the proposal to the Local Executive (Mayor) and head of offices of the municipality of San Jorge, Samar.

2. Upon acceptance and approval of the Mayor of the San Jorge Samar, validation of field data will be conducted to ensure accurate and reliable information for the preparation of the detailed engineering design.

3. Preparation of detailed engineering designs and estimates. This part of the proposal will implement Intellectual Property on knowledge generated based on this study. The detailed design is not included herein for intellectual protection ownership of the authors.

4. Presentation to LGUS, DPWH, NIA and DILG the detailed engineering design for possible funding.

5. Upon approval, implementation planning and construction of structural measures of flood control such dikes and canals.

IV. CONCLUSIONS

Based on the findings of the study, the following conclusions were arrived at:

1. Gandara River Basin at San Jorge channel is considered a flood prone as situated at a much lower elevation at an average of 5m to 10m elevation through its reach. Topographically, flooding of land adjacent to the Gandara River at San Jorge is greatest at Poblacion and all rest of the urban barangays and other adjacent rural barangays near the river.

2. Flood Plain area is wider as well in this areas.

3. Siltation is prevalent, and since no mitigating measures are intently implemented, a flood control program must be one of pressing concern of the concern authorities to somehow alleviate the living condition of San Jorge community.

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